In the forthcoming issue

1. Detection of Radioactive Material in Public Places: BARC’s Handheld Tele Radionuclide Detector
   S.K. Bharade et al.

2. An Engineering Forbidden Zone for Light
   R.V. Nair et al.

3. Processing Food for Convenience: Challenges and Potentials
   Jyoti Tripathi et al.

4. Aluminium Foam Fabrication by Powder Metallurgy Route
   Umashankar et al.

5. Velocity Field Measurements Using Digital Particle Image Velocimetric System
   A. Kansal et al.

6. Recovery of Cesium from High Level Liquid Nuclear Waste by an Advanced Polymer Composite
   L. Varshney

7. Biological Process for Denitrification of High Nitrate Bearing Waste Effluents of Reprocessing Plant Origin
   Sandhya et al.
## CONTENTS

**Editorial Note**

**Director’s Speech on 64th Anniversary of the Independence Day**

### Research Articles
- Radiation Processing of Temperate Fruits of Kashmir Valley
  Peerzada R. Hussain, Raghuveer S. Meena, Mohd A. Dar and Ali M. Wani
- Friction Stir Welding of Aluminium Alloys
  N.T. Kumbhar, G. K. Dey and K. Bhanumurthy
- Matrix Assisted Laser Desorption Ionization Mass Spectrometry (MALDI-MS)
  T. Jayasekharan and N. K. Sahoo

### Technology Development Articles
- Building Web Based Surveillance, Personnel Tracking and Secure Software Solutions
  D K Dixit, Renuka Ghathe, Bhagwan Bathe, Gurmeet Singh, Abhishek Bajpai, Mahesh Date, Chethna Rastogi, Umesh C Lad, S K Parulkar, A G Apte, G P Srivastava
- Behaviour of Single Piles in Liquefied Soils during Earthquake
  V.S. Phanikanth, K. Srinivas, Deepankar Choudhury and G. R. Reddy
- Composite Polyamide Reverse Osmosis (RO) Membranes – Recent Developments and Future Directions
  A.K. Ghosh, R.C. Bindal, S. Prabhakar and P.K. Tewari

### Feature Article
- Precision-Micro-Nano Engineering

### News and Events
- ISMAS International Discussion Meet on Elemental Mass Spectrometry in Health and Environmental Sciences (ISMASDMHEAL2011); Highlights
- BARC Transfers Technologies
- “National Fire Service Week”: a report
- Theme Meeting on Very High Energy Gamma Ray Astronomy; a report
- Theme Meeting on “Thermo-mechanical Deformation of Pressure: Tube under Accident Condition”: a report
- Authors’ Workshop: a report
- Nuclear Energy Awareness & Applications (NEAA-2010) Symposium: a report

### BARC Scientists Honoured
From the Editor’s Desk

We are happy to inform you all, that the Editorial Committee of the BARC Newsletter has a New Chairman, Dr. Tulsi Mukherjee, Director, Chemistry Group and a Vice Chairman, Dr. N. Ramamoorthy, Senior Advisor to Director, BARC. Both these Senior Officers with their vast and varied expertise and experience, will provide valuable inputs, which will further enhance the quality of the BARC Newsletter.

Dr. V. Venugopal, Director, Radiochemistry and Isotope Group, was the First Chairman of our Committee, who retired in June this year. We would like to place on record, our heartfelt thanks and sincere appreciation for all his efforts.

We would like to thank you all, for your overwhelming response to the Founder’s Day Special Issue of the BARC Newsletter. For the first time, all the papers were uploaded directly by the BARC Scientists and Engineers, through a special web link created on the BTS, thus saving time and effort.

This issue carries seven different articles, ranging from Electronics & Instrumentation, Metallurgy and Material Science to Earthquake, Chemical and Nano Engineering, Food processing and Mass Spectrometry.

We hope that you would all continue to give your R&D contributions to the BARC Newsletter.

Dr. K. Bhanumurthy
On behalf of the Editorial Committee
“प्रिय सहिष्नु,

सबसे पहले में आप सभी को अपने देश के स्वतंत्रता दिवस की 64वीं वर्षगांठ के अवसर पर बधाई देते हैं। आज की सुबह, हम सब यहाँ न केवल अपने राष्ट्रपति के गर्व और सम्मान का रक्षा करने की शाखा देखने के लिए उपस्थित हैं बल्कि उन सभी शहीदों को अपनी श्रद्धांजलि अर्पित करने हेतु भी एकत्रित हैं जिन्होंने देश की स्वतंत्रता के लिए सजीव पूर्वांग बलिदान किया है। इस अवसर पर, हम अपने सेवन बलों के सदस्यों को भी अभिवहन करते हैं जो हमारे देश की सुरक्षा करते हैं।

इस अवसर पर हम अपने कार्यों का पुनरालोकण करते हुए विश्वसनीय समय में प्राप्त उत्साहियों का अथरवत है। जैसा कि आप जानते हैं, हमारे केन्द्र के कार्यक्रमों में नाभिकीय उद्योग, नाभिकीय ईंधन चक्र, रोडिया आइसोटोप के उपयोग एवं आइसोटोपों के अनुप्रयोग सहित अनुसंधान रिएक्टरों से संबंधित विभिन्न प्राप्त प्रश्नों, भौतिक विज्ञान तथा अनुभवकुल अनुसंधान एवं महत्वपूर्ण गतिविधियाँ शामिल हैं। मैं यह केन्द्र द्वारा रहने ही में किए गए कुछ उल्लेखनीय विकासात्मक कार्य और प्राप्त उत्साहियों का वर्णन करना।

अनुसंधान रिएक्टर

अनुसंधान रिएक्टर ध्वनि रोडिया आइसोटोप के उपयोग हेतु मुख्य सुविधा और नूतन बीम अनुसंधान हेतु राष्ट्रीय सुविधा के रूप में लगातार कार्यस्थल रहा है। 25 वर्ष पुराना इस रिएक्टर के सुसंगीतक विषयक के अंतर्गत अनेक महत्वपूर्ण उपकरणों का अन्वेषण पूरा करना है। इसमें मुख्य मोटर प्रत्येकविभाग सेट और लिस्ट गियर, चैनल फ्लो मोनिटर गेंग और मुख्य नियंत्रण कक्ष के आई अंदौ सी पैनल शामिल हैं। सार्वजनिक को पूर्णता: इंजनियर द्वारा किया गया है। इसकी प्रक्रम प्रणालियों परिशंक में अंतर्गत सुरक्षित रखी गई है।

उत्तर आर्थिक रिएक्टर की विशेषता रिएक्टर प्रणालियों का विस्तृत ईंधनियरों प्रारंभि पर है। उत्तर रिएक्टर द्वारा विद्युत अनुसंधान, रोडिया समस्त संस्थानों का उत्पादन, नूतन संस्थानों के अंतर्गत एवं परिपक्व, प्रयोग परिषद तथा बुधवार परिषद प्रणालियों के लिए विस्तृत सुविधाएं उपलब्ध कराया जाएगी।

उच्च फलक अनुसंधान रिएक्टर (एचएफआरआर) का संकल्पनात्मक अभिकल्पन पूरा किया जा चुका है। इस नवीन अनुसंधान रिएक्टर का अभिकल्पन मुख्यतः उच्च विश्लेषण अंतरिक्ष रोडिया आइसोटोपों के उपयोग और नाभिकीय ईंधन एवं रिएक्टर पद्धति का परीक्षण नियुक्त किया गया है।

नाभिकीय विश्लेष संबंधी अनुसंधान एवं विकास पुष्टी रिएक्टर द्वैताच्छ द्वारा विकास होता है, हमारे रिएक्टर केन्द्र नाभिकीय अनुसंधान कार्यक्रमों में संबंध संयुक्त राष्ट्र के साथ नियमित रूप से जोड़ा है। तराईगुरु में विस्तृत बंधन के 540 मेगावाट पीएमडीआरआर (प्राकृतिक) का 1:4 संबंध रिएक्टर मात्री के निर्माण एवं कमीशनिंग किया गया है। इस मॉडल का हाल ही में अधिकल्पन यथा देखा कि 1.77 मेगावाट पीएमडीआरआर (आरआर) का 1:4 संबंध भवन का निर्माण एवं कमीशनिंग किया गया। इस मॉडल का हाल ही में अधिकल्पन यथा देखा कि 1.77 मेगावाट पीएमडीआरआर (आरआर) का 1:4 संबंध भवन का निर्माण एवं कमीशनिंग किया गया। यह भौतिक एवं सांग विद्यासे से ग्रामीण विद्यार्थी प्रतिभार शिक्षाओं के साथ अंतरराष्ट्रीय राउंड रोल्ल अधिकार के रूप में परीक्षण द्वारा किया विश्लेषित किया जा रहा है।

भवनों को संबंध भौतिक भार परिस्थितियों के अर्धव उपग्रह तहत (गतिविधियों) की समझना संबंध संस्था का महत्वपूर्ण पहल है। वे वृहत प्रमाण तकनीकी संख्याओं पर फिर एग महत्वपूर्ण प्रयोग द्वारा वह पाया गया है कि मुख्ती नाभिकीय परिस्थितियों
प्रगत भारी पानी रिएक्टर (एचडब्ल्यूआर)

एचडब्ल्यूआर भारी पानी रिएक्टर को किन्हीन भ्रम करने के दिशा में एचडब्ल्यूआर की पर्यायवर्तन सुविधाओं के विस्तृत इंजीनियरिंग अपग्रेड द्वारा करा गया है।

एचडब्ल्यूआर के संरचना में कुछ विशेष घटनाएं हो लिए हैं इसलिए इसकी विस्तृति का विश्लेषण किया गया है जिसमें इसका अनुपत्तिता साधन वही रहा है। रिएक्टर का वही अप्रभावण अविगत देश के लिए प्रयुक्त भौतिक अविगत प्रतियों के वेश्य के अन्तर्गत एचडब्ल्यूआर क्रियाकाल सुविधा (ThO₂-1%wt %PuO₂) में परिश्रम या प्राकृतिक कुंपलिंग युक्त कारक चुना गया है। इसके साथ-साथ संरचना में इसका भौतिक अविगत प्रतियों के वेश्य के अन्तर्गत एचडब्ल्यूआर क्रियाकाल सुविधा (ThO₂-1%wt %PuO₂) में परिश्रम या प्राकृतिक कुंपलिंग युक्त कारक चुना गया है। इसके साथ-साथ संरचना में इसका भौतिक अविगत प्रतियों के वेश्य के अन्तर्गत एचडब्ल्यूआर क्रियाकाल सुविधा (ThO₂-1%wt %PuO₂) में परिश्रम या प्राकृतिक कुंपलिंग युक्त कारक चुना गया है।

U-भाता उपयोग के रूप में उदार परिवर्तन पुनःचलन परिवर्तन (सोअरसी) तकनीक को प्रयोग करते हुए, त्वरित दौरे वाला का निर्माण प्राप्त किया गया।

सीधे रिएक्टरों हेतु प्रगत ईथनों का विकास वापस पैक ईथन

भारी भंड के तीव्र रिएक्टरों के लिए प्रगत ईथनों के विकास के क्षेत्र में कामयाब रहा है। इस गैरशिक्षा के अंतर्गत विभिन्न विषय में संबंधित भारी भंड के सोल-जेल प्रक्रिया का प्रयोग करते हुए आयार जोड़ने के लक्ष्य के लिए सबसे लाभदायिक व्यवहार आधारित है।
छोटे आकार के (लगभग 100 माइक्रोन) UO₂ सूक्ष्म गोलों के साथ आईजीआर सिस्टम रिनेवर्टोआर में विस्तार हेतु जान दिन के इंद्रण पद्धति के रूप में प्रयुक्त किए जा रहे हैं।

धातिक इंधन
क्योंकि सीमी सांचे में यूरिनाम/U-मिश्रभूत के इंधनकार कार्बंगिंग, कास्ट रिच्चू द्वारा डीमोलिंग, इन दों के दीर्घ के अचरण एवं स्वच्छता निरोक्षण प्रणाली क्रमशः एक ग्राफ बॉक्स सुविधा स्वयं प्रभाव करी है। आवश्यक विनिर्देशों को पूरा करने वाले प्रतिकृत U-6 wt% Zr मिश्रभूत धातिक इंधन के आवश्यक संयंत्र में संचालन के लिए इस सुविधा का सफलतापूर्वक प्रयोग किया गया। यूरिनाम का लगातार कार्बंगिंग सफलता पक्वकार की गई। इससे सांचे के हेतु धातिक इंधन के संचालन के ध्वनि अवयव अपरिष्कार को घटाने में सहायता मिली।

सीडीआरएमईटी इंधन
सीडीआरएमईटी इंधन के लिए प्रतिकृत U साईंच में परिभाषित न्यूट्रा और 15% एक्स 30% सीडीआरएमईटी इंधन संघटन किए गए और इन्हें Ar एक्स निर्विश्वास में 1090°C पर स्थिरित किया गया। डायलिमोलिंग का प्रयोग करते हुए उपयुक्त समय इंधन के संबंध में आचरण का मूल्यांकन किया गया। यह देखा गया है कि Ar वातावरण में संतरण उच्चकोट का था।

पूनसंसाधन
द्रव्य स्थित प्लूटोनियम संयंत्र सुरक्षित रूप से प्रचालनात्मक रहा और गुणवत्ता सार्वजनिक प्राप्ति भंडारण इंधन गुणवत्ता का पूनसंसाधन किया गया। इसके अतिरिक्त, धोयिता रॉफेंटिस से धोयिता को पून:प्राप्ति हेतु प्लूटोनियम धार्मिक पृथ्वी क्रांति सुविधा (यूटायर्सिकस) प्रचालित की गई।

कल्पनाकल्प ध्यात्र स्थित पूनसंसाधन संयंत्र को संतोषजनक एवं संरक्षित रूप से प्रचालित किया गया। नामक की किसने पूर्वकालिक तरीके के अधीन, प्रम-2 तारापुर संयंत्र में उपग्रह आर्थिक रूप से चुका है। अन्तिरिक्त अपरिष्कार दक्षिण कार्यान्वयन है।

थायी मृत्यु सव मूल संसाधन संयंत्रों के अभिलोकन सामान्य रूप से प्राप्त आर्थिक प्राप्ति करने के लिए, एक पूर्ण आकार के प्रोटोटाइप सतत धर्माधीनता का संचालन एवं स्थापना किया गया। इस दक्षिण का प्रचालन अनुकूलित परिस्थितियों (यूरिनाम नाइट्रेट के साथ) के अंतर्गत किया गया ताकि उपयुक्त डाटा प्राप्त किया जा सके और निर्माण पद्धति, सुरू लड़न, हल आदि से पद्धति को पृथ्वी.प्राप्ति के विशेष प्रभावित पहलूओं पर दृष्टिकोण उपलब्ध हो सके।

देश में पहली बार हाईड्रोक्विल आमेपी नाइट्रेट (एचएचएन) के संतरण प्रक्रिया की उपलब्धता में इसका प्रयोग किया जा सके। इस पद्धति को लॉटरी अवसर लेकर लघु बीमारियों के रूप से उपलब्ध किया गया।

३००Sr, ३०४Y एवं ३२४Am जैसे उपयोगी आप्रवंशों के संतोष अपरिष्कार से पृथ्वी.प्राप्ति की गठन और प्राप्तकारों को आपूर्ति होती रही।

नामक की कार्यान्वयन
हल्के सेल के अंदर जूल गलतक के सुपर विभव एवं संचालित मैदान में स्वच्छन्द विकास की गई और जूल गलतक प्रणाली का अन्तिरिक्त मैदान-रैम व्यवस्था के साथ संचालन और प्राप्त कार्यान्वयन सुविधा, तारापुर में तोस अपरिष्कार निर्माण कार्य समापन के अन्तर्गत में है।

कल्पनाकल्प ध्यात्र स्थित अपरिष्कार निर्माण संयंत्र में, अन्तिरिक्त उच्च स्तरीय अपरिष्कार (एचएचएन) का प्रयोग करते हुए दृष्टकोण तथा संरक्षित गलतक का निकरण कमालन किया गया। बाह्यिक नामक जूल, ताम्य एवं स्तर प्राप्त समापन जैसे घटकों का पृथ्वी.स्थापना किया गया।
पर्यावरण ऑवरों ओर विकर्ण संरक्षण

एक ही भाषा द्वारा वर्णित रूपांतरण

पृष्ठ पर लिखी गई पत्रिका के केंद्रीय विषय पर स्पष्ट लिखी गई है। पारंपरिक रूप से, इस पत्रिका का उद्देश्य विभिन्न मानवीय और वैज्ञानिक विषयों के बारे में और उनके संबंधित अध्ययन के लिए जानकारी प्रदान करना है।}

BARC NEWSLETTER
भौतिक विश्लेषण

इंडेस में किरणपूंज रेखा विकास गतिविधि के एक भाग के रूप में खगोल भौतिकी और पर्यावरण विश्लेषण से संबंधित अगुप्तों के संदर्भमें अध्ययन के लिए उच्च विभंगन निर्यात परंपरागत किरणपूंज रेखा का कमीशन किया गया।

इंडेस में पृथ्वी, तनुस्फोट और बहुपरिस्तर के अभिलक्षण के लिए प्रतिवर्तित मानक के साथ EXAFS किरणपूंज रेखा का संचालन किया गया।

रसायन विश्लेषण

उच्च अमीलीय माध्यम में पट्टोलक्षण को आत्मा गतिविधि के मॉनिटर के रूप में एक संगठन विकसित नैनो-डाईमंड फिल्म का संभायत अध्ययन संपन्नतापूर्वक पूरा किया गया।

एक सरल और किंवताती हादेजोल आवाहित पद्धति विकसित किया गया जिसमें साइटिक अमल भारित क्रापास रोज के साथ संयुक्त एयरोजेल जेल निरस्त्र किया गया था। हादेजोल एक्साइड शामिल है। इसमें इक्सपर खोला प्रतिरोधी गुणवत्ता है और अल्प-जीर्ण त्वचा के संतरण में डीपिंग मात्रारूप के रूप में इसका प्रभाव उपयोग है।

मिश्रित रोगाणु किरणों का उपयोग करके जैव-विभंगनक्रियाएं पर अध्ययन के लिए 1.5 C/N अनुरूपता पर एसीडेट को वापस लाने के लिए 4,050 मिम्प्रा तक नैट्रा-N/L (18,000 mg/L NO₃ के समत्वता) का उपयोग किया जा सकता है।

इसे 6 तीव्र आवश्यकता प्रणाली पैमाना अनुक्रमण वैंच रिजर्व में प्रवर्तित किया गया।

जेव विश्लेषण

एक विश्लेषण जोध में पता चला कि बहुत से द्वृत्त प्रतिरोधी प्राकृतिक वीजाइंकों के एक जनक अनुमान 1,4-नो-धियॉक्ट्रोन (एनक्स) ने 4 Gy गामा विकरण की एक खुराक से पृथ्वी के लिमिटेडसाइडों और आत्म की कृतिकाओं को बढ़ाया। चूंकि में, 2m/kg NQ दिए जाने से (मिश्रित इन-नाबिको) विकरण प्रतिरोध अच्छा-लक्ष्य संदर्भ में महत्वपूर्ण है, इसे स्वीकार तथा स्वीकार कर लिया गया।

इस संधिका किरणेक्सियाम ओ पेडलसे सुनामिक फीटर Nrf-2 (नामिकीय फीटर E2 संबंधित फीटर-2) का संकरण शामिल है।

खाद्य प्रौद्योगिकी

आप के स्वास्थ्य जैसे कार्बोहाइड्रेट से भरपूर तलहुए खाद्य पद्धति में एक न्यूरोप्लास्टिक और एक संभावित क्षेत्र में एक्सोमेदर अल्फा सरकर टेट्रोडिन अल्फा उच्च सरकर पर मोजदु होना रिपोर्ट किया गया है। तत्परता के दौरान अमीलीय अल्फा रोगीय मात्रा ग्राहक के साथ खाद्य पद्धति में मोजदु शक्ति की पट्टी हुई मात्रा लूकाहोज को और खींची होने पर इस औषध की उपस्थित होती है। अंकित होते हैं लेकिन रोजन के लिए कीर्तित किया गया, आलू और शेयर खास में एक्सोमेदर को मात्रा इसके संगत अस्तित्व कांडों को अधिक अधिकता पड़ गई है।

कीर्तित पद्धति और सव्वलिव्य में इसके कटने के बाद भूख रंग हो जाने में कहीं आती है। पहली बार जब काटने पर पिछले के लिए शेयर कर (एश गोड) पर अध्ययन किया गया तो वह देखा गया कि विकरण प्रक्रिया के दौरान अपने पूर्ववर्ती (पीकल) से मुक्त ग्राहक रिप्रोझेक्ट अयोग्य, केवल हुए मोजदु और लूकाहोज का रंग भूख बनाने में शामिल एनीमैस अप्लीफेयर आक्सोडेज के प्राकृतिक अवरोधक के रूप में कार्य करता है।

नामिकीय-कृषि

कृषि के क्षेत्र में, धेर धेर विकरण प्रतिरोध उपरिवारीती फसल को किस्में जारी की गई। TAT-96-29 नाम से पहली किस्म, महाराष्ट्र में खेती के लिए जारी की गई। TG 47 नामक अन्य बड़ी बीज बाली मूली मूफ़ाली को किस्म, अंग्रेजीदेश में खेती के लिए भोमा के रूप में जारी की गई।

वस्त्र, खाद्य और कागज उत्पादों के बाह्य-वाम उपचार संयंत्रों (ईंटीपी) में उपयोग जैविक अपाध्यों की बढ़त मात्रों के प्रकार के लिए निर्माण अध्ययन प्रौद्योगिकी का संस्कारपूर्वक विस्तार किया गया। इस तरह के चार संयंत्र प्रशासित किए गए।
आइसोटेप अनुप्रयोग

केला के तिरुवनंतपुरम के तटीय क्षेत्र में विभिन्न प्रकार के ज्वार-भाल को स्वागतिकों में लोकसंगठन स्वागतिकों (एसजीडी) का माना जाने के लिए जोड़ा किया गया। प्राकृतिक 232Rn (अर्ध जीवन 3.8 दिन) का उपयोग द्वारा रूप में किया गया। यह अध्ययन, तटीय क्षेत्र के अंदर समुद्री अंतर्राष्ट्रीय का रखरखाव करने द्वारा जलमार्ग में भूमिज्ञ के विवेकपूर्व उपयोग में सहायक होगा।

लघुलेख 177 आधारित रोडोमॉडेलों के विकास का अंच हमारे प्रायोगिक से सफलताकी परीक्षण अनुसार हुए हैं। लघुलेख में, भारत के कुछ नामित औषधिविद्यालय, नूरीएडोक्सीन ड्रग्स के उपयोग होने के 177Lu-DOTATATE नन्दन के 177Lu का उपयोग कर रहे हैं। भारत उन साल देशों में से एक ही जो क्षेत्र के उपयोग के लिए 177Lu आधारित घिस्कर्स का अनुसरण कर रहे हैं।

वड़डायर के आयार्स स्वास्थ्यकों अनुसंधान किरण एंटी-तालोआई (एएटीआई) सुसंधा को आयार्स में उभयता दोस मात्रा वाले नए 66 एमएलडी सेवन उपचार संयंत्र के साथ अब जोड़ा गया है।

पदार्थ कार्यक्रम

7000 से 11000 द्वारा संबंधित ज्ञान पर काष्ठ Zr-2.5 Nb पर संसाधन नकदों बनाए गए। उपयोग अंकितों के आधार पर, विभागित किया गया। इस अंकित के कारण एंटी-तालोआई (एएटीआई) संयंत्र में दोस मात्रा के काम (ओलिंपिक) सफलता प्राप्त की गया। यह कार्य हि.बाबा स्विट्च नामित इंस्टीटुट के सहयोग से किया गया।

युक्रेन चुंबकीय केटोरों प्रभाव पर अध्ययन करने के लिए ज्ञान Ni-Mn-Sn प्रणाली पर आधारित लोहचुंबकीय शेष मंगेषी मिश्रण का श्रेणी का अनुसरण नकद होने के 0.35m CMOS प्रोग्रामों के वाले तथा विभिन्न संसूचिक अनुप्रयोगों में उपयोग में आने-आने तीन ASIC या अनुप्रयोग, अनुप्रयोग और अनुप्रयोग का अंकरित, विकास और परीक्षण सफलता प्राप्त किया गया। अनुप्रयोगों, वोल्टमेट्र भारतीय न्युनमार्ग प्रणाली कार्य में उपयोग किया जाने वाले प्रतीकों प्रति चेवर संसूचिक के लिए एक अनुभव रोड-आउट है, अनुप्रयोग,
संहत गामा संसूचना जांचों के लिए एक अभिधित फोटोडाययड और रीडआउट इलेक्ट्रॉनिक्स है, और अणुसूचक, सिलिकोन प्रकार का आंतरिक और प्रताप संसूचक के लिए एक निम्न क्षमता अग्र-भाग रीडआउट है।

एक जलवेष्टी न्यूक्लियर प्रणाली (आईएनएस) विकसित किया गया है, जिसे भारत केंद्र द्वारा विकसित पाइप निरीक्षण (PIG) गेज के साथ युक्त किया जा सकता है। आईएनएस ऑप्टिस्की का पर्यंत प्रक्रमण, पाइपलाइन का 3-डी ले आउट का सही-सही निर्देशन कर सकता है। फरीदाबाद के आईओएल अनुसंधान एवं विकास केंद्र में परीक्षण पाश (लूप) में प्रणाली का पर्यंत को गई है।

त्वरक एवं उच्च शक्ति इलेक्ट्रॉनिकी

एडीएससी हेन्ड्रू अनुसंधान एवं विकास कार्यक्रम के अंतर्गत सीसा-विस्फार-पुंपक (एलबो) इंटिग्रेटेड पर आधारित उच्च तीव्रता न्यूट्रिनो समुखस्तता इलेक्ट्रॉन तथा गशोरी के विकास के लिए अभ्यंत किया गया। अनुसंधान एवं विकास अभ्यंत हेन्ड्रू 30 MeV एवं 500 माइक्रो-पीटोन्नाइल श्रेणी के विकास के लिए अभ्यंत किया गया। २००० और ३००० उल्टा माइक्रो-पीटोन्नाइल में संयोजन किया गया।

इंदौरी स्थित ४० MeV RF इलेक्ट्रॉन त्वरक प्राप्तालन रहा और इसका अनेक योगदान विकार में प्रयोग किया जा रहा है। भीलवाड़ के हेन्ड्रू सिलिकोन पावर डक्ट्रोड बियर का 0.4 kGy पर फिल्टर से पावर डक्ट्रोड का उत्क्रम पं: प्रतिप (Ttr) समय 14 माइक्रो सेकंड से लगभग 6 माइक्रो सेकंड तक हो गया है।

एचपीएम उपाध्य लेने के लिए रिफ्लेक्स ड्रायोड और परावलंकों के साथ ३०० kV, १२ kA, ३०० ns, १० Hz पुसरावर तर की रेंज तक सहित एक द्विवेष्टीय प्रकार का उच्चतर वातावरण जनरेटर का अभिकल्पन एवं संचारण किया गया। यह प्राप्तालन रहा और उच्च शक्ति माइक्रोवेव निर्माण के लिए इसका प्रयोग किया गया।

अन्य प्रगत प्रौद्योगिकीय कंप्यूटर

न्यूनतम समानांतर संसाधन अनुपम सूचर कंप्यूटर को ४७ टेपशाला पर वैबार्स करके अनुपम-अधारात्मक नाम से प्रयोजनात्मक बीतिया को जारी किया गया।

क्रयायो प्रौद्योगिकी

क्रयायो प्रौद्योगिकी अनुसंधान एवं विकास अनुसंधान अनुसंधान के विकास में विषेष उपलब्धियाँ प्राप्त कर खेल ५०० W तक प्रकार को गई।

निर्लब्धीकरण

३०० kV, १२ kA, ३०० ns, १० Hz द्वारा विकसित भौतिकीय दर्शक के विकास में विषेष उपलब्धियाँ प्राप्त कर खेल ५०० W तक प्रकार को गई।

प्लांवा प्रौद्योगिकीया

३०० kV, १२ kA, ३०० ns, १० Hz द्वारा विकसित भौतिकीय दर्शक के विकास में विषेष उपलब्धियाँ प्राप्त कर खेल ५०० W तक प्रकार को गई।

प्लांवा प्रौद्योगिकीया

३०० kV, १२ kA, ३०० ns, १० Hz द्वारा विकसित भौतिकीय दर्शक के विकास में विषेष उपलब्धियाँ प्राप्त कर खेल ५०० W तक प्रकार को गई।
रोबोटिकी

सौर विद्युत संयंत्र में प्रयुक्त 1.8 m x 3m आकार के परवलयी सौर पररित्वक्तों को स्थायीत्व समय के लिए एक उपकरण का विकास किया गया। हाल ही में इस उपकरण को पूर्ण के निकट विद्युत सौर विद्युत संयंत्र में क्षेत्र परीक्षण के लिए उपलब्ध कराया गया।

भूकंप विश्लेषण

भारत केंद्र के भूकंप डाटा केंद्रों (SDCs) में सूचना गतिक
भूकंप सहित भूकंपी प्रभावों का तथ्य एवं उसका पालन करने के उद्देश्य से अनेक नई विद्यालयों का विकास किया गया और उनका तपासना के साथ रिपोर्ट किया गया।

एसडीसी, भारत केंद्र से यह प्रमाणित किया गया है कि सामान्यतः छठे अन्तरराष्ट्रीय अंतरराष्ट्रीय भूकंपी एजेंसियों का तुलना में 2500 किमी के घरे के भूकंप स्थानीय घटनाओं का रिपोर्टें अंतिम प्रारंभ हो जाती है।

सामाजिक प्रयास एवं प्रोत्साही हस्तांतरण

अभिलक्षी जिलों के जल अभाव क्षेत्र निम्नक्षेत्र गांव में समस्यावर्धित जलवायु परिवर्तन तकनीक के उपयोग द्वारा 30,000 लीटर प्रति घंटे की निगरानी कष्टों का वातावरण जलस्रोत को ग्राहण की गई। भारत केंद्र के आकृति कार्यक्रम के अंतर्गत इस जल स्रोत को किसानों के उपयोग के लिए स्थापित किया गया।

50,000 केले के पौधों को क्षेत्र कठोरन सुविधा के साथ एक ऊतक संरचना प्रोत्साहन का चरणार्थ किया गया एवं अभावक्षी, महाराष्ट्र में आकृति कार्यक्रम के अंतर्गत कठोर एवं अनुरक्षण में प्रशिक्षित किया गया।

ग्रामीण क्षेत्र के लिए आकृति प्रोत्साही पैक पाँच और पाठ्यों को हस्तांतरित किया गया। पहली बार दो नई प्रोत्साही उद्योग को हस्तांतरित की गई।

चिनित्सा संबंध

हमारे वासी औषधालय को पूर्णतर सुसंचालित किया गया ओर मार्च 2011 से यह पूर्णरूप से कार्यान्वयन है। भारत केंद्र अपराधी के अधृतिकोण पर लाभाधिकारों को उत्तर संबंध चर्चा करने के लिए अनेक नए उपकरण का प्राप्त किया गया।

प्रशासन वर्ग

प्रशासन वर्ग द्वारा प्रशासन, स्थापना, मानवविकासित नियोजन, कार्यकर्ता डाटा प्रचार, वित्त एवं लेखा और सुरक्षा के क्षेत्रों में महत्वपूर्ण योगदान दिया गया।

सुरक्षा एवं प्रत्यक्ष संरक्षा

हमारे केंद्र की सुरक्षा अवस्था महत्वपूर्ण है। भारत केंद्र की सुरक्षा एवं सी.आर.एसएफ के कार्यवाहन हमारी स्थापना को प्रत्यक्ष सुरक्षा उपलब्ध कराते में सरकारी कार्य करते हैं।

में, भारत केंद्र के अभिलक्षी कार्यकर्ताओं की प्रशिक्षण करता हूँ जिन्होंने हमारे केंद्र को विभिन्न स्थापना को सुरक्षित करने में महत्वपूर्ण भूमिका निभाई है। में अपने केंद्र के सभी अधिकारियों और कार्यकर्ताओं को भी सरकार करता हूँ जो सुरक्षा कार्यों को अपनी पूरी प्रभावीता तरीके से निष्ठुर में सहयोग देते हैं।

में अपने सभी साइडक्स से आग्रह करता हूँ कि वे वर्तमान परिस्थितियों में सरकार सावधान एवं सतर्क रहें।

भूदृष्टि एवं बागवानी

भारत भूदृष्टि एवं व्यवसायी अनुसंधान अनुसार के कामिओं के उल्लेख को प्रतिस्पर्धा इस संस्थान से संदर्भित दिखाई देती है। में इस अवसर पर उनकी सेवाओं की सहमति करना चाहता हूँ।
निष्कर्ष

प्रिय साध्वी,

यहाँ मैंने वर्ष के दौरान किए गए कार्यक्रमों की संक्षिप्त ज्ञान ही प्रस्तुत की है। समय की कमी के कारण बहुत सी बातों को चर्चा में नहीं कर पाया हूँ। इसका अर्थ यह नहीं कि वे कम महत्त्वपूर्ण हैं।

पिछले वर्ष में इसी अवसर पर अपने भाषण में अंतर्राष्ट्रीय सहयोग के संदर्भ में वैश्विक चुनौतियों को पूरा करने के लिए अपनी श्रेष्ठता बनाए रखने पर जोर दिया था। आगामी १२ वीं पंचवर्षिय योजना के प्रस्ताव इन्हीं लक्ष्यों को ध्यान में रखकर बनाए गए हैं।

जैसा कि आप सभी जानते हैं हमारे कार्यक्रमों द्वारा प्रदत्त सेवाएं हमारी सामाजिक आवश्यकताओं के लागभग सभी क्षेत्रों को समाहित करते हैं जिनमें खाद्य, जल, पर्यावरण, विश्वसनीय सेवा, उद्योग, शिक्षा तथा राष्ट्रीय सुरक्षा शामिल हैं। समाज के हित के लिए अब हमें और अधिक प्रयास करने होंगे। हमने इस आवश्यकता को पूरा करने के लिए नयी फहर की है। मैं परमाणु ऊर्जा विभाग के परिवेश के हमारे सभी सदस्यों से आप्रवाश करता हूँ कि वे समाज की आवश्यकता की पूरी के लिए हमारो सामाजिक कार्यक्रम में सक्रिय रूप से योगदान दें।

मित्रों, अंत में इस अवसर सुभ किया गया है अवसर पर आए, हम यह टुड़ संकल्प करते हैं कि अपने लोगों के लक्ष्यों के लिए हम नामीकृत विज्ञान एवं प्रौद्योगिकी के अग्रणी क्षेत्रों में उत्कृष्टता को बनाए रखने हेतु पूर्ण समर्पण की भावना से कार्य करेंगे।

- जय हिंद -"
64th Anniversary of the Independence Day
Monday, August 15, 2011

Address by Dr. R.K. Sinha, Director, BARC

“Dear colleagues,

Let me first extend my greetings to you all on the occasion of the 64th anniversary of the independence day of our country. This morning, we have assembled here not only to take a collective pledge to preserve the honour and dignity of our national flag, but also to pay our homage to those who have made supreme sacrifices for the sake of freedom of our country. We also salute the members of our armed forces, who provide security to our country.

We take this opportunity to review our work and take stock of what we have achieved in the recent past. As you know, our mandate includes nuclear energy and nuclear fuel cycle, research reactor along with radioisotope production and isotope applications, different advanced technologies associated with these programmes, basic science and applied research, and strategic activities. Let me cite a few examples to illustrate some of the notable developmental work carried out and achievements made recently in our Centre.

Research Reactors

Research reactor Dhruva continued to serve as a major facility for radioisotope production and as a national facility for neutron beam research. As a part of the refurbishment programme of this 25 year old reactor, replacement of several major equipment has been completed. These include main Motor-Alternator sets and switch gears, channel flow monitoring gauges and I&C panels in the main control room.

The core of CIRUS has been fully defueled. Its process systems are kept under preservation mode.

Detailed engineering of various reactor systems of upgraded APSARA reactor is in progress. The upgraded reactor will provide enhanced facilities for beam tube research, radio-isotope production, calibration and testing of neutron detectors, material testing and bulk shielding experiments.

The conceptual design of a High Flux Research Reactor (HFRR) has been completed. This new research reactor is designed primarily to meet the large requirements of high specific activity radio-isotopes and to provide enhanced facilities for basic research in frontier areas of science and for applied research related to development and testing of nuclear fuel and reactor materials.

Nuclear Power Related R&D

Even before the accident at Fukushima, our reactor safety research programmes covered extreme internal as well as external event scenarios. A 1:4 Containment Test-Model of the 540 MWe PHWR (BARCOM), with extensive instrumentation was constructed and commissioned at Tarapur. The model was recently subjected to an over-pressure test when at 1.77 times the design pressure, the first milestone, viz. “first appearance of crack” was reached. The test data are being analysed as an International Round Robin exercise with four Indian and eleven foreign participating organisations from seven foreign countries.
Understanding the behaviour of buildings under relevant seismic loading conditions is an important aspect of plant safety. Through a major experiment on two large reinforced concrete structures, we found that the overall behaviour of the structures under seismic conditions can be closely simulated by a simpler push-over procedure. This finding will reduce the need for expensive shake-table test or elaborate non-linear dynamic analysis for seismic qualification.

On the process side, the effectiveness of water injection into moderator side as a Severe Accident Management Guidelines (SAMG) action to mitigate the consequences of Station Black Out (SBO) was assessed for a large PHWR.

The tsunami evaluation exercise for all the coastal sites has been underway since last three years and a National Round Robin Exercise has been carried out under this programme. A detailed analysis procedure has been formulated for local inundation mapping and analysis has been completed for Tarapur site.

**AHWR Programme**

Towards an early launch of AHWR project, the work for detailed engineering design of conventional engineering systems of AHWR has been started in consultancy mode.

Accident Management Analyses have been carried out for AHWR for some of the extreme events, including Large Break Loss of Coolant Accident, along with non-availability of Emergency Core Cooling System, together with loss of Moderator Heat Sink.

As a part of validation of the physics design parameters and the calculational models used for thorium based fuel, integral experiments with (ThO$_2$ - 1% wt% PuO$_2$) cluster and a mixed cluster consisting of Thoria and natural uranium have been performed in AHWR critical facility yielding valuable data relevant for design validation of AHWR. The fuel cluster was later loaded in a regular fuel position of Dhruva to study the irradiation behaviour of the thoria based AHWR fuel.

The experimental programmes towards evaluation of design margins for AHWR continued with the setting up of several new facilities and conduct of experiments in the existing ones. Innovative experiments to detect occurrence of critical heat flux in a new experimental set up were conducted to detect occurrence of this phenomenon.

**Advanced Nuclear Fuels**

**PFBR Fuel Fabrication**

Fabrication of the Mixed Oxide fuel pin for the first core of PFBR is in progress in Advanced Fuel Fabrication Facility of BARC at Tarapur. Laser decontamination of these pins has been incorporated in the process flow sheet. The use of laser decontamination system has reduced the exposure to operating personnel.

**AHWR Low Enriched Uranium Fuel**

As a part of development of LEU fuel for AHWR, ThO$_2$ –UO$_2$ pellets (300 Nos.) of different compositions having UO$_2$ from 8 to 22.5% were compacted and sintered in various atmospheres like, Ar, Ar-8%H$_2$, and N$_2$. The co-efficients of expansion of these fuel compacts have been determined. The evaluation of further thermo-physical properties of these fuels is in progress.

By utilising appropriate conversion-recycle-conversion (CRC) technique, a zero discharge of fluoride effluent has been achieved in U-metal production unit.
Development of advanced fuels for Fast Reactors

**Vibro pack fuel**

BARC has been working in the area of development of advanced fuels for fast reactors. As a part of this activity, plutonium rich mixed oxide microspheres of nearly 780 micron diameter were prepared for the first time in the world at BARC, by internal gelation method using sol-gel process. These microspheres, along with smaller size (around 100 micron) UO$_2$ microspheres prepared at IGCAR, will now be used as fuel material of a test pin for irradiation in FBTR at IGCAR.

**Metallic Fuel**

A glove box facility consisting of, injection casting of uranium/U-alloy rods in quartz tube moulds, demoulding of cast rods, end-shearing of rods and an automated inspection system, has been set up. This facility has been successfully used for fabrication of required numbers of natural U-6wt% Zr alloy metallic fuel slugs meeting required specifications. Continuous casting of uranium has been carried out successfully. This will help in reducing alpha waste during the fabrication of metallic fuel for FBR.

As a part of development of mechanically bonded metallic fuel for fast reactor, U-15%Pu slug has been fabricated for characterisation. The above alloy has been investigated for several of its relevant properties.

**CERMET fuels**

As a part of development of fuel for Fast Reactors, Cermet fuels comprising of 15% and 30% by volume of UO$_2$ dispersed in U metal powder were compacted and sintered at 1090°C in Ar and vacuum. The shrinkage behaviour of the above cermet fuels were evaluated using a dilatometer. It was observed that sintering was superior in Ar atmosphere.

**Reprocessing**

Plutonium Plant at Trombay continued to operate safely and the irradiated fuel bundles received from Dhruva/CIRUS were reprocessed. In addition, Uranium Thorium Separation Facility (UTSF) was operated to recover thorium from thoria raffinate.

Reprocessing Plant at Kalpakkam was operated quite satisfactorily and safely. Under the Nuclear Recycle Board, the PREFRE-2, Tarapur Plant has started production. Additional Waste Tank Farm is also operational.

In order to realise the design through-put of future future large scale reprocessing plants, a full size prototype continuous rotary dissolver has been fabricated and installed. This unit will be operated under simulated conditions (with uranium nitrate) to generate useful data and provide feedback on various aspects such as material of construction, remote handling, recovery of material from hulls, etc.

For the first time in the country, a process has been developed for synthesis of Hydroxyl Amine Nitrate (HAN) to be employed as an alternate solvent in spent fuel reprocessing. The material has been indigenously produced up to litre scale.

Recovery of useful isotopes such as $^{90}$Sr, $^{90}$Y & $^{241}$Am from radioactive waste was continued and supply to the users was maintained.

**Nuclear Waste Management**

Technology for remote dismantling and decommissioning of Joule Melter inside hot cell was developed and decommissioning of Joule Melter System is nearing completion with very low man-
rem expenditure and solid waste generation at the Advanced Vitrification facility, Tarapur.

At Waste Immobilisation Plant, Kalpakkam, inactive commissioning of second Joule Heated Ceramic Melter using simulated High Level Waste (HLW) was carried out. Remote replacement of components such as off-gas jumper, thermo wells, thermocouples and level probe has been achieved.

Vitrification technology employing Cold Crucible Induction Melter (CCIM) crossed another milestone by successful completion of simulated waste feed experiments.

A first time activity in DAE to retrieve, reduce the volume and dispose of the pressure tubes from the en-masse coolant channel replacement campaign of MAPS, has been taken up at the Centralised Waste Management Facility, Kalpakkam.

A process has also been developed for the synthesis of cesium-specific crown ether and indigenous production of the material up to kilogram scale. Inorganic ion-exchanger media, in bead form have been developed for removal of specific isotopes such as $^{106}$Ru, $^{99}$Tc, $^{144}$Ce from low and intermediate level liquid wastes.

**Environmental Monitoring and Radiation Safety**

Preliminary estimates of the release rates of different radio-nuclides into the atmosphere and into the Pacific Ocean due to Fukushima nuclear accident were derived using indigenously developed environmental models. Reasonable matching of the estimated release rates was observed with the values reported by different agencies. All the environmental survey laboratories in the country carried out a special campaign to monitor very low level of radioactivity in the environmental matrices. The data have been regularly updated in the departmental websites and communicated to the IAEA. We were able to confirm that this event has not caused any noticeable impact on India.

The solar powered Environmental Radiation Monitor (ERM) for open field installation was enabled with data communication facility using Short Message Service (SMS) of Global System for Mobile Networking (GSM), Local Area Network (LAN) and Optical Fibre Based Communication channels. These stand-alone automated systems transmit background environmental radiation data to a central station at Mumbai and serve as an early warning system, in case of a nuclear emergency due to an increased gamma radiation level in the environment. Industrial grade production of these units has been initiated under an MoU with ECIL.

Inhalation dosimeter badges have been developed for directly monitoring the cumulative doses due to radon, thoron decay products using direct progeny sensors. These badges have been deployed in about 2000 places within the country and also in about 1000 locations in Europe, based on the request from several foreign institutions.

The R&D efforts to enhance safety during transportation of radioactive materials through public domain have resulted in successful development of Poly Urethane Foam (PUF), which is being further qualified for its use as thermal shielding and impact limiter in the transportation packages. Mapping of lead melting in real time was captured for the first time by adopting neutron radiography, using a dedicated beam facility at CIRUS. This experimental data will facilitate validation of computer codes used for modeling the behaviour of lead during the hypothetical accident of a spent fuel transport cask being engulfed in fire.

Two Emergency Response Centres (ERCs) have been established at IPR, Gandhinagar and RMP, Mysore with radiation monitoring systems and trained
Emergency Response Teams (ERTs). This brings the total number of ERCs for preparedness and response to nuclear and radiological emergencies to 20 in the country.

Technical support was provided to National Disaster Management Authority (NDMA) for the preparation of guidelines on Preparedness and Response to Nuclear Disaster.

**Physical Sciences**

As a part of beam line development activity at INDUS, High Resolution Vacuum Ultraviolet beam line has been commissioned for spectroscopic study of molecules of interest to astrophysics and environment science. The EXAFS beam line at INDUS has been augmented with fluorescence measurement facility for characterisation of surface, thin films and multilayers.

A quadrupole mass spectrometer, which has a resolution of 1 AMU and mass range of 150 AMU, has been fabricated and installed at Heavy Water Plant, Tuticorin.

**Chemical Sciences**

The feasibility study of in-house developed nano-diamond film as monitor of alpha activity of plutonium, in highly acidic medium, has been successfully completed.

A simple and inexpensive hydrogel-based material has been developed, which consists of nitrogen oxides releasing agarose gel, combined with citric acid loaded cotton gauze. It has excellent antimicrobial properties and has potential as a dressing material for ulcerative skin infections.

The studies on bio-denitrification using mixed microbial granules showed that treatment of up to 4050 mg NO$_3$-N/L (equivalent to 18,000 mg/L NO$_3$) could be achieved by supplying acetate at a C/N ratio of 1.5. This was demonstrated in 6 litre volume laboratory scale sequencing batch reactors.

**Biological Sciences**

In a significant finding, 1,4-Naphthoquinone (NQ), a parent molecule for many anti-tumour natural compounds, protected lymphocytes and intestinal cells from mice against a dose of 4 Gy gamma radiation. In the mice, 2 m/kg NQ given in-vivo restored radiation induced bone marrow suppression. The possible mechanisms involve activation of redox transcription factor Nrf-2 (nuclear factor E2 related factor-2).

**Food Technology**

Acrylamide, a neurotoxin, and a probable carcinogen, has been reported to be present at significantly higher levels in carbohydrate-rich fried foods, such as potato chips. The compound originates from the reaction of amino acid asparagine with reducing sugars like glucose present in food during frying. The acrylamide content in chips prepared from potatoes irradiated for sprout inhibition, was found to be lower than that in the corresponding non-irradiated controls.

The browning of cut fruits and vegetables is reduced in irradiated fruits and vegetables. For the first time, in a study conducted on pre-cut ready to cook ash gourd, it has been shown that gamma resorcylic acid liberated from its precursor during radiation processing acts as a natural inhibitor of polyphenol oxidase, the enzyme involved in brown discoloration of cut fruits and vegetables.

**Nuclear Agriculture**

In the field of agriculture, two new Trombay radiation induced mutant crop varieties have been released. The first variety, named TAT-96-29, was released for cultivation in Maharashtra. Another large seed confectionary groundnut variety, TG 47 has been released as Bheema for cultivation in Andhra Pradesh.
Nisargruna technology has been successfully extended to process large quantities of biological sludge generated in Effluent Treatment Plants (ETP) of textile, food and paper industries. Four such plants were set up.

Isotope Applications

Investigations were carried out to quantify the Submarine Groundwater Discharge (SGD) occurring under various tidal conditions in Thiruvananthapuram coast, Kerala. Natural $^{222}\text{Rn}$ (half life = 3.8 days) was used as a tracer. The study will help in the judicious exploitation of groundwater in coastal aquifers by maintaining the seawater interface well within the coastal zone.

Our efforts towards development of Lutetium-177 based radiopharmaceuticals have shown positive results. Currently, six nuclear medicine departments in India are using the high specific activity $^{177}\text{Lu}$ produced in the Dhruva reactor, for the preparation of $^{177}\text{Lu}$-DOTATATE for the treatment of neuroendocrine tumors. India is among one of the seven countries which are pursuing $^{177}\text{Lu}$ based therapy for the treatment of cancer.

Sludge Hygienisation Research Irradiator (SHRI) facility, Vadodara has now been linked to the new 66 MLD sewage treatment plant that has higher solid content in the sludge.

Materials Programme

Processing maps have been generated on cast Zr-2.5Nb over a temperature range of 700°C to 1100°C. On the basis of the data generated, forging has been carried out successfully on full scale cast ingots of Zr-2.5Nb by a manufacturer. This work was carried out in collaboration with Nuclear Fuel Complex, Hyderabad.

A new class of ferromagnetic shape memory alloys based on Ni-Mn-Sn system known to exhibit inverse magnetocaloric effect was studied. Single crystals of the thermoelastic shape memory alloy Cu-16Zn-16Al were successfully prepared using Bridgmann methodology and soft mould technique.

A prototype of ITER Test Blanket Module (TBM) first wall is being fabricated by machining, bending and laser welding. Laser welding studies on ferritic martensitic steel P91 were carried out in this connection, followed by mechanical testing of the weld joints with and without a post weld treatment.

After successful augmentation of Phase-I part of Lithium Metal Plant, and after obtaining the regulatory clearance, the plant was operated for demonstration of its capability by achieving desired grade of lithium, required for the ITER TBM programme.

A large number of special shapes of vacuum hot-pressed beryllium have been fabricated as per the user specifications. These shapes have been accepted and are being used for neutron physics experiments.

Electronics & Instrumentation

Helicopter-borne Time Domain Electromagnetic (TDEM) system for aerial exploration of uranium ores was successfully flight tested recently. During this test, the underslung system, including 22 m diameter transmitter, was suspended 30m below the helicopter and 30m above ground.

Differential microbarometer to measure very small atmospheric pressure variations of the order of microbars around the mean atmospheric pressure, in infrasonic range, has been developed to facilitate its large scale production in the country.

Three ASICs - ANUSPARSH, ANUDRISHTI and ANUSUCHAK in 0.35 µm CMOS technology, and to be used in different detector applications, were designed, developed and tested successfully. The ANUSPARSH is a front-end readout for Resistive Plate Chamber detectors to be used in the planned Indian
Nutrino Observatory, the ANUDRISHTI is a monolithic photodiode and readout electronics for compact gamma detection probes and the ANUSUCHAK is low power front-end readout for silicon type Intrinsic and type detectors.

An Inertial Navigation System (INS) has been developed, that can be coupled to the Pipe Inspection Gauge (PIG) developed by BARC. Post processing of the INS data can accurately determine the 3-D layout of the pipeline. Trials of the system have been made in the test loop at the IOCL R&D Centre, Faridabad.

**Accelerator & High Power Electronics**

As a part of R&D programme for ADSS, studies were initiated to develop high intensity neutron spallation targets based on Lead-Bismuth-Eutectic (LBE) liquid metal. An LBE target module consisting of gas driven liquid metal circulation system with remote dismantling facility has been designed to couple with 30 MeV and 500 micro-Ampere proton beam for R&D studies. A target module has been fabricated for full scale trials with LBE before coupling it to the proton beam.

The 10 MeV RF Electron Accelerator at EBC has been operational and being used for several industrial process development. Irradiation of silicon power diode chips for BHEL at 0.4 kGy improved the reverse recovery time (Trr) of power diodes from 14 microseconds to about 6 microseconds.

A bipolar type six stage Marx generator of rating 300kV, 12kA, 300ns, 10Hz repetition rate with a Reflex Triode and reflectors for HPM generation was designed and fabricated. It has been operational and used for generation of high power microwaves.

**Other Advanced Technologies**

**Computers**

The latest parallel processing ANUPAM supercomputer, benchmarked at 47 Teraflops, and called “ANUPAM-Adhya” has been released to users.

**Cryo-Technology**

A significant milestone was achieved in the development of an advanced indigenous helium refrigeration system for cryogenic application. During operational trials, refrigeration power of about 500 W was achieved at 20K.

**Desalination**

Field test of BARC developed membrane based water purification system was carried out on tube well water for 24 villages in six districts of Punjab for removal of uranium from the ground water. Purified water containing less than 6 ppb uranium (which is far below the AERB permissible limit of 30 ppb) was produced from the raw water having 685 ppb uranium, The unit can be installed in homes and can be used as a point of use device with very low electrical power consumption.

**Plasma Technologies**

As a part of the development of dry processes for reduction of Uranium – Hexafluoride (UF6) to Uranium - Tetra Fluoride (UF4), thermal plasma assisted as well as flame reduction based bench scale setups were successfully designed, constructed and operated.

**Pulse Power Technologies**

A bipolar type six stage Marx generator of rating 300kV, 12kA, 300ns, 10Hz repetition rate with a Reflex Triode and reflectors for HPM generation was designed and fabricated. It has been operational at 225 kV and used for generation of High Power Microwaves in the range 1.2 GHz to 3.8 GHz.

**Robotics**

A gadget has been developed for automated
cleaning of parabolic solar reflectors of size 1.8 m x 3 m used in the solar power plant. The gadget has recently been provided for field testing in a solar power plant near Pune.

**Seismology**

With the objective of promptly detecting, locating and identifying seismic events, including tsunamigenic earthquakes, several new analysis techniques have been developed and implemented at the Seismic Data Centers (SDC) of BARC. It has been demonstrated that from SDC, BARC, regional events located within a radius of 2500 km are, in general, reported much faster as compared to that by any other national and international seismological agencies.

**Societal Outreach & Technology Transfer**

An underground water source with a discharge capacity of 30,000 lph has been identified using Isotope Hydrology technique in a village called Nimkhed in Amravati District, a water scarce area. This water source has been established for use of farmers under BARC’s AKRUTI Programme.

A tissue culture laboratory with field hardening facility of 50,000 banana plantlets has been made operational and first batch of hardened plantlets have been sown in the field in AKRUTI programme at Amravati, Maharashtra.

A brackish water Reverse Osmosis (RO) plant with 300 lph capacity has been set up in a coastal village named Farare in Dapoli, through AKRUTI programme. The villagers have been trained to operate, run and maintain the plant.

AKRUTI Tech Pack, meant for rural sector, was transferred to five more parties. Two new technologies were transferred to the industry for the first time.

**Medical Services**

Our Vashi Dispensary is completely renovated and from March 2011 it is fully functional. Several new equipment have been procured for the BARC Hospital to facilitate its further modernisation and enhanced services to the beneficiaries.

**Administrative Group**

The administrative Group continued to provide vital supporting functions in the fields of administration, establishment, including manpower planning, personnel data management, finance and accounts, and security.

**Security & Physical Protection**

Security of our Centre is of paramount importance. BARC security and CISF personnel have been performing a commendable task of providing the physical protection of our establishment. I take this opportunity to express appreciation of the BARC Fire Service personnel for their role in the protection of the various establishments of our Centre. I also compliment all officers and staff of our Centre for extending their cooperation to help the security personnel in discharging their duties effectively. I urge all my colleagues in our Centre to continue to remain vigilant and alert in the present environment.

**Landscape and Gardening**

The contributions made by the personnel of our Landscape & Cosmetics Maintenance Section is evident from the beautiful ambience of this venue. I take this opportunity to acknowledge their services.
Closing Remarks

Dear Colleagues,

I have attempted to give here only a few brief glimpses of some of our activities carried out by us during the recent past. Due to constraint of time, I could not cover many more, which are by no means less important.

In my speech last year, on the same occasion, I had highlighted the importance of continuing to maintain our excellence to meet the new challenges in the context of the emerging international co-operation. I would like to mention that our proposals for the forthcoming XII Five Year Plan, particularly address the realisation of this objective.

As you are aware, our programmes and deliveries directly address nearly all sectors of our societal needs, including food, water, environment, energy, healthcare, industry, education and national security. We now have a need to further strengthen the visibility of these deliveries to the society at large. We have already taken new initiatives to meet this need. I urge all members of our DAE family to contribute to our outreach and public awareness programmes with greater vigour.

Friends, finally on this very special day, let us firmly resolve and rededicate ourselves to continue our pursuit of excellence in the frontier areas of nuclear sciences and technologies for the betterment of the quality of life of our people.

- Jai Hind -"
Radiation Processing of Temperate Fruits of Kashmir Valley
Peerzada R. Hussain, Raghuveer S. Meena, Mohd A. Dar and Ali M. Wani
Astrophysical Sciences Division, Nuclear Research Laboratory, BARC, Srinagar.

Abstract:
Kashmir valley is famous for its temperate horticulture. Main temperate fruits grown commercially in the valley include apple, pear, peach, plum, cherry, strawberry and apricot. These fruits being perishable and susceptible to microbial spoilage, have a short shelf-life. The short shelf-life in an impediment in their transportation and marketing and results in huge losses. Study was carried out at NRL, Srinagar to investigate the effect of gamma irradiation on the keeping quality of most of these fruits. The effect of gamma irradiation alone and in combination with other techniques like controlled low temperature storage, edible polysaccharide coating and calcium chloride treatment was studied in detail. Our results revealed that there is a great potential for the use of radiation in extending the storage life of most of the temperate fruits produced in the valley of Kashmir.

Keywords: Gamma irradiation, Temperate fruits, Quality improvement, Shelf life extension

Introduction
The valley of Kashmir is famous for its temperate horticulture. Nearly 75% of India’s temperate fruits are grown in the valley of Kashmir. Main temperate fruits presently being grown include apple, pear, peach, plum, cherry, strawberry and apricot. The area under cultivation of fresh fruits is 161136 hectares and production of fresh fruits is 957861 metric tons. Among fruits, apple has a leading position both in terms of cultivation and production followed by pear. Apple occupied about 50% of the total area under its cultivation and constitutes around 90% of the total fruit produced in the state. These fruits being perishable in nature hence have short shelf-life at optimal temperatures. Short shelf life of the fruits represents a serious constraint for efficient handling, transportation and marketing chain of the produce. Inappropriate post-harvest management practices and lack of proper scientific storage and transportation facilities result in huge post-harvest losses of the order of 20-40% during handling, packaging, and transportation of the produce. Microbial contamination besides contributing to the losses, poses potential health risks as well. Therefore, the post-harvest treatment of fruits has become necessary to provide longer life to the fruit, which at the same time establishes price for the grower during the glut season.

Gamma irradiation at present is used as the potential method of food preservation. Gamma irradiation effectively delays the ripening and senescence of climacteric fruits, sprouting of bulb and tuber crops and checks the microbial proliferation, thus extends the shelf-life of perishable foods. It is widely used as a quarantine treatment for export purposes and has emerged as a potential alternate to the use of chemical preservatives. Moreover, gamma irradiation treatment can be performed at room temperature and can be applied to bulk as well as prepackaged food, thus obviating the chances of cross contamination. Being a cold process in nature preserves the food in natural form and does not destroy heat-labile aroma and other sensitive constituents of food. Additionally, it can improve food security by cutting down food losses caused by storage insects, microorganisms and physiological
changes. Combinatory treatments have also widely been investigated as they often result in synergistic effects. Gamma irradiation in combination with other treatments (e.g., heat, washing, modified atmosphere storage, edible coating process) decreases the microbial contamination level leading thus to an improvement of shelf life.

Radiation processing of most of the tropical fruits has been extensively studied at Food Technology Division, BARC, Mumbai over the decades. The commendable efforts of radiation processing studies carried out at FTD enabled the market access to Indian Mango from Deogarh to DC, Washington (Sharma, 2008; Hajare et al., 2010; Thomas and Janave, 1975; Thomas, 1986; Dharkar et al., 1970). However, little information is available in the literature on the radiation processing of temperate fruits of Kashmir valley. At NRL, BARC Srinagar, studies have been conducted during the last five years on the effect of gamma irradiation on the Kashmir valley fruits using the PANBIT gamma irradiation facility. These studies were aimed at evaluating the effect of gamma irradiation alone and in combination with edible coating, calcium chloride dip treatment and low temperature storage for the quality improvement, shelf-life extension and as a quarantine treatment for export purposes. The fruits after harvesting at their commercial maturities followed by subsequent pre-cooling and grading were subjected to gamma irradiation alone and in combination with polysaccharide based edible coatings and calcium chloride dip and the synergistic effect on the storage quality and shelf-life extension was evaluated. Table 1 shows the fruits that have been studied so far.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Fruits tested</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pear (Pyrus communis L.)</td>
<td>William/Bartlett</td>
</tr>
<tr>
<td>2</td>
<td>Apple (Malus domestica)</td>
<td>Ambri, Golden Delicious, Royal Delicious, Red Delicious</td>
</tr>
<tr>
<td>3</td>
<td>Strawberry (Fragaria spp.)</td>
<td>Confitura</td>
</tr>
<tr>
<td>4</td>
<td>Peach (Prunus Persica Bausch)</td>
<td>Elberta</td>
</tr>
<tr>
<td>5</td>
<td>Dried apricot (Prunus armeniaca L)</td>
<td>Halmann</td>
</tr>
<tr>
<td>6</td>
<td>Plum (Prunus domestica L.)</td>
<td>Santaroza</td>
</tr>
<tr>
<td>7</td>
<td>Cherry (Prunus avium L.)</td>
<td>Misri, Double</td>
</tr>
</tbody>
</table>

The level of treatments to which the fruits were subjected and subsequent storage conditions are presented in Table 2.

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Irradiation dose (kGy)</th>
<th>CMC con. (% w/v)</th>
<th>Storage condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pear</td>
<td>0.8 - 2.0</td>
<td>0.25 - 1.0</td>
<td>Ambient (25±2 °C, RH 70%) Refrigerated (3±1 °C, RH 90%)</td>
</tr>
<tr>
<td>Strawberry</td>
<td>0.5 - 2.0</td>
<td>0.5 - 1.0</td>
<td>do</td>
</tr>
<tr>
<td>Peach</td>
<td>1.0 - 2.0</td>
<td>0.5 - 1.0</td>
<td>do</td>
</tr>
<tr>
<td>Apple</td>
<td>0.1 - 0.5</td>
<td>0.25 - 1.0</td>
<td>Ambient (15±2 °C, RH 80%) Refrigerated (3±1 °C, RH 90%)</td>
</tr>
<tr>
<td>Dried apricot</td>
<td>1.0 - 3.0</td>
<td>-</td>
<td>Ambient (12-25±2 °C, RH 70-80%)</td>
</tr>
<tr>
<td>Plum</td>
<td>0.2 - 1.5</td>
<td>-</td>
<td>Ambient (25±2 °C, RH 70%) Refrigerated (3±1 °C, RH 90%)</td>
</tr>
<tr>
<td>Cherry</td>
<td>0.3 - 1.5</td>
<td>-</td>
<td>Ambient (25±2 °C, RH 70%) Refrigerated (3±1 °C, RH 90%)</td>
</tr>
<tr>
<td>CMC = Carboxymethyl Cellulose</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results of the studies
Following are the highlights of the results obtained for various fruits.

1. Pear (*pyrus communis* L. Cv. Bartlett/William)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Decay percentage</th>
<th>Shelf-life extension (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amb. storage</td>
<td>Ref. storage</td>
</tr>
<tr>
<td>Control</td>
<td>97.2% after 14 DOS</td>
<td>ND up to 16 DOS</td>
</tr>
<tr>
<td>Irradiation alone 1.5 – 1.7 kGy)</td>
<td>ND up to 16 DOS</td>
<td>ND up to 45 DOS</td>
</tr>
<tr>
<td>CMC Coating alone (1.0% w/v)</td>
<td>ND up to 12 days</td>
<td>ND up to 35 DOS</td>
</tr>
<tr>
<td>CMC Coating, Irradiation (1.0% w/v, 1.5 kGy)</td>
<td>ND up to 22 days</td>
<td>ND up to 60 DOS</td>
</tr>
</tbody>
</table>

ND = No Decay; DOS = Days of storage; Amb. = ambient; Ref. = refrigerated

(Wani et al., 2007, 2008; Hussain et al., 2010)

(a) After 7 days (b) After 14 days

Effect of gamma irradiation treatment on delay in ripening (a) and decaying (b) of pear during storage under ambient conditions.
2. Strawberry (*Fragaria spp.* Cv. *Confitura*)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Appearance of mold growth</th>
<th>Shelf-life extension (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ambient storage</td>
<td>Refrigerated storage</td>
</tr>
<tr>
<td>Control irradiation alone</td>
<td>at 1st DOS after 2 DOS</td>
<td>after 3 DOS after 12 DOS</td>
</tr>
<tr>
<td>(2.0 kGy)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMC Coating alone (1.0 % w/v)</td>
<td>at 1st DOS after 5 DOS</td>
<td>after 5 DOS</td>
</tr>
<tr>
<td>(1.0 % w/v)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(CMC Coating, Irradiation)</td>
<td>after 2 DOS after 21 DOS</td>
<td>after 21 DOS</td>
</tr>
<tr>
<td>(1.0 % w/v, 2.0 kGy)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DOS = Days of Storage

*(Hussain et al., 2007)*

Effect of gamma irradiation on fungal growth of strawberry after 12 days of refrigerated storage
### 3. Peach (*Prunus persica Bausch*) Cv. Elberta

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Decay percentage</th>
<th>Shelf-life extension (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amb. storage</td>
<td>Ref. storage</td>
</tr>
<tr>
<td>Control</td>
<td>51.1% after 6 DOS</td>
<td>40.0% after 20 DOS</td>
</tr>
<tr>
<td>Irradiation (1.2 – 1.4 kGy)</td>
<td>ND up to 7 DOS</td>
<td>ND up to 20 DOS</td>
</tr>
<tr>
<td>CMC coating (1.0% w/v)</td>
<td>ND up to 5 days</td>
<td>ND up to 12 DOS</td>
</tr>
<tr>
<td>CMC coating, Irradiation (1.0% w/v, 1.2 kGy)</td>
<td>ND up to 12 days</td>
<td>ND up to 30 DOS</td>
</tr>
</tbody>
</table>

* Irradiation enhanced the Phenylalanine ammonia lyase (PAL) and antioxidant activity of peach fruit. ND = No Decay; DOS = Days of Storage

*(Hussain et al., 2010, 2008)*

**Effect of Radiation Treatments on inhibition of Decay in Peach Fruit**
4. Apple (*Malus domestica*)

1. Response of apple varieties to irradiation treatment was cultivar dependent. Gamma irradiation doses of 0.2, 0.3 and 0.5 kGy proved beneficial in maintaining the storage quality of Ambri, Golden delicious, Royal delicious and Red delicious apples under ambient as well as refrigerated conditions.

2. Irradiation treatment proved beneficial than control in maintaining the overall quality of apple varieties by about 30 days under ambient conditions and 90 Days under refrigerated storage conditions (Hussain et al., 2008)

3. Irradiation in combination with edible coating (1.0% conc.) was helpful in maintaining the quality of apple varieties up to 100 days of ambient storage.

4. Irradiation in combination with calcium chloride dip treatment (2.0% w/v) extended the shelf-life of Red delicious apples by 20 – 25 days at 17±2 0C, RH 75% following 90 days of refrigeration (Hussain et al., 2011).

Effect of gamma irradiation and edible coating treatment on storage quality of apple varieties. (After 100 days of ambient storage)
5. Cherry (*Prunus avium* L.)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Appearance of mold growth</th>
<th>Shelf-life extension (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amb. storage</td>
<td>Ref. storage</td>
</tr>
<tr>
<td>Control</td>
<td>after 3 DOS</td>
<td>after 21 DOS</td>
</tr>
<tr>
<td>Irradiation (1.2 kGy)</td>
<td>after 9 DOS</td>
<td>NMG up to 35 DOS</td>
</tr>
</tbody>
</table>

NMG = No mold growth; Amb. = ambient; Ref. = refrigerated
6. Plum (*Prunus domestica* L.)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Decay percentage</th>
<th>Shelf-life extension (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amb. storage</td>
<td>Ref. storage</td>
</tr>
<tr>
<td>Control</td>
<td>13.5% after 6 DOS</td>
<td>12.5% after 30 DOS</td>
</tr>
<tr>
<td>Irradiation (1.2 – 1.5 kGy)</td>
<td>ND up to 16 days</td>
<td>ND up to 30 DOS</td>
</tr>
</tbody>
</table>

ND = No decay; DOS = Days of storage; Amb. = ambient; Ref. = refrigerated

7. Dried apricot (*Prunus armeniaca* L.)

The study revealed that medium dose radiation processing of dried apricots proved beneficial in terms of quality maintenance and quarantine control for export purposes of commercially sun dried apricots. Radiation treatment of dried apricots at dose levels of 2.5 and 3.0 kGy proved beneficial in retention of higher levels of â- carotene, ascorbic acid and color values without impairing the taste. Irradiation at all dose levels facilitated the release of residual sulphur dioxide during storage, thereby lowering the residual sulphur dioxide of pre-sulfured dried apricots significantly below the prescribed limit for dried products. Irradiation at 3.0 kGy gave about 1 log reduction in microbial load of dried apricots.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>β- Carotene (mg/100g)</th>
<th>Sulphur dioxide (ppm)</th>
<th>Microbial load (cfu/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>8.6 ± 0.33</td>
<td>590.4 ± 2.3</td>
<td>5.4 ± 0.3</td>
</tr>
<tr>
<td>1.0 kGy</td>
<td>9.6 ± 0.30</td>
<td>545.5 ± 2.5</td>
<td>5.2 ± 0.2</td>
</tr>
<tr>
<td>1.5 kGy</td>
<td>9.6 ± 0.30</td>
<td>490.2 ± 2.4</td>
<td>5.0 ± 0.1</td>
</tr>
<tr>
<td>2.0 kGy</td>
<td>10.1 ± 0.32</td>
<td>405.6 ± 2.2</td>
<td>4.8 ± 0.2</td>
</tr>
<tr>
<td>2.5 kGy</td>
<td>10.8 ± 0.25</td>
<td>382.6 ± 2.3</td>
<td>4.6 ± 0.1</td>
</tr>
<tr>
<td>3.0 kGy</td>
<td>11.4 ± 0.29</td>
<td>350.1 ± 2.3</td>
<td>4.4 ± 0.2</td>
</tr>
<tr>
<td>LSD</td>
<td>0.34</td>
<td>2.2</td>
<td>0.13</td>
</tr>
</tbody>
</table>

(Hussain et al., 2011)

Values are sum of means ± SD (n = 3); LSD = least significant difference (pd”0.05). Values reported are after 18 months of ambient storage.
Conclusion

Gamma irradiation alone and in combination with polysaccharide based edible coatings proved significantly effective in delaying the onset of decay, improving keeping quality and extending the shelf-life of tested fruits under ambient as well as refrigerated conditions. The optimized doses can be used as quarantine treatment for export purposes without any deleterious effect on physico-chemical parameters. Therefore, radiation processing technique offers huge potential for the quarantine treatment as well as shelf-life extension of temperate fruits for domestic as well as export markets.

Acknowledgements

The help and valuable suggestions received from Dr. A. K. Sharma, Head FTD, BARC during the initial stages of this work and the continued co-operation by other scientific staff of FTD particularly Dr P. S. Variyar is gratefully acknowledged.

References


Friction Stir Welding of Aluminium Alloys

N.T. Kumbhar and G.K. Dey
Materials Science Division
and
K. Bhanumurthy
Scientific Information Resource Division

Abstract
Friction Stir Welding (FSW) is a solid state joining technique, widely used for welding of aluminium, magnesium, copper and titanium alloys. Being a solid state joining process, friction stir welding offers various advantages like low distortion, absence of melt-related defects, high joint strength, etc. as compared to other conventional fusion welding techniques. A brief overview of the friction stir welding process and recent developments are presented in this paper. In addition, a composite picture of the work done at BARC, relating to the microstructural developments in a friction stir welded Al 5052 alloy is presented.

Introduction
Friction stir welding is one of the new entrants to the solid state joining techniques, which have made remarkable progress in welding technology. Friction stir welding was developed in 1991 [1] and is essentially a solid state joining process, widely used for the welding of light and difficult-to-weld metals and their alloys like aluminium, magnesium, copper etc [2]. Recently, its applications have been extended to the welding of high melting point materials such as various types of steels [3], Ti alloys [4], Ni-based superalloys [5], the welding of metal matrix composites and polythene [2]. Friction stir welding is being used in various engineering applications, which require the joining of dissimilar material combinations and which are not viable using conventional fusion welding techniques. With recent developments in technology of friction stir welding, it is now possible to carry out dissimilar welding of various types of steels with alloys of aluminium, magnesium, copper, titanium and also other alloy combinations [6]. Moreover, workpieces in the form of plates, sheets and hollow pipes can be welded by this method. Over a period of time developments in friction stir welding have led to different variants like friction stir processing, friction stir spot welding, friction stir channeling etc. [2]. Thus, it can be said that friction stir welding and its variants have brought a revolution in the field of solid state joining technology.

Friction Stir Welding : The Process

Friction Stir Welding (FSW) is a simple process in which a rotating cylindrical tool with a shoulder and a profiled pin is plunged into the abutting plates to be joined and traversed along the line of the joint. A schematic of the friction stir welding process is shown in Fig. 1.

Fig. 1: Schematic of the friction stir welding process
The plates are tightly clamped on to the bed of the FSW equipment to prevent them from coming apart during welding. A cylindrical tool rotating at high speed is slowly plunged into the plate material, until the shoulder of the tool touches the upper surface of the material. A downward force is applied to maintain the contact. Frictional heat, generated between the tool and the material, causes the plasticized material to get heated and softened, without reaching the melting point. The tool is then traversed along the joint line, until it reaches the end of the weld. As the tool is moved in the direction of welding, the leading edge of the tool forces the plasticized material, on either side of the butt line, to the back of the tool. In effect, the transferred material is forged by the intimate contact of the shoulder and the pin profile. It should be noted that, in order to achieve complete through-thickness welding, the length of the pin should be slightly less than the plate thickness, since only limited amount of deformation occurs below the pin. The tool is generally tilted by 2-4°, to facilitate better consolidation of the material in the weld. Upon reaching the end of the weld, the tool is withdrawn, while it is still being rotated. As the pin is withdrawn, it leaves a keyhole at the end of the weld. This is the main disadvantage of FSW and few variants are being used to overcome this aspect.

Microstructure during FSW

During friction stir welding, a variety of interactions occur amongst the tool, workpiece, backing plate and surrounding environment. These interactions affect the temperature distribution and material flow [7,8]. As a result of these complex interactions, the microstructure in and around the weld region is affected. This has resulted in the classification of friction stir welds, into four microstructurally distinct regions. According to Threadgill [9] the four regions are (i) Parent Material, (ii) Nugget, (iii) Heat Affected Zone (HAZ) and (iv) ThermoMechanically Affected Zone (TMAZ). All these regions are identified in Fig. 2, which shows the schematic of a typical cross-section of a friction stir weld. The parent material (or base material) is the region which does not undergo deformation and the microstructure in this region is not affected by the heat produced during the process. No detectable changes are seen in the microstructure of this region. The nugget region is formed by the intense plastic deformation induced mainly by the tool pin and consists of fine recrystallized grains. Hence this zone is also referred to as ‘dynamically recrystallized zone’. The heat affected zone is the region which is affected only by heat and there is no plastic deformation. In this region, the microstructure and/or properties are modified by the thermal heat. The thermomechanically affected zone surrounds the nugget and it experiences lower temperatures and less deformation, as compared to those in the nugget. In this region, the material is plastically deformed by the tool and is affected by the heat produced (both due to deformation and friction) during the process.

Fig. 2: Schematic of the cross-section of the friction stir weld showing the various characteristic regions
Friction stir welding is regarded as an asymmetric process mainly due to the material flow being affected by the rotation and translational motions of the tool. This asymmetry is reflected in the shape of the nugget and to some extent on temperature distribution, on either side of the nugget [7]. The side of the weld, where the local direction of the tool is the same as the traversing direction, is called the ‘advancing side’. The other side, where the directions are opposite and the local movement of the shoulder is against the traversing direction, is called the ‘retreating side’ [2,7,9].

Present Status of Friction Stir Technologies

Applications

Friction Stir Welding has grown into an important industrial process that has led to many worldwide applications, predominantly in the fabrication of aluminium components and panels. FSW is being used in all transport industries including shipbuilding, automotive, rail and aerospace industries [10]. In shipbuilding industry, the FSW process is used for the production of large aluminium panels, which are made from aluminium extrusions. Large tanks for satellite launch vehicles are fabricated by FSW from high-strength aluminium alloys for the aerospace industry. Several companies (The Boeing Company, Eclipse Aviation Corporation, Airbus etc.) manufacture lightweight aluminium airframe structures, fuselage and wing applications using FSW for commercial and military aircrafts. The railway industry uses FSW for the production of large prefabricated aluminium panels, which are made from aluminium extrusions. The automotive industry uses FSW in the production of components like light alloy wheels and fuel tanks.

Design and development of tools

The design of the tool is a critical factor as a good tool can improve both the quality of the weld and the maximum possible welding speed. It is desirable that the tool material is sufficiently strong, tough and hard wearing, at the welding temperature. Further, it should have good oxidation resistance and low thermal conductivity, to minimize heat loss and thermal damage to the machinery further up the drive train [2]. Tool steels have been widely used for welding aluminium alloys within thickness ranges of 0.5 - 50 mm, but more advanced tool materials like Carbides, Polycrystalline Cubic Boron Nitride (PCBN) and tungsten rhenium (W-Re) alloys are necessary for more demanding applications such as highly abrasive metal matrix composites or higher melting point materials like steel or titanium. Improvements in tool design have been shown to bring about substantial improvements in productivity and quality [11]. Modifications in the design of the pins (Threaded pins and fluted pins) ensured, that the plastically deformed material is fully delivered around the pin, and from the upper parts of the joint to the lower parts. This results in efficient mixing and enables the use of higher speeds and results in better quality, void free welds. Tools with scrolled shoulders eliminated weld surface undercutting and the flash that extrudes under the tool shoulder.

Process Parameters

In friction stir welding process, a number of process parameters have to be defined to get good, defect-free joints. The important process parameters are tool rotation speed, tool traverse speed, tool tilt angle, insertion depth of the tool pin, etc [2]. The quality of friction stir welds depends upon the use of an optimum combination of these process parameters. For harder alloys or alloys with thicker sections, slower traverse speeds and lower rotational speeds are used. Increasing the rotational speed or decreasing traverse speeds increases heat input and welding temperatures. However, extremely high or low travel and rotational speeds can adversely affect properties. Any inappropriate combination of the process parameters may result in incomplete welds or the formation of defects or weld flaws. The most
common defects observed during friction stir welding are: the groove and channel defects, lazy S defect, 'Kissing bond' defect, formation of voids, root flaws, joint line remnants, etc. [9].

**FSW of Al alloy 5052 at BARC: Experimental work**

The aim of the study is to provide a composite picture of microstructural development associated with FSW of AA5052 and correlate these with associated mechanical (mainly tensile) properties.

Friction stir welding (FSW) of partially recrystallized aluminium 5052 alloy plates with dimensions 300 mm × 50 mm × 5 mm and having the chemical composition – 2.3 Mg, 0.15 Si, 0.2 Fe, 0.1 Cr, 0.02 Cu, 0.02 Mn, 0.01 Ti, 0.01 Zn, Bal — Al (all in wt.%), was carried out using a dedicated, locally designed and fabricated friction stir welding equipment. A commercial High Speed Steel (HSS) tool, having a cylindrical geometry with 4.8 mm pin length was used for friction stir welding with a tilt of 3°. Further details of the dimensions of the plate and the tool design can be found in our earlier work [12]. FSW trials were carried out at 1120 and 1400 rpm and for various traverse speeds ranging from 60 mm/min, 80 mm/min and 100 mm/min. The qualification of Defect-free joints was done through X-ray radiography and also by dye penetration tests. The transverse cross-section of the specimen (welded at tool rotation speed of 1400 rpm and tool traverse speed of 80 mm/min), prepared using standard metallographic procedure, was used for optical as well as electron microscopy observations. The microstructural characterization using electron microscopy comprised of techniques like electron probe microanalysis, orientation imaging microscopy, transmission electron microscopy and scanning electron microscopy. A Vickers’ microhardness profile was obtained in the mid-thickness region across this structure using a load of 50 g and a 10 s dwell time. Standard tensile specimen having gauge length of 25 mm and gauge width of 5 mm were cut from the welded plates, by keeping the tensile axis perpendicular to the welding direction. The tensile specimens were tested by using screw-driven Instron machine, at a strain rate of $10^{-4}$ s⁻¹. The fractured surfaces were further examined using scanning electron microscopy.

**Results and Discussion**

**Optical microstructure**

The parent AA5052 material microstructure consists of pancake-shaped and elongated grains in the rolling plane, whereas, in the cross-section plane perpendicular to rolling direction, the grains are equiaxed. At the region of the joint (interface), intense plastic deformation (aided by the tool, along with the frictional heat thus generated between the tool and the plates), results in the refinement of the grain structure. This region, which is referred to as the ‘nugget’, assumes roughly the shape of the tool pin, depending on the process parameters and the interaction of the material with the tool pin and tool shoulder. Fig. 3 shows the optical micrograph of the cross-section of the friction stir welded specimen (welded at 1400 rpm and 80 mm/min).

![Fig. 3: Optical micrograph of the transverse cross section of the friction stir welded AA 5052 specimen](image)

**EBSD and TEM**

Fig. 4a shows the inverse pole figure map of a section from the Base Material (BM) region. The grain structure in the base material in the cross-
section is equiaxed similar to the parent material in the transverse cross-section plane. From the grain boundary distribution it is observed, that most of the BM region is covered with high angle grain boundaries with clean grain interiors suggesting that the parent material was partially recrystallized. The BM region shows a typical rolling deformation texture as expected for a rolled aluminium plate [12].

The nugget consists of fine equiaxed grains which are formed due to the breakup of the original grain structure, because of the severe plastic deformation and the frictional heat input. Fig. 4b shows the inverse pole figure map of a section in the nugget region and the appropriate colour coding, corresponding to the orientation of the grains. Apart from the fine grain distribution, a section of the onion rings can be identified (in the middle-lower part of the figure). Alternating rings of near – <101> and <111> orientation can be seen in the lower right portion of the figure. The (111) pole figures and [001] inverse pole figures, corresponding to each of the regions A to C, identified in Fig. 4a, are represented in a chart given in Fig. 4c. It was found that the misorientation (GAM and KAM) values were higher in the nugget than those for the base material (BM). This combination indicates possible involvement of both plastic deformation and softening, in the formation of the nugget.

To further explore the microstructural developments in the nugget, TEM specimens were examined. As shown in Fig. 5, the equiaxed nugget grains had clear signatures of plastic deformation – signatures
both in terms of dislocation substructure and also in misorientation build-up. To explain the observed patterns of microstructural developments, it is important to discuss/hypothesize about the two apparent causes – plastic deformation and thermal activation through localized heating/ friction. In the FSW, plastic deformation evidently has an important role. The strain path is expected to be complex and large strains with strong shear and possible solid-state stirring are often hypothesized [13].

Indirect evidence of thermal activation is identifiable from clear softening of the partially recrystallized base material near the FSW interfaces. Direct evidences of thermal activation vs. plastic deformation are difficult to distinguish or demarcate – their effects on the respective microstructural parameters (GAM, grain interior dislocation structure, grain refinement, etc.), often being cumulative and/or subtractive. For example, both severity of plastic deformation and higher working temperature may aid geometric dynamic recrystallization and corresponding grain refinement, while developments in GAM are expected to be aided by low working temperature and by higher plastic strains. A temperature profile on a FSW is expected to show a decrease in temperature from the center of the weld (or nugget region) towards the respective interfaces. Such a temperature profile, experimental or simulated, is typically reported to be nearly symmetric. Plastic deformation, on the other hand, was asymmetric. For example, evidence of strong shear (and of grain fragmentation) was observed on the advancing side (AS), while the retreating side (RS) had captured clear indications of the initial stages of geometric dynamic recrystallization [12,14]. The final microstructure appears to be a result of asymmetric and heterogeneous plastic deformation, aided by differential thermal activation (arising from the temperature profile).

**Mechanical properties**

The microhardness profiles were taken at the mid-thickness region on the transverse cross-section, across the weld nugget, along the line AB as shown in Fig. 3. It was found that there was a marginal increase in microhardness in the nugget, as compared to the base material. The microhardness near advancing side interface (ASI) region was higher than that at any other region of the weld. The regions near the HAZ and base material (BM) on the retreating side, exhibited marginally higher microhardness than their counterparts at the advancing side.

Tensile properties of all the welded specimens for various combinations of tool rotation speeds and tool traverse speeds are shown in Fig. 6. It was observed that the Ultimate Tensile Stress (UTS) values for the specimens welded with various traverse speeds (60, 80 and 100 mm/min) at 1120 rpm are in the range 260–265 MPa, which is higher than for those welded at 1400 rpm (UTS values being just above 200 MPa). The % elongation of the specimens welded with tool rotation speeds of 1400 rpm was significantly lower (10% approx.) compared to those for welded with speeds of 1120 rpm. In fact, the ductility for these specimens was around 18%, which is significantly more compared to that of their counterparts welded at 1400 rpm. It is also seen, that the yield strength (Ys) values for
all the specimens remained more or less constant and in the range 93–103 MPa. Most of the specimens fractured on the retreating side, except the specimen welded at the process parameters of 1400 rpm and 100 mm/min, which fractured in the nugget. From the fractography analysis, it was found that the mode of failure is basically ductile in nature [15]. The voids, typical 10–30 µm in size, formed due to coalescence of microvoids could be noticed. For, the specimen which failed in the nugget, did not reveal any presence of voids. It is quite clear from these, that the process parameters substantially influence the nature of fracture in these specimens.

Conclusions

Friction Stir Welding has evolved as a mature and efficient solid state joining method, for the joining of aluminium alloys. However, there is a need to develop special materials/tool design for the joining of steels, zirconium and titanium alloys.

The present study on Al 5052 alloy provides an in-depth study for characterizing the microstructure, microchemistry, microtexture and mechanical properties. In addition, the study convincingly shows that under optimized condition, the welded specimens show superior mechanical properties. In general, the specimens showed ductile mode of fracture.

Acknowledgements

The authors thank Dr. A. K. Suri, Director, Materials Group, BARC and Shri B. P. Sharma, former Associate Director, Materials Group, BARC for their keen interest in this work. The authors thank Prof. I. Samajdar, IIT (B) Mumbai for useful suggestions and discussions of the electron backscattered diffraction analysis results. One of the authors (NTK) acknowledges the fellowship provided by the Department of Atomic Energy, India under the Mumbai University – BARC collaborative research scheme and also thanks all his colleagues at the Materials Science Division specially Dr. P. Sengupta, Shri A. Laik and Shri P. S. Gawde for their continued support and encouragement.

References

Matrix Assisted Laser Desorption Ionization Mass Spectrometry (MALDI-MS)

T. Jayasekharan and N. K. Sahoo
Applied Spectroscopy Division

Abstract

A state of the art Matrix Assisted Laser Desorption Ionization (MALDI) technique in combination with linear and reflectron Time of Flight Mass Spectrometer (TOFMS) facility has been developed for the detection, identification and characterization of peptides, proteins, DNA, other molecular complexes and clusters. The performance of the indigenously developed MALDI-TOF mass spectrometer has been tested extensively by recording the mass spectra of many different molecules (inorganic, organic, and biomolecules) in the molecular weight range up to 50,000 Da. The mass spectra are calibrated and the mass to charge (m/z) ratio of these molecules are measured more accurately. The detection sensitivity of the spectrometer is very high and is capable of detecting peptide and proteins in the sub picomole range. Recently this spectrometer has been utilized to characterize the silver ion complexes of two peptides namely human Angiotensin and Substance P.

Introduction

Mass spectrometers are analytical instruments that convert neutral molecules into gas phase ions and separate these ions according to their mass-to-charge ratios (m/z), and are the most powerful method to probe the structure and composition of matter. For many years the mass spectrometers were restricted to the analysis of volatile compounds by electron impact or other ionization methods. The application of mass spectrometers for the analysis of biomolecules posed a greater challenge due to the poor volatility, polar and charged nature of these molecules. In late 1980s two new soft ionization techniques viz., Matrix Assisted Laser Desorption Ionization (MALDI) and Electrospray Ionization (ESI) translated the biomolecules into gas phase ions without fragmentation, and revolutionized the structural analysis of biomolecules.

MALDI is a laser based technique which produces intact protonated/deprotonated molecular ions such as \([M + nH]^{+}\) and \([M - nH]^{-}\) of non volatile, thermally fragile, and massive bio molecules in gas phase [1]. In this technique analyte macro molecules are embedded in UV/VIS/IR radiation absorbing low molecular weight organic molecules (matrix) and are deposited on a solid target and air dried. A low power UV/VIS/IR laser beam of short pulse duration (nanoseconds) is used to desorb and ionize the analyte macromolecules from condensed phase to gas phase. Following absorption of laser radiation by matrix, a plasma plume is generated that ejects neutrals and ions of the matrix and analyte molecules in gas phase. MALDI source is preferentially coupled with linear and/or reflectron TOF-mass analyzers [2, 3]. Different type of mass analyzers is used depending on the properties of molecules to be analyzed. For example, a simple linear TOF analyzer is preferred for analyzing the intact high mass ions of peptides, proteins, and oligonucleotides while reflectron analyzer is used for analyzing the fragment ions and small molecules with higher resolving power and mass accuracy. The schematic of a typical MALDI-TOFMS is depicted in Fig. 1. The matrices usually contain OH and/or NH$_2$. 

T. Jayasekharan and N. K. Sahoo
Applied Spectroscopy Division

Abstract

A state of the art Matrix Assisted Laser Desorption Ionization (MALDI) technique in combination with linear and reflectron Time of Flight Mass Spectrometer (TOFMS) facility has been developed for the detection, identification and characterization of peptides, proteins, DNA, other molecular complexes and clusters. The performance of the indigenously developed MALDI-TOF mass spectrometer has been tested extensively by recording the mass spectra of many different molecules (inorganic, organic, and biomolecules) in the molecular weight range up to 50,000 Da. The mass spectra are calibrated and the mass to charge (m/z) ratio of these molecules are measured more accurately. The detection sensitivity of the spectrometer is very high and is capable of detecting peptide and proteins in the sub picomole range. Recently this spectrometer has been utilized to characterize the silver ion complexes of two peptides namely human Angiotensin and Substance P.
functional groups that act as protonating agents and the protons are believed to be transferred from these groups during desorption/ionization process. MALDI processes involve large number of physical and chemical process occurring at different time scales, the exact mechanism of the process has been the subject of extended discussion [4]. This technique has found immense application in proteomic research, disease diagnostics, drug analysis, polymer analysis and other chemical/biological research areas. In recent years MALDI-MS become the method of choice for rapidly identifying proteins and determining the primary structures by bottom-up and top-down approaches [5, 6].

**MALDI-Mass Spectrometry**

Briefly the home built MALDI-TOFMS consists of three circular stainless steel (SS) electrodes, a pair of deflector plates, a three meter long hollow flight tube, and a Microchannel Plate detector (MCP). The circular discs acts as acceleration and extraction grids. A pair of deflector plates are used to steer the direction of the ions, hollow flight tube provides field free region for the ions. The entrance and the exit of the flight tube are coupled with the TOF assembly and a detector respectively. A reflectron grid assembly is placed near the first detector to reflect the ions back to the second detector. The entire assembly is pumped by two turbo molecular pumps through gate valves for better vacuum \((1x10^{-7}\text{ mbar})\). The samples (analyte + matrix) are deposited on a flat polished SS sample probe and are inserted into the TOFMS through a vacuum interlock, and is in flush with the acceleration grid. A stepper motor is attached with the sample probe for positioning the samples and is controlled through a Personnel Computer. Laser radiation of wavelength \(\lambda = 266\) or \(355\) nm, harmonics produced by a Q-switched Nd:YAG is allowed to impinge on the sample surface through a quartz lens of focal length \(20\) cm. Typically \(10-50\ \mu\text{J/pulse}\) energy is focused on the sample spot size of \(-100\mu\text{m}\).

The molecular ions are generated by MALDI or LDI processes, and the generated ions are promptly extracted and accelerated by different combination of static electric field of \(1-30\ \text{kV}\) on different grids (depending on the mass of the ions) and detected by MCP detector in a linear TOFMS. In reflectron these ions are further reflected back by series of grids/voids and are detected by another MCP. Depending on the mass of the ion typically \(1-10\ \text{kV}\) DC is used in the reflectron to compensate the initial distribution kinetic energy of the ions, as well as to increase the flight path of the ions for better resolution. Data acquisition is performed using a Tektronix digital storage oscilloscope.
(200MHz, 2GS/s) triggered by a photodiode pulse produced by the laser radiation. The oscilloscope is interfaced with a PC for data transfer and further analysis. Each laser shot produces complete mass spectra of the sample. The photograph of the home built MALDI-TOFMS is shown in Fig. 2. Table I lists important specifications of the indigenously developed MALDI mass spectrometer in the Applied Spectroscopy Division of BARC.

Typical MALDI mass spectra obtained for insulin molecule and the fragmented

Table 1: Features of the home built MALDI-TOFMS

<table>
<thead>
<tr>
<th>Component/Feature</th>
<th>Important Specifications</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser</td>
<td>$\lambda = 266, 355 \text{ nm},$ Energy/pulse $= 0.5 \text{ mJ},$ Rep. Rate $= 1$-20 Hz, Pulse width $= 5 \text{ ns}$ Average power $= 2.4-2.6 \text{ W @20 Hz}$</td>
<td>For desorption and ionization</td>
</tr>
<tr>
<td>Q- Switched Nd:YAG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3rd &amp; 4th harmonics)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear Time-of-flight Mass Spectrometer</td>
<td>Total Length $= 3 \text{ m},$ X-Y deflection, Ion gates</td>
<td>For Mass Dispersion</td>
</tr>
<tr>
<td>Reflectron</td>
<td>Length of reflectron $= 12 \text{ cm},$ Total flight length of MALDI-TOFMS $= 5 \text{ m}$</td>
<td></td>
</tr>
<tr>
<td>Ion Detector</td>
<td>Gain $= 10^{6},$ Area $= 18 \text{ mm}^2$ (MCP)</td>
<td>Micro Channel Plate</td>
</tr>
<tr>
<td>Vacuum</td>
<td>$1 \times 10^{-7} \text{ mbar}$</td>
<td>TMP 500l/sec</td>
</tr>
<tr>
<td>DC Power supplies</td>
<td>$0-30 \text{ kV}, 10 \text{ mA}, 300 \text{ W}$</td>
<td>For extraction and acceleration</td>
</tr>
<tr>
<td>Sample holder</td>
<td>Stepper motor controlled by PC/micro controller for analysis of 10 samples at one load.</td>
<td>To change the position of the samples</td>
</tr>
<tr>
<td>Mass range</td>
<td>$1 - 50,000 \text{ Da}$</td>
<td>Tested with various inorganic, organic, peptide, protein molecules</td>
</tr>
<tr>
<td>Mass calibration/precision</td>
<td>$\pm 0.01% \ (&lt; 1000 \text{ Da})$ $\pm 0.02% \ (1-10 \text{ K Da})$ $\pm 0.05 - 0.2% \ (10-50 \text{ K Da})$</td>
<td>Tested with inorganic, organic molecules, $C_{60}$, pthalocyanin, Porphyrazins, peptides and proteins</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>Sub pico moles</td>
<td>For peptides and proteins</td>
</tr>
<tr>
<td>Organic Matrices used</td>
<td>$\alpha$-Cyano hydroxy cinnamic acid, 2,5 dihydroxy benzoic acid, Sinapinic acid, Nicotinic acid, Ferrulic acid, Caffeic acid etc.</td>
<td>Mass spectra also show the photo dissociated products.</td>
</tr>
<tr>
<td>Peptides/Proteins studied</td>
<td>Substance-P, Angiotensin, Insulin, Cytochrome-C, Lysozyme, Trypsin, Carbonic Anhydrase, Thermolysin.</td>
<td>Tested at different concentrations, and in different matrices.</td>
</tr>
</tbody>
</table>
product ions of substance P using this spectrometer are shown in Figs. 3 and 4.

The bioinorganic chemistry of Ag⁺ is diverse and interesting since it is considered as soft cation and it prefers to bind ligands that are relatively polarizable. Silver ion also forms strong s - p bonds by back donation of the electrons from the d orbitals of the metal to the p orbitals of the ligand. Human Angiotensin I (Mr = 1296.5 Da) is a 10 amino acid residue peptide and is a vasoconstrictor precursor under physiological conditions whose primary sequence is Asp-Arg-Val-Tyr-Ile-His-Pro-Phe-His-Leu. Substance P is also an oligopeptide and is a neurotransmitter found in central and peripheral nerves which contains 11 amino acid residues, its primary sequence is Arg-Pro-Lys-Pro-Gln-Gln-Phe-Phe-Gly-Leu-Met-NH₂ (Mr = 1346.7 Da). Ag⁺ has been used to label peptides and proteins that have

Characterization of Peptide - Metal ion complexes

Metal ions interact with the peptides and form metal ion-peptide complexes and these complexes play broad role and functions in biology. Investigation of the intact metal ion complexes of peptides/proteins and their fragmented ions in gas phase using mass spectrometry provides valuable insight about the primary structure of the peptides, location of the metal ion binding sites, possible dissociation sites, and the nature of bonds exist between them.
sulfur containing residue, it is therefore of interest to probe the specific binding of silver ion to these residues which are analytically useful. We have detected, identified, and characterized silver ion complexes of peptides \([M + (Ag)_n]^+\), \(M = \) Angiotensin I and Substance P where \(n = 1-8\) & \(17-23\) for Angiotensin I and \(n = 1-5\) for Substance P using this mass spectrometer [7]. The MALDI mass spectra of hybrid silver ion-peptides complexes obtained using this spectrometer are shown in Figs. 5 and 6.

**Conclusion**

A state-of-the-art matrix assisted laser desorption ionization time-of-flight mass spectrometer with linear as well as reflectron modes of operation has been developed for the analysis of macromolecules up to the mass range 50 kDa. The performance of the spectrometer has been tested extensively by recording the mass spectra of inorganic, organic, biomolecules and clusters. The mass spectra are calibrated using known molecular species and the molecular mass of unknown molecule is measured precisely. Further, the spectrometer has been used to characterize the silver ion complexes of *Angiotensin* and *Substance P* for their silver ion binding ability.

**Acknowledgements**

The authors gratefully acknowledge the contributions and motivation of Drs. S.C. Sabharwal, M. A. N. Razvi, H. S. Misra, G. L. Bhale, Divisional machine-shop personnel, and others who greatly assisted in the development of the project.

**References**

Introduction

BARC is involved in number of important projects where a variety of digital information is processed, stored and communicated. In order to develop an electronic system with low vulnerability, several applications and components are developed, using various technologies like encryption, RFID, biometrics, mobile communication and public key infrastructure. In this article, some representative applications in the following areas are described:

1. Personnel tracking & Time attendance systems
2. Public Key Infrastructure (PKI)
3. Web based Surveillance Systems
4. Security Gadgets & Secure Software Applications

This will give a flavour of the width and depth of the domain of secure digital applications. The development is done across multiple platforms on desktops, mobile phones, handheld devices and embedded systems. An RFID card based access control and personnel tracking system (Chitragupt), and an enhanced state of the art web based surveillance system for the security personnel is implemented.

Identity Verification, Personal Tracking & Attendance System (Chitragupt)

BARC is a secure campus, where entry of only identified, verified and authorized personnel is permitted. The identity management is generally based on one or more of the three factors of authentication, ‘what you are’, ‘what you know’ and ‘what you have’. The biometric information verification is the ‘what you are’, Password/Passphrase is an example of ‘what you know’ and Identity cards fall under the ‘what you have’ category.

Chitragupt is an identity-card issuance, verification and validation system. In this system, RFID based identity cards are issued to the personnel, the authenticated photos of every individual are displayed at manned entry-gates and optionally, PIN of the ID-card holder is also verified thus incorporating all the three factors of authentication to a large extent. It provides a secure, authentic, accountable and scalable access control and personnel tracking solution. Fig. 1 shows the architecture of the system and it’s interaction with
other sub-systems. The whole system may be broadly classified into three major subsystems:

1.1 Identity card issuance
1.2 Identity card verification
1.3 Logging and reporting for different types of users
1.4 describes the key features of this system.

Identity-card Issuance

Employees & Temporary Entry Permit (TEP) cards

The issuance of identity cards to employees and long term visitors (TEP) is carried out in two phases. In the first phase a few authorized personnel are identified and issued specialized authority cards. As this process is very crucial, these cards are prepared on an isolated secure node in the presence of multiple authorities. There are five types of such authorities to perform different roles, so that no single person can misuse the system. The second phase involves issuing Identity cards to employees and TEP personnel by the authorized persons.

Full accountability of each issued card is ensured and the application for printing and personalization is designed and tested for high throughput. Fig. 2 shows a snapshot of ID card issuing application for employees.

Casual Entry Permit card (CEP)

All the short duration visitors are issued CEP cards for which the forms are applied and approved through an online application provided on BOOST web site. Fig. 3 show a snapshot of CEP card issuing application.

An RFID based Casual Entry Permit (CEP) issuance system is deployed at entry gates. It downloads approved forms, verifies digital signature of the approving authority and issues a pre-printed RFID card to the visitor with one day validity. Photos of the visitors are captured and uploaded at all designated manned security nodes instantaneously. It is a robust and secure application which is operational 24X7.

Identity Card Verification

The identity cards are verified with two types of devices:
1. Fixed RFID readers
2. Handheld RFID readers
Fixed RFID readers are installed at the entry gates and all the building entrances of BARC. These are SIM (Subscriber Identification Module) enabled which authenticate the personnel cards by verifying the Digital signature of the card data at the time of swipe. A snapshot of exit wing is shown in Fig. 4.

Handheld identity card readers are provided for authentication and verification of vehicle commuters at entry points. These handheld devices operate in ‘Fail safe’ mode, thereby closing safely when battery power is low. The handheld just needs to be placed on the cradle for up loading the data. Fig. 5 shows a snapshot of hand-held reader.

Similar RFID cards are fixed in all the staff vehicles so that the same handheld readers are used additionally to monitor them. This will facilitate BARC Emergency Preparedness. Fig. 6 shows line diagram of hand-held reader uses for personnel as well as vehicles.

In-house developed hand-held device

There was a need of in-house development of a reliable, modular and compact RFID card reader based on mifare technology with enhanced features like local image display, remote video monitoring, access control, secure communication protocol, remote configuration and management.

In order to fulfill these requirements an RFID
hardware module is designed, developed and integrated with open source hardware and indigenous software.

Fig. 7: Indigenous handheld Reader

Fig. 7 shows a snapshot of this hand-held device. Key features:
- Power Efficient Design.
- Based on open source Linux.
- Higher resolution color graphics LCD display.
- Wireless communication via Blue-tooth.
- Touch screen.

Logging and Reporting for different types of users

Online reports of personnel and vehicle tracking systems are accessible on Identity Validation System (IVS) web site. Reports are available for three classes of users - security, administration and individuals.

The administrative users can view attendance related reports of persons under their administrative control. Location based head count and vehicle monitoring reports are provided for the emergency and security usage.

A graphical representation of daily and monthly population and vehicle traffic is available for efficient manning at the entry points.

Key features of Chitragupt system

- All the authority cards and reader SIMs are prepared on an isolated secure node in the presence of multiple authorities.
- All keys are encapsulated into the cards at the time of preparation and never get exposed outside the cards.
- A unique key is used for each issued card to prevent single point failure.
- Employee data at central database is digitally signed by the authorized persons.
- Data inside the issued cards is digitally signed by authorized person and verified at the readers at entry gates on each swipe.
- Swipe records are digitally signed from the readers itself before sending to the server.
- Authenticated photos are displayed at manned security nodes at each swipe.
- System is designed keeping future scalability across DAE units in simplified manner.

The system is spread across BARC Trombay campus, and at RRCAT Indore, VECC Kolkata and BARC hospital. It is further extended to BARC staff buses.

Public key infrastructure

A Public Key Infrastructure (PKI) is setup to facilitate digital signature based applications as digital signatures are well accepted by the Indian law under the IT Act 2000.

Issuance of Digital Certificate

Computer division functions as Registration Authority (RA) under the Certifying Authority (CA) of National Informatics Centre (NIC), New Delhi for issuance of digital certificates to authorities within BARC. Tamper proof USB tokens are provided to the authorities for this purpose.

A PKI server is developed to store user’s certificates in the local repository to provide the public key certificates over the local network for verifying digital signatures. Fig. 8 shows all the steps of issuing digital signature certificates from NIC CA and its uses thereafter.
applications are being added to BOOST. Fig. 9 shows a snapshot of online CEP application on BOOST and Fig. 10 show high level architecture of BOOST.

**Boost**

BOOST (BARC Online Operations of Secure Transactions) site is developed for processing online applications with digital signatures. Presently Casual Entry Permit (CEP), Casual Leave, Out-Duty, C-Off applications are supported and many new

**Crypto Token Library**

The USB crypto tokens issued can as well be used with other applications supporting Digital Signatures and encryption / Decryption. For this purpose a special plug-in library is developed for performing all security related tasks. The verification of digital signatures is done by fetching public key certificates from PKI server available on the intranet.

A third party software is developed using this library. A secure document exchange application, DocShield, is also developed using the same library.

**Surveillance Systems**

BARC is spread across a few kilometers along the sea and to ensure effective surveillance by the security personnel is a huge task. A state of the art, web based surveillance system is established that enhances the security measures at the entry gates, improves security...
guard on the sea face especially at night, and helps carrying out security drills.

**Web Based Surveillance System**

The system includes static network cameras, Pan/Tilt/Zoom Dome Cameras and static CCTV cameras installed at various key locations in BARC campus.

Web Based Remote Monitoring System (WBRMS) is developed for the surveillance of various geographically spread unmanned stations that does smoke and motion detection and monitors several environmental parameters like temperature, humidity. Fig. 12 show a typical architecture of the system and Fig. 13 show a snapshot of WBRMS website.

The setup includes a specialized network camera with Real Time Operating System (RTOS). A specialized embedded card is used for measuring the analog input from temperature, humidity sensor after signal conditioning, reading the digital contacts from fire alarm and controlling the PTZ (pan, tilt,
Zoom) of camera and other contacts such as air-conditioner. In case of any emergency a system generated intimation is sent by audio/video/e-mail.

**Security Gadgets & Secure Software Applications**

Apart from the above systems for personnel tracking and surveillance, several security gadgets and secure software applications are developed on desktops and mobile phones, as per the requirements from the users and technology updates from time to time.

### Secure Network Adapter (SNA)

It is a Virtual Private Network (VPN) adapter, with support for proprietary encryption algorithm and key management protocols, used to provide data communication security over a public network and restrict access from private network to public network.

A Secure Network Adapter is developed based on a proprietary protocol. It supports speed ranging from 2 Mbps to 100 Mbps and multiple interfaces like Ethernet, E1 etc. Fig. 14 shows a snapshot of SNA.

### Multi Encryption Line Interface Card (MELIC)

MELIC system (Secure Telephone Apparatus) is developed in collaboration with Ms. ECIL for secure Voice, Data and Fax Communication on PSTN line suitable for a close user group applications.
A central setup for key generation and distribution is created. Fig.16 shows a snapshot of MELIC Telephone Instrument.

**Hardware Encryption Module**

It is a standalone crypto accelerator developed using FPGA technology suitable for high throughput of the order of 3.312 Gbps. The major challenge is to develop number of mathematical models for the transformations, required in the encryption algorithm, based on Galois field, pipe-lining, and finding out the most optimum model considering delay and resource (CLB) constraints.

**Secure Applications on Mobile Phones**

Mobile phones enable the authorities to carry out their work even when not at their desk. With the increased mobile computing power and features, it becomes feasible to have all communication and document storage on mobile phones. Having limited resources in terms of processing power and memory as compared to general purpose PCs, a major challenge was the selection of appropriate encryption algorithms and key exchange protocols. A few applications for secure mobile communication are developed.

**Secure SMS and MMS**

This application facilitates users to communicate with each other through encrypted SMS. A secure voice MMS application is developed with the purpose of sending encrypted messages by voice recording, instead of using the cumbersome keypad. Fig.-17 shows a snapshot of SMS application on mobile phone.

Key features:
- The authentication is done with unique username, password and passphrase.
- Confidentiality is achieved using 128 bit encryption algorithm.
- Integrity check is implemented using Message Digest.
- Digital signatures are used to prevent sender Non-Repudiation.
- Time-stamps are added to prevent replay attack.

**Mobile Alert System**

A system is developed, that will send alert messages from a central server to the registered mobile phones. Different tones can be configured for different types of alerts messages. The message can also be encrypted if desired. Fig.-18 shows the flow diagram of the alert system.

**Secure Video Conferencing System**

This is an indigenously developed desktop-based conferencing application with encryption support using Java Media Framework. Server-Client architecture is used where the server manages the connection between the clients, generates and distributes session key for every session to encrypt audio/video streams and controls the quality of service. Fig. 19 shows a Snapshot of Secure Video Conferencing.

The video and audio streams are first compressed and then encrypted and later sent over the network.
using RTP over UDP. The video streams are compressed in H.263 format and the audio streams are compressed using G.723 format.

Public key algorithm is used for authentication and key establishment and users are issued USB crypto token using which they can participate in a secure video conference. All the compression/decompression and encryption/decryption are done using software codec only.

Secure Mail Client

E-mail sent over the Internet is more like paper mail on a postcard, than mail in a sealed envelope. It can easily be read, or even altered, by anyone with privileged access to any of the computers (including mail servers) along the route followed by the mail. Hackers can read and/or forge e-mails.

Fig. 20 shows how the secure mails are composed before sending. This application enables the users to compose, send and read secure E-Mails. It allows the users to send video mails also using webcam and mike. For encrypting and digitally signing the E-Mails it follows a scheme which is very similar to PGP. GUI is very similar to Outlook Express. All the users are issued USB based crypto token using which...
they can send/receive secure e-mails. Fig. 21 shows a snapshot of secure mail client application.

Users need a simple desktop PC, web-cam and headphone. It can be used for any mail server which provides IMAP/POP3 and SMTP access to the users.

Future Plans
The secure digital application projects undertaken, completed and deployed are designed for scalability and enhancement using the upcoming technologies. The process of developing new applications and enhancing the existing one is crucial for their sustainability.

A comprehensive indigenously designed identity card verifier is being developed which will have features like camera, video streaming, storing of photo, barred cards list and network connectivity. It is planned to replace existing Identity cards with Java cards to provide end to end security without altering the present infrastructure. The access control system with biometric support that addresses the ‘what we are’ category is being studied for its reliability and occasions where they can be used.

Several digital signature based applications are under production to have an authentic online system and a local Certification Authority (CA) will be setup to issue digital certificates on a large scale to enable more persons in BARC to sign digitally.

As handheld devices and mobile phones are equipped with features available on desktops/ laptops, applications are being developed so they can be used in a secure manner for communication and as a laptop alternative.

Development of Secure Network Adapter with more enhanced security features like location based encryption scheme, Security analysis and 1 Gbps network throughput is under process.
Behaviour of Single Piles in Liquefied Soils during Earthquake

V.S. Phanikanth and K. Srinivas
Architecture & Civil Engineering Division
and
Deepankar Choudhury
Associate Professor, Indian Institute of Technology, Bombay
and
G.R. Reddy
Reactor Safety Division

Abstract

Analysis of pile foundations for earthquake loads, requires the consideration of inertial loads due to soil-pile-super structure interaction and also need the evaluation of kinematic interactions due to the movement of the surrounding soil and the pile. Also such soil-pile interaction analysis, must consider the stiffness degradation due to earthquake loading in liquefying soils. In the present study, pile-soil interaction analysis is attempted by considering stiffness degradation effects for a range of earthquakes with different amplitudes [Maximum horizontal acceleration, (MHA)], frequency contents, and different durations. The pile response is observed for both rigid piles and flexible piles under earthquake loading. Effects of both kinematic and inertial interactions are considered by using seismic deformation method. Results of ground response analysis obtained from separate study were used for soil-pile interaction analysis. Pile response for kinematic interactions is validated with the available solutions in the literature. Parametric studies have been carried out to understand the effect of depth of embedment, depth of liquefying layer etc. and their results are presented. It is observed that the effect of depth of liquefying layer has significant influence on the pile bending response. Also it is observed that the peak bending moment occurs at the interface of liquefying and non-liquefying layer.

Introduction

Pile foundations supporting super structure shall be designed for lateral loads arising due to wind loads, seismic loads, wave forces etc. in addition to the vertical loads. During earthquake loading the pile will be subjected to lateral loading due to kinematic and inertial interactions. For piles in liquefying soils the presence of liquefying layer makes the pile vulnerable to buckling due to significant stiffness degradation. Also this involves the consideration of bending-buckling interaction phenomenon [Dash et al. 2010].

For soil-pile response analysis several approaches have been proposed including sophisticated mathematical or numerical analyses and simplified methods. The finite difference technique is most commonly adopted due to its simplicity. However, finite element techniques have more flexibility to perform seismic analysis of soil pile interaction in both frequency and time domain. In the present study a pseudo static analysis is carried out using seismic deformation method and the behavior of liquefying soils under earthquake loads is studied and their results are presented.
Design Approaches

The current design methods are based on pile design against bending failure due to lateral loads such as inertia load and loads due to lateral spreading. The most commonly used methods [Bhattacharya 2007, Liyanapathirana and Poulos 2005] are discussed below:

i) Force based method or limit equilibrium method: In this method, lateral pressure acting on the pile is estimated and response of the pile is evaluated. Pile yielding and allowable deflection are checked in this method.

ii) Displacement based method or p-y method or seismic deformation method: In this method, free field ground displacement is evaluated and the displacement profile is applied on the pile and pile response is evaluated.

For the seismic analysis of piles in liquefying soils Liyanapathirana and Poulos 2005, proposed pseudo-static method which is simple and practicable and yet gives reasonably accurate results. The method mainly involves two solution stages. In the first stage a free field ground response analysis is carried out to obtain maximum ground displacement along the depth of the pile and ground surface acceleration. In the second stage a pseudo-static analysis is carried out for the pile, subjected to the maximum ground displacements along the depth, and the pseudo-static loading at the pile head is computed by multiplying the cap mass with the maximum ground acceleration. In the present study the above approach is adopted and the ground response analysis results obtained in stage I, using different earthquake loadings are used to obtain the pile response in the second stage.

Limit Equilibrium Method

Dobry et al. 2003, presented a simplified limit equilibrium method for computing maximum bending moment in a pile and is given as:

\[ M_{max} = (0.5A_p H_p + A_c H_c) p_L \]  

where \( A_p \) = Area of pile exposed to lateral liquefied soil pressure and \( H_p \) = length of pile exposed to lateral liquefied soil pressure, and \( A_c \) = Area of pile cap exposed to lateral liquefied soil pressure and \( H_c \) = Height of force \( F_c \) above the bottom of liquefied sand layer; \( F_c \) = Lateral equivalent force on the pile cap and \( p_L \) is the limiting liquefied soil pressure.

Seismic Deformation Method or p-y Method

The most commonly used model for predicting the non-linear behavior of soil is using p-y curves (API, 2003). The basic differential equation of laterally loaded pile is as given below:

\[ EI \frac{dy}{dz^2} + E_s y = F \]  

Where,

\( y \) = lateral deflection of pile
\( z \) = distance along the pile from the top
\( EI \) = flexural rigidity of pile
\( E_s \) = soil modulus
\( F \) = applied force per unit length of the pile

In earthquake engineering the equation (2) is modified as given below [AIJ, 2001]:

\[ EI \frac{dy}{dz^2} = -k_s D (y-y_g) \]  

\( y_g \) = ground displacement; \( D \) = diameter of pile; \( k_s \) = subgrade modulus.

p-y curves are usually employed for obtaining the pile response (Matlock 1970, Reese et al. 1974)
Using the above equation, pile response due to kinematic interactions may be evaluated. Also by adding inertia loads on right side of equation (3) and using principle of superposition the combined pile response due to kinematic and inertial loading may be obtained.

In case of liquefying soils, the subgrade modulus is degraded and the degradation of \( k_{hn} \) with increasing displacement is expressed as [Tokimatsu et al. 1998, Tokimatsu 1999]:

\[
k_h = k_{hn} S_f
\]

(4)

where \( S_f \) is the scaling factor for the liquefied soil.

Variation of horizontal subgrade modulus, \( k_{hn} \) (for non-liquefied soils) with depth in the soil deposits is correlated with the Standard Penetration Test (SPT) \( N \) values. The modulus of subgrade reaction for non-liquefied soils \( k_{hn} \) proposed by AIJ (2001), JRA (1996) is given as:

\[
k_{hn} = B_0 \times E_o \times 0.75
\]

(5)

\[
E_o = 0.7 N
\]

(6)

Where \( k_{hn} \) is the modulus of subgrade reaction in \( MN/m^3 \), and \( E_o \) is the modulus of deformation in \( MN/m^2 \), \( N \) is the SPT value, and \( B_0 \) is the diameter of the pile in \( cm \).

As soil liquefies, the stiffness of soil degrades. It can be found from the case studies that the modulus of subgrade reaction for the laterally spreading soils can be reduced by a scaling factor, termed as stiffness degradation parameter, \( S_f \) varying from 0.001 to 0.01 (Ishihara and Cubrinovski, 1998) as compared to normal soil condition where there is no liquefaction. The degree of stiffness degradation in the laterally flowing deposits is related to the displacement of the pile relative to the surrounding soil.

**Validation of Pile response for Laterally spreading grounds**

Based on the Equation (3) a computer program is developed for single piles in liquefied soil by using MATLAB (2004). The pile top (node ‘1’, Fig. 2) is assumed to be free headed and pile tip (node ‘n+1’) as floating tip in the present study.

By applying central difference method at point ‘i’ (Fig. 2):

\[
\rho_f \frac{\partial^2 y_i}{\partial t^2} - 4 \rho_f \frac{\partial^2 y_i + 6 y_i - 4 y_{i-1} + y_{i-2}}{(h)^2} + k_i (y_i - y_{i+1}) = 0
\]

(7)

\( n \) = number of elements along the pile, \( h \) = segment length = \( L/n \) and \( k_i \) is modulus of subgrade reaction
In the present study kinematic and inertial loads are imposed separately and the combined response is algebraically added. The kinematic interaction response is obtained by considering the ground deformations \( y' \) alone. In the second stage inertial loads \( (H) \) alone are applied at the pile top as equivalent static loads and the pile bending response is obtained. In order to estimate the peak bending moment due to combined inertial and kinematic loads, Tokimastu et al. (2005), Tokimastu and Suzuki (2005) suggested that when \( T_b \) (natural period of structure) > \( T_g \) (ground natural period), the peak pile bending moment in the pile can be estimated by the SRSS (square root of sum of squares) of the individual moments due to the inertial and kinematic loads. When \( T_b < T_g \), the peak bending moment in the pile can be computed by the algebraic addition of inertia and kinematic components. In the present study the bending moments in the pile considering kinematic and inertial interactions are algebraically added at various nodes along the pile length.

The computer program developed is initially validated by using available solutions in literature (Meera and Basudhar 2008) for kinematic interactions. The validation on flexural behavior of pile is performed for free headed pile with floating tip at the base. The notations used are: non-liquefied depth factor \( r = L_1/L \), liquefied depth factor \( s = L_2/L \), embedded depth factor \( t = L_3/L \), pile flexibility factor \( R = E_p/(LE) \), ratio of young’s modulus of the pile to the soil modulus \( K = E_p/E_s \), the pile length to pile diameter ratio \( L/D \) (slenderness ratio), soil modulus to soil strength ratio \( Q = E_s/s_u \), vertical load factor \( V = 4P/\pi D^2 E_s \), horizontal load factor \( H = H/s_u D^2 \), moment factor \( M = M/s_u D^3 \), ratio of distance of location of pile from the waterfront to the affected distance of lateral spreading, i.e., location factor \( L_x = x/L \), scale factor for liquefied soil \( S_f \), and gradient of surface topography \( \lambda \).

The pile deflections and moments also depend on the gradient of the surface topography and hence are evaluated by considering various slopes. The results are given in terms of non-dimensional coefficients. The non-dimensional deflection coefficient, is \( Y = y/D \), where \( y \) is pile deflection, \( D \) is diameter of pile and non-dimensional bending moment coefficient is, \( M' = M/s_u D^3 \), where \( M \) is the bending moment developed at the pile soil interface, \( s_u \) is the shear strength of soil. The various input parameters considered for obtaining the effect of lateral spreading are: \( L/D = 25; r = 0.20; s = 0.60; K = 500; R = 1.0 \times 10^{-4}; Q = 200; S_f = 0.01; L_x = 0; V = 0; H = 0; M = 0 \).

The soil pile interaction is performed with the above input parameters and the results of the present study

Table 1: Variations of non-dimensional deflection coefficient \( Y \) and non-dimensional moment coefficient \( M' \) with slope – Present study vs. those obtained by Meera and Basudhar (2008).

<table>
<thead>
<tr>
<th>Slope (%)</th>
<th>Present study</th>
<th>Meera and Basudhar (2008)</th>
<th>% diff. (absolute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S(%) )</td>
<td>( Y' )</td>
<td>( M' )</td>
<td>( Y' )</td>
</tr>
<tr>
<td>10</td>
<td>2.214</td>
<td>217.11</td>
<td>2.232</td>
</tr>
<tr>
<td>20</td>
<td>2.783</td>
<td>272.90</td>
<td>2.805</td>
</tr>
<tr>
<td>30</td>
<td>3.181</td>
<td>311.98</td>
<td>3.207</td>
</tr>
<tr>
<td>40</td>
<td>3.498</td>
<td>343.05</td>
<td>3.526</td>
</tr>
</tbody>
</table>
are compared with results obtained by Meera and Basudhar 2008, and are given in Table 1. Clearly it can be seen that the results are in good agreement with that of available solutions in the literature. Also the variation of pile deflections and bending moments are plotted in Fig. 3A and Fig. 3B respectively by considering various ground surface topographies (slopes). It is observed that the ground surface slope has significant influence on the pile response and it is found that the amplification factor is about 1.60 for non-dimensional deflection and bending moment coefficients when the ground surface slope is increased from 10% to 40% and hence pile design must consider the slope effects in laterally spreading grounds. Also it can be seen that the maximum bending moments are observed at the interface of liquefying soil layer to non-liquefied layer.

**Behavior of Piles under Seismic Loads**

Having validated the pile response to kinematic loading in liquefying soils, the pile behavior is studied for both non-liquefying and liquefying conditions for selected ground motions. The boundary conditions are considered as free headed top and floating tip base. In the present study four typical strong motion earthquake events corresponding to Bhuj (2001) earthquake, Loma Prieta (1989) earthquake, Loma Gilroy (1989) motion and Kobe (1995) earthquake are considered for soil pile interaction analysis. These earthquakes represent wide range of amplitudes [maximum horizontal accelerations (MHA) of 0.106g for Bhuj (2001), 0.278g for Loma Prieta (1989), 0.442g for Loma Gilroy (1989) and 0.834g for Kobe (1989) motion respectively], frequency contents and durations. Time history of Kobe (1995), Loma Prieta (1989) and Loma Gilroy (1989) are available in DEEPSOIL v5.0 library [Hashash et al. 2008].

**Response of laterally loaded pile in liquefying soils**

Having validated the pile response under kinematic loading, the pile response is studied for liquefying soils due to earthquake loads. The pile length is considered as 10.0m and pile radius is considered as 0.25m in the present study. Young’s modulus of the pile is assumed as 2.74×10^7 kN/m^2. The various input parameters considered for seismic soil pile interaction for both liquefying and non-liquefying conditions are presented in Table 2 representing SPT, modulus of deformation, degraded subgrade modulus etc., at various depths. The relative stiffness factor (L/T) for the pile soil system varies from approximately 2.8 to 3.4 (for liquefied case) and hence the pile behavior is expected to be rigid/semi-rigid. For non-liquefying soils it can be seen that L/T varies from 7.0 to 8.5 and hence pile behavior is expected to be flexible. Results of
equivalent linear ground response analysis performed from a separate study for this soil deposit are used in the present analysis. The results obtained from ground response analysis of local soil sites are approximated as linearly varying along the depth of soil deposit. The peak ground accelerations at ground surface obtained from ground response analysis [Phanikanth et al. 2010] are 0.251g for Bhuj (2001) motion, 0.641g for Loma Prieta (1989) motion, 1.136g for Loma Gilroy (1989) motion, and 0.917g for Kobe (1995) motion respectively. It was assumed that the entire soil deposit is liquefying and hence stiffness degradation is considered as \( s_f = 0.01 \) for evaluating the pile response.

The kinematic interactions are considered based on the results obtained from the ground response analysis and the inertial interactions are considered by multiplying the cap mass and peak surface acceleration. In the present study the ultimate pile capacity is estimated as 90.0t and the inertial loads \( (H) \) are applied at the pile top obtained by multiplying cap mass with peak ground acceleration at the ground surface. Thus the inertial loads for Bhuj (2001) input motion, Loma Prieta (1989) motion, Loma Gilroy (1989) motion and Kobe motion respectively.

### Table 2: Input parameters for soil-pile interaction, liquefied soils

<table>
<thead>
<tr>
<th>Layer No.</th>
<th>Stratum</th>
<th>Layer thickness (m)</th>
<th>Depth below GL (m)</th>
<th>SPT value (N)</th>
<th>( E_o ) (MPa)</th>
<th>( B=D=) pile dia. (cm)</th>
<th>( k_{bn} ) (MN/m²)</th>
<th>( k_{hp} = k_{bn} \cdot s_f ) (kN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Filled up soil</td>
<td>1.5</td>
<td>1.5</td>
<td>10</td>
<td>7</td>
<td>50</td>
<td>29.78</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>Yellowish loose sand</td>
<td>1.5</td>
<td>3</td>
<td>12</td>
<td>8.4</td>
<td>50</td>
<td>35.74</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5</td>
<td>4.5</td>
<td>13</td>
<td>9.1</td>
<td>50</td>
<td>38.72</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5</td>
<td>6</td>
<td>16</td>
<td>11.2</td>
<td>50</td>
<td>47.65</td>
<td>0.01</td>
</tr>
<tr>
<td>3</td>
<td>Black clayey soil</td>
<td>2</td>
<td>8</td>
<td>20</td>
<td>14</td>
<td>50</td>
<td>59.57</td>
<td>0.01</td>
</tr>
<tr>
<td>4</td>
<td>Yellowish clayey soil</td>
<td>1.8</td>
<td>9.8</td>
<td>25</td>
<td>17.5</td>
<td>50</td>
<td>74.46</td>
<td>0.01</td>
</tr>
<tr>
<td>5</td>
<td>Greyish hard rock</td>
<td>-</td>
<td>&gt; 9.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
(1995) motion are estimated as 222.0 kN, 567.0 kN, 1003.0 kN and 810.0 kN respectively. The soil pile response in liquefying soils considering subgrade modulus evaluated with $s_f = 0.01$ ($=1/100$) is obtained considering both inertial and kinematic interactions together is shown in Fig. 4a with inertial response and kinematic response added algebraically. It was observed that the pile response is significantly affected in the presence of liquefiable layer and also it is observed that the amplification factor is approximately about 2.50 in peak bending moments. The pile deflections are presented for liquefying soils in Fig. 4b for kinematic and inertial interactions and in Fig. 4c for inertial interactions only. It can be seen that, the pile deflections due to inertial loads are significant and also from the load significantly and the amplification is found to be approximately 2.50. Kagawa (1992) reported that the amplification in peak bending moments for liquefying soils is as high as 6.0 compared to non-liquefying soils and many failures observed during earthquake are due to inability of pile to sustain such large bending moments. The bending moment along depth is also plotted for Loma Prieta (1989), Loma Gilroy (1989) and Kobe (1995) input motions, based on ground response results obtained and considering inertial and kinematic interaction added algebraically and are also shown in Fig. 5a.

Also to understand the kinematic response of the pile with respect to the ground response under earthquake event, the pile deflections under kinematic loading are compared with ground displacements for both liquefying and non-liquefying soils. It can be seen that the pile is flexible under non-liquefied condition ($L/T$ varies from 7.0 to 8.5) where as pile tends to be rigid when soil is liquefying ($L/T$ varies from 2.8 to 3.4). The ground displacements obtained from ground response analysis results for Kobe (1995) and Loma Gilroy (1989) motion are approximated as parabolically varying to obtain the pile deflections under kinematic loading and the results are shown in Fig. 5B. It is found that when the pile is flexible the pile displacements (kinematic) nearly match with the ground displacement where as when the pile is rigid there is relative displacement between the soil and the pile.

**Comparison of responses of fully liquefying and non-liquefying soils**

The pile response is evaluated with and without stiffness degradation effects and for different ground motions. The variation of pile bending moment for kinematic and inertial interactions along depth of the pile for fully liquefying and non-liquefying soils for Bhuj (2001) motion is plotted in Fig. 5a. Clearly it can be seen that for the piles in liquefying condition the bending moments are amplified significantly and the amplification is found to be approximately 2.50. Kagawa (1992) reported that the amplification in peak bending moments for liquefying soils is as high as 6.0 compared to non-liquefying soils and many failures observed during earthquake are due to inability of pile to sustain such large bending moments. The bending moment along depth is also plotted for Loma Prieta (1989), Loma Gilroy (1989) and Kobe (1995) input motions, based on ground response results obtained and considering inertial and kinematic interaction added algebraically and are also shown in Fig. 5a.

Also to understand the kinematic response of the pile with respect to the ground response under earthquake event, the pile deflections under kinematic loading are compared with ground displacements for both liquefying and non-liquefying soils. It can be seen that the pile is flexible under non-liquefied condition ($L/T$ varies from 7.0 to 8.5) where as pile tends to be rigid when soil is liquefying ($L/T$ varies from 2.8 to 3.4). The ground displacements obtained from ground response analysis results for Kobe (1995) and Loma Gilroy (1989) motion are approximated as parabolically varying to obtain the pile deflections under kinematic loading and the results are shown in Fig. 5B. It is found that when the pile is flexible the pile displacements (kinematic) nearly match with the ground displacement where as when the pile is rigid there is relative displacement between the soil and the pile.
Conclusions

1) The ground surface slope has significant influence on the pile response and it is observed that the amplification factor is about 1.60 for non-dimensional deflection and bending moment coefficients when the ground surface slope is increased from 10% to 40% and hence pile design must consider the slope effects in laterally spreading grounds. Also pile response under kinematic loads is validated with available solutions in the literature and the results are in good agreement with the available solutions.
2) Flexible piles tend to deform along with the ground with little relative displacements and hence in the presence of high inertial loads the total pile bending response is mainly due to inertial interactions. Rigid piles being stiff, deform with higher relative displacements between ground and pile, resulting in high passive resistance from the soil. The pile bending response due to kinematic loads is also significant.

3) The pile response in liquefied soils is significantly amplified compared to that in non-liquefying soil and the amplification in peak pile bending moment is found as high as 2.50. The effect of depth of liquefied layer has significant influence on the soil pile response. Maximum pile bending moments occurs at the interface of the liquefying and non-liquefying layer. Maximum pile bending moments are developed when the thickness of liquefying soil layer is approximately 60% of the total thickness of the soil layer.

References

Geotechnical Special Publication No. 181, ASCE.


Composite Polyamide Reverse Osmosis (RO) Membranes – Recent Developments and Future Directions

A.K. Ghosh, R.C. Bindal, S. Prabhakar and P.K.Tewari
Desalination Division

Abstract

Thin Film Composite – Polyamide (TFC-PA) are commonly used reverse osmosis (RO) membranes in water desalination and waste water applications. Their poor chlorine tolerance and fouling characteristics constrain the life and performance leading to stringent chemical pretreatment requirements. In this context, development of fouling resistant and chlorine tolerant RO membranes would be relevant to reduce the cost of pretreatment in aqueous based separations. In this article, we briefly review the commercially available polymeric RO membranes and then discuss our views on current proposals for fouling resistant RO membranes mostly based on nano-composite material chemistry. In addition, development of similar RO membranes in Desalination Division, BARC is also discussed.

Keywords: Polyamide, composite membrane, reverse osmosis, fouling resistant, chlorine resistant

Introduction

Reverse Osmosis (RO) membrane technology is one of the mature separation technology tools used in various industries for separation either as unit separation process or as combination with other processes. The productive RO membrane should offer simultaneously high solute rejection, water permeability, chemical stability and good chlorine resistance particularly for aqueous separations. Cellulose acetate and aromatic polyamide group of polymers are known as two best polymer materials for reverse osmosis (RO) applications till date [1]. Cellulose acetate (CA), cellulose triacetate (CTA) and cellulose acetate-cellulose triacetate blend (CAB) membranes are prepared generally in asymmetric form and hence give relatively lower flux compared to the new generation thin-film composite (TFC) membranes. In addition, CA based membranes are susceptible to microbiological attack, undergo compaction at higher pressures, and limited chemically stability. On the other hand, polyamide membranes exhibit more flux at a given applied pressure, less microorganism susceptible and are more stable over a wider range of pH values than CA membranes. Thus, polyamide TFC membranes are currently the most widely used desalination membranes. TFC-RO membranes comprise of ultra-thin polyamide film formed in situ by polycondensation reaction of polyfunctional amine and acid chloride monomers over a porous polysulfone support membrane [2]. However, their poor chlorine tolerance (chlorine is inexpensive and effective biocide widely used in water pretreatment) constrains their life and performance characteristics leading to stringent pretreatment requirements. High feed pressures applied for RO applications damage polymeric membranes internally due to physical compaction of the porous support membrane and hence irreversible, internal fouling remains a serious concern for RO membranes till date. Apart from the internal fouling, surface fouling due to
scaling and deposition of organic materials, bioorganisms etc. also is a serious problem limiting the life of RO membranes. Hence development of fouling and chlorine resistant RO membrane with better water flux is a thrust area of membrane research. In this article, we discuss the present status of composite polyamide RO membranes and future direction of research towards development of more fouling resistant and chlorine resistant RO membranes keeping salt rejection and water permeability intact or better than the present membranes.

Strategies for synthesis of high flux fouling resistant and chlorine resistant polyamide membrane

More than 30 years, water flux and solute rejection of polyamide TFC membranes have continually improved but still these membranes are not fouling resistant. Internal fouling due to compaction can be managed to certain extent if macrovoids in support membrane can be lesser number and/or by using higher molecular weight polymer. Similarly, organic and biofouling resistant membrane needs to be such that the foulants should not attach to the surface of the membrane easily. In most of the studies so far, only one type of fouling can be solved at a time. For example, if higher molecular weight polymer is used, internal fouling due to compaction can be solved by certain extent but it does not give surface fouling resistant membranes. On the other hand, in surface functionalization by chemical modification of polymer to get surface fouling resistant membrane, chain breakage or degradation of polymer results in low compaction resistant membranes. Similarly, blending of functional polymer with base polymer can also used for preparation of organic and biofouling resistant membranes but very few polymers are compatible with commonly used membrane polymers. However, concept of a mixed-matrix membrane (a small filler material is dispersed throughout a larger polymeric matrix) has brought new degrees of freedom to the development of advanced membrane materials with improved mechanical, chemical, and thermal stability, as well as enhanced separation capacity [3]. And flux can also be increased by using porous nanomaterials in mixed-matrix membrane which opens a preferential flow path for pure water to flow from the feed side to the permeate side of the membrane.

For preparation of chlorine resistant polyamide composite membrane, correlation between the chemical structure of polyamides and membrane chlorine interaction need to be known. In case of polyamides synthesized from aromatic primary diamines compounds, N-chlorination followed by chlorination of aromatic ring by Orton Rearrangement is responsible for changing chemical property of polyamide [4]. The Orton rearrangement takes place only when amide linkage is directly connected with benzene ring (especially from amine side). Aliphatic polyamides, on reaction with chlorine yield N-chlorinated amide which can be regenerated to the initial amide by treatment with reducing agent [4]. Tertiary polyamides are inactive towards oxidative chlorine. So, the strategies for better chlorine resistance are: (a) by protecting active sites on aromatic rings, (b) by synthesizing polymers with tertiary amide groups, (c) by incorporating aliphatic secondary and tertiary amide linkage not directly connected with aromatic rings. Other than polyamides, polysulfone has much better chlorine resistance as it has chemically strong bonds between carbon, sulfur, and oxygen. But polysulfone is hydrophobic and hence RO types of membrane cannot be prepared unless chemical structure of polysulfone is altered by introduction of controlled levels of hydrophilicity while retaining its physical properties. Sulfonated polysulfone has been reported for making nanofiltration (NF) and loose RO membranes that are found highly tolerant to aqueous chlorine solution [5]. However, these are asymmetric membranes and hence flux is expected to be less
than that of TFC membranes. Some of the nanomaterials like carbon nanotube (CNT) can have certain extent of chlorine tolerance and hence can be embedded onto the membrane surface to make it chlorine resistant.

**Discussions**

*Present status in developments of thin film composite (TFC) RO membranes*

The present RO membrane market is dominated by thin film composite (TFC) polyamide membranes consisting of three layers: a polyester nonwoven fabric act as structural support (~100μm thick), a microporous interlayer support of polymer like polysulfone (~ 40-50 μm thick), and an ultra-thin polyamide barrier layer on the top surface (~0.2-0.25μm thick). However, some of the other polymeric materials other than polyamide also work as very good TFC RO membranes. Table 1 shows details of some of the commercially available TFC RO membranes and similar membranes developed in our division in terms of polymer used as thin film as well as membrane performance in RO testing condition [2, 6]. The membrane preparation machines used for TFC RO membrane making in two steps are shown in Fig.1. The processes and exact chemistries for producing most of the successful commercially available RO membranes are shown in Fig.1. The processes and exact chemistries for producing most of the successful commercially available RO membranes are shown in Fig.1. The processes and exact chemistries for producing most of the successful commercially available RO membranes are shown in Fig.1. The processes and exact chemistries for producing most of the successful commercially available RO membranes are shown in Fig.1. The processes and exact chemistries for producing most of the successful commercially available RO membranes are shown in Fig.1. The processes and exact chemistries for producing most of the successful commercially available RO membranes are shown in Fig.1.

<table>
<thead>
<tr>
<th>RO membrane</th>
<th>Material</th>
<th>Testing condition (Pressure, Feed solution)</th>
<th>Permeate flux (m². m⁻². day⁻¹)</th>
<th>Salt rejection (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS-200</td>
<td>Sulfonated polyfuran</td>
<td>&gt; 100 bar, 3.5% NaCl</td>
<td>0.8</td>
<td>99.8</td>
</tr>
<tr>
<td>PES-1000</td>
<td>Polyether-polyfuran</td>
<td>&gt; 69 bar, 3.5% NaCl</td>
<td>0.5</td>
<td>99.9</td>
</tr>
<tr>
<td>CP</td>
<td>Sulfonated polysulfone</td>
<td>&gt; 69 bar, 3.5% NaCl</td>
<td>0.06</td>
<td>98</td>
</tr>
<tr>
<td>NS-100</td>
<td>Polyamide (aliphatic-aromatic)</td>
<td>&gt; 100 bar, 3.5% NaCl</td>
<td>0.7</td>
<td>99</td>
</tr>
<tr>
<td>PA-300/RC-100</td>
<td>Polyamide (via polyepiamine)</td>
<td>&gt; 69 bar, 3.5% NaCl</td>
<td>1</td>
<td>99.4</td>
</tr>
<tr>
<td>NS-300</td>
<td>Poly(piperazine-amide)</td>
<td>&gt; 100 bar, 3.5% NaCl</td>
<td>3.3</td>
<td>68</td>
</tr>
<tr>
<td>FT-30</td>
<td>Fully aromatic polyamide</td>
<td>&gt; 15 bar, 0.2% NaCl</td>
<td>1</td>
<td>99</td>
</tr>
<tr>
<td>UTC series</td>
<td>Fully aromatic polyamide</td>
<td>&gt; 15 bar, 0.5% NaCl</td>
<td>0.8</td>
<td>98.5</td>
</tr>
<tr>
<td>BARC-TFC1</td>
<td>Polyamide (aliphatic-aromatic)</td>
<td>10 bar, 0.2% NaCl</td>
<td>0.45</td>
<td>92.0</td>
</tr>
<tr>
<td>BARC-TFC2</td>
<td>Fully aromatic polyamide</td>
<td>10 bar, 0.2% NaCl</td>
<td>0.55</td>
<td>97.0</td>
</tr>
</tbody>
</table>

Table 1: Details of the some of the commercially available TFC RO membranes

![Fig. 1: Pictures of (a) support membrane casting machine and (b) thin-film polyamide coating machine](image)
Novel composite polyamide RO membranes

Commercially available TFC polyamide membranes are not fully fouling resistant though they show excellent permeability and selectivity. By membrane surface hydrophilization in post-treatment, different researchers attempted to increase further the permeability and organic fouling resistance up to a certain extent but problem of physical

![Fig. 2: Fully aromatic polyamide prepared via interfacial polymerization of meta-phenylenediamine and trimesoyl chloride.](image)

are still proprietary. A recent study substantially revealed the physicochemical properties of some of the commercially successful RO membranes [7]. The membrane samples studied included two high pressure seawater RO membranes (SWC4 and SW30HR) and six brackish water RO membranes (LFC1, LFC3, ESPA3, LE, XLE, and BW30). Membranes SW30HR, BW30, LE, and XLE are Dow FilmTec (Minneapolis, MN, USA) membrane and SWC4, LFC1, LFC3, and ESPA3 are Hydranautics (Oceanside, CA, USA) membrane. It was found that the uncoated fully aromatic RO membranes had surface elemental compositions very close to the predicted values for polyamide based on the classical interfacial polymerization chemistry of meta-phenylenediamine and trimesoyl chloride but the coated membranes had higher oxygen and lower nitrogen content. The presence of -OH groups in coating layer was further confirmed by high resolution XPS scans. Streaming potential measurements showed the zeta potential of coated membranes was significantly less negative than that of uncoated ones, consistent with ATR-FTIR and XPS results. The uncoated membranes are ESPA3, SWC4, LE, XLE and probably the polyvinyl alcohol (PVA) coated membranes are LFC1, LFC3, BW30, and SW30HR. So far the best commercially successful TFC polyamide RO membrane has the ultra-thin barrier layer made of cross-linked aromatic polyamide prepared via interfacial polymerization of meta-phenylenediamine and trimesoyl chloride (as given in Fig. 2). From Table-1, it can be seen that BARC-TFC1 and BARC-TFC2 are typically brackish water RO membranes. BARC-TFC2 membrane that is prepared using meta-phenylenediamine - trimesoyl chloride system gives better flux membranes with higher salt rejection than that of prepared using polyethylene imine (PEI) – isophthaloyl chloride (IPC) system (BARC-TFC1). However, the application areas where upto 92% solute rejection with moderate product permeation is acceptable, BARC-TFC1 is more preferable than BARC-TFC2 membrane because stability of raw materials used in former membrane is better than that used in later membrane. Polyethylene imine (PEI) is a very stable chemical and it gives more stable aqueous solution (does not oxidize or change color in presence of air and light) than meta-phenylenediamine. Hence, PEI aqueous solution is used repeatedly and it gives obvious economic advantage. In addition, isophthaloyl chloride (IPC) is easy to purify by simple recrystallization from hexane unlike trimesoyl chloride. But for application where high salt rejection is desired, BARC-TFC2 type membranes need to be used. So, both the reagents (meta-phenylenediamine and trimesoyl chloride) either need to be prepared fresh or need purification just before use to make high salt rejecting TFC RO membranes.
compaction, biofouling and chlorine tolerance was still not satisfactory. In this section, we limited our discussions only on development of fouling resistant TFC polyamide membranes using nanocomposite materials chemistry and of chlorine resistant TFC polyamide membranes using polycondensation reaction of easily synthesized new reactants.

**Thin film nanocomposite (TFN) RO membranes with enhanced permeability and fouling resistance**

It is known that the rejection of monovalent ion in a mixed ion solution is lower than that for a pure solution of monovalent salt. So, the filtration mechanism is not only dependent on size exclusion, but also on Donnan exclusion due to the charged double layer induced by adsorbed ions on the pore or the intercrystalline walls. But ions can be completely excluded by membranes with pore sizes smaller than the size of the hydrated ions in feed solution. Nanoparticles like LTA-type zeolite nanoparticle exhibits 0.4nm pores and MFI-type has 0.56 nm pores which are lower than the size of the common ions presents in contaminated water but bigger than the size of a water molecule (0.278nm). So, LTA-type zeolite particles in the size range of 50–150nm with a Si/Al ratio of 1.5 are taken to make inorganic-organic thin film nanocomposite (TFN) membranes with assumption that nanoparticles will create a straight path for flowing of pure water only retaining salt ions from salt water. Moreover, these particles are very hydrophilic (contact angle < 5°), with negative charge which are highly repulsive to anions. The zeolite nanoparticles are dispersed in hexane solution of trimesoyl chloride before the interfacial polycondensation reaction takes place. TFN RO membranes are prepared with various zeolite loadings, size and consequent changes in membrane characteristics have been reported [8, 9].

TFN membranes are smoother, more hydrophilic and more negatively charged than normal TFC membranes prepared under identical condition. Hence TFN membranes have less fouling tendency than the TFC membrane. Also TFN membrane exhibits two times more flux and a slight improvement in salt rejection relative to the hand cast TFC membrane without zeolite nano-particles. Fig. 3 gives conceptual illustration of TFC and TFN membrane structures. Fig. 4 illustrates the membrane separation performance as a result of variation in zeolite nanoparticle loading.
In another study, the compaction behavior of hand-cast polysulfone-nanocomposite supported polyamide composite membranes relative to pure polysulfone supported polyamide composite membranes are evaluated to control irreversible, internal fouling of RO membranes by physical compaction [10]. Nanocomposite support membranes are prepared using silica particles in the size range of approximately 34 to 130 nm and zeolite particles with size range of approximately 250 to 300 nm. Cross-sectional SEM images of uncompacted (as-cast) and compacted at two different pressures namely, 1724 kPa and 3448 kPa are shown in Fig. 5. The figure suggests that membranes containing nanoparticles underwent less compaction, while the pure polymer based membrane experienced a drastic change in thickness and support structure.

A recent study suggests that membranes comprising sub-nanometer diameter CNT can desalt water when used as RO membranes [11]. The narrow pores reject ions extremely well, but conduct water at 5-1000 times (depending on the loading of nanotubes) the rate of commercially available TFC RO membranes. The primary causes of salt rejection and water transport in these studies is the narrow, smooth, nonpolar nature of the CNTs; hence, separation performance may not be specific to chirality of concentric walls. To get photocatalytic reactivity and antifouling properties in TFC membrane, anatase TiO₂ nano-particles (<10 nm) are dip-coated onto...

Fig. 5: SEM cross-section images of TFC (a1-uncompacted, a2-compacted at 1724 kPa, a3-compacted at 3448 kPa) and ST50 silica-TFC (b1-uncompacted, b2-compacted at 1724 kPa, b3-compacted at 3448 kPa) membranes
Chlorine tolerant TFC and TFN membranes

The chlorine resistant polyamide membranes reported so far are either prepared from aliphatic polypiperazinamides or from some complicated polymeric systems where water flux is less. Moreover, aliphatic polypiperazinamides can not be used at higher pressure due to compaction problem. In order to get high flux chlorine resistant polyamide membrane, the membrane polymer should have benzene ring to give structural rigidity and mechanical strength, secondary aliphatic amide groups not directly connected with benzene ring for chlorine resistivity and substituted hydrophilic group in benzene ring for higher hydrophilicity. To get the polymers with above characteristics, the following system can be tried.

For TFC polyamide membrane preparation, amine part can be poly (enamine)-graft-poly (m- nitro styrene) and acid part can be oxalic acid. So, poly (enamine)-graft-poly (m- nitro styrene) need to be synthesized first from graft copolymerization of enamine over poly (m-nitro styrene) polymer. Reaction of this graft copolymer with oxalic acid over support membrane gives cross linked polyamide TFC membrane. In this TFC membrane, both amide group and aromatic rings are present but amide linkage is not connected directly with aromatic ring.

1st Step: Synthesis of crosslinked copolymer of Poly(enamine)-grafted-poly(nitrostyrene)

Graft copolymerization of poly (meta-nitrostyrene) with enamine could be followed procedure similar to graft copolymerization of polyvinylidene difluoride (PVDF) with N-isopropylacrylamide as reported in literature [13].

For sake of simplicity in writing the chemical equation, the following notation is used in the second step of the reaction.
TECHNOLOGY DEVELOPMENT ARTICLE

In BARC, we have already perfected silver and silver-copper based nanocomposite biofouling resistant ultrafiltration (UF) membranes [15]. Nanocomposite UF membranes are generally more compaction resistant than corresponding pure polymer.

2nd Step: In situ polycondensation of Poly (enamine)-grafted-poly (nitrostyrene) with oxalic acid.

In this case, oxalic acid is water soluble but difficulties may arise if poly(enamine)-graft-poly (m-nitrostyrene) copolymer is not soluble in a water immiscible organic solvent. In case suitable water immiscible organic solvent is not found, then the target polymer can be synthesized by solution polymerization technique and the synthesized polyamide polymer can be used for making asymmetric membranes.

Recently, it was reported that nanocomposite TFC RO membranes containing multi-walled carbon nanotube (MWCNT) has enhanced chlorine tolerance than normal TFC membranes [14]. In the MWCNT loading range of 0.1–1% (w/v), chlorine resistance of organic/inorganic nanocomposite RO membranes was improved as the amount of MWCNT increased.

In BARC, we have already perfected silver and silver-copper based nanocomposite biofouling resistant ultrafiltration (UF) membranes [15]. Nanocomposite UF membranes are generally more compaction resistant than corresponding pure polymer.
membrane. So, using these compaction and biofouling resistant support membranes (silver and silver-copper based polysulfone nanocomposite), preparations of CNT and porous silica based thin film nanocomposite (TFN) membranes are on progress to get high flux, fouling resistant and chlorine tolerant membranes. A conceptual picture of a probable fouling resistant nanocomposite membrane is given in Fig.6.

Conclusions

More resistance to physical compaction, chemical, biological and chlorine attack is most desirable to make significant reductions in both capital investment and operating costs of desalination by RO. Incorporation of nano-technology in membrane preparation could offer an attractive alternative to prepare real fouling resistant membranes and hence many scientists believe that nanotechnology would bring revolutionary advancements to the desalination industry. Among others, zeolite, silica based thin film nano-composite membranes and carbon nano-tube membranes are two most likely novel materials for enhanced RO desalination performance in the future but still a number of challenges remain with regard to their practical implementation. The major practical challenges are (a) high cost of nanomaterials, (b) the extra energy required to effectively disperse the nano-particles into the barrier layer, (c) health and safety issues for use of nanomaterials in the domestic water industry as sometime these are toxic and (d) the difficulty in scaling up nano composite membrane manufacturing processes for commercial use. However, zeolite and silica based thin film nano-composite membranes appear to be more readily adaptable to commercial use due to their similarity to current commercial RO membranes than carbon nano-tube based membranes where alignment of CNT into the polymer matrix is still a challenge. However, for nanocomposite chlorine tolerant membrane, low concentration of CNTs can be used in which at least few CNTs remain aligned and others give chlorine tolerances.

References

Introduction

In the beginning the classical precision engineering practices were followed to craft components and products by the state-of-the-art techniques with 2σ acceptance level. Probabilistic, skill oriented machining techniques were explored and developed. To prove the phenomenon and to run pilot scale studies this was the only approach available indigenously. Stringent time schedules were setting the pace. Multi pronged approach of learning, acquiring knowledge and developing the skill base, be it in-house or by out-reach was adopted. The focus was on learning various machining processes, more so, their capabilities and limitations and availability of the experts and skill sets across the country. Over a period of time, Precision Engineering has expanded significantly, several technologies and associated metrology have been developed for improving the performance of these components products & systems. Recently, the domain of Precision Engineering has expanded further by utilizing the experience of precision machining and engineering to develop MEMS-based Silicon micro-sensors and novel Opto-mechanical sensors that can be deployed for harsh operating conditions. This article presents an overview of the technologies and components developed for DAE programs in mission mode and presents a holistic view of an integrated Micro-Nano Engineering program aimed at DAE applications for the future.

Ultra-Precision Metrology

In the first phase of product development, vendors were involved in the manufacturing of critical components having intricate micro-patterns. However, metrology tools that were required to characterize and measure these components were missing at the vendor’s end, primarily because the measuring machines were very costly and they required very stringent environmental conditions to be maintained for reliable measurement and metrology. To overcome this problem, an Ultra-Precision Metrology Lab (UPML) was established with suitable measuring machines and systems. The UPML was a precision-environment controlled, class-10,000 cleanroom metrology lab housing High Precision Universal Measuring Machine (UMM) with sub-micron measurement accuracy with 95% confidence level. It also housed a three dimensional surface-topography measuring machine with nanometer resolution, an advance signature analysis tool for manufacturing engineers. To bridge the gap between three-dimensional measurements by Universal Measuring Machine (UMM) and two-dimensional topography by surface texture a Multi-Sensing and Measuring Machine was added to view and measure 2D and 3D surface features which could not be measured with the other two machines. The UPML is shown in Fig.1a, and typical
The sight was now set on achieving sub-micron accuracies on the size as well as geometry of the precision machined components having nanometer level of surface finishes. Vendors were induced to develop process capabilities, Central Machine Tool Institute (CMTI) Bangalore was commissioned to develop ultra-precision lathe popularly known as Diamond Turning Machine (DTM).

**Diamond Turn Machining**

Diamond Turn Machining (DTM) is a deterministic nano regime machining wherein the size tolerance and shape can be controlled within few hundreds of nano-meters and the surface finish within few tens of nanometers by employing an ultra-precision machine and an extremely sharp single crystal diamond tool. The technology is developed for the machining of the wide range of engineering materials i.e. ferrous as well as non-ferrous materials. The salient features of DTM process are a) Atomic Cluster Machining, b) Extremely high loop stiffness between tool and work piece, c) Ability to apply and maintain very small depth of cuts and feed rates as low as few nanometer, d) Low thermal and low sub surface damage.

Some of the components machined by DTM technology are shown in Fig.2. The comparison of CNC surface and DTM machined surface are shown in Fig 3. The measurement was carried out on a high-resolution surface profilometer. The $R_a$ value is 0.16 micron for CNC machined and lapped surface, while it is 10 nm for DTM machined surface.

![Fig. 1b: Three dimensional surface-topography of a Micro-grooved channels and measurement of $H_2$ Blister on Zircalloy Tube](image)

![Fig. 2: Solid circular and square honeycomb Al-alloy mirrors machined by DTM](image)

![Fig 3: Comparison of Ultra Precision Lapping and DTM Surface](image)

![Fig. 4: Indigenously Developed Single-Crystal Diamond Tool & X-Ray Reflectivity pattern (measurement done at RRCAT Indore)](image)

Single crystal diamond tool with ultra sharp cutting edges to the tune of 200nm, as compared to 5μm for very fine conventional tool, is an essential part of DTM process. These tools are very expensive and are presently being imported. An initiative has been taken to develop these tools indigenously. Fig(4) shows a precision diamond tool developed indigenously. The X-ray reflectivity pattern of the machined surface by indigenously developed tool as shown is $26^\circ A$. Presently single crystal diamond
Non-Conventional Machining Processes

Classical machining processes use either a hard wedge shaped tool or abrasive grits to remove material on selective basis. These material removal processes are popularly known as Conventional machining processes viz. turning, drilling, milling as well as grinding, lapping and honing processes. There are needs to remove materials in exotic shapes, sizes or materials, which cannot be accomplished by classical or conventional machining process. The alternative processes called Non-conventional Machining processes deploy thermal, abrasive or chemical means to remove the materials and are basically Electro-Discharge-Machining (EDM), Photo-Chemical Machining (PCM), Laser Beam Machining (LBM), Electron Beam Machining (EBM), Abrasive Jet Machining (AJM), Focused Ion Beam Machining (FIB) and Deep-Reactive Ion Etching (DRIE) to name a few ranging from Micro-machining to nano-machining processes. Some of these processes viz. EDM, LBM, PCM and AJM are used by advance manufacturing shops while others are still at lab-scale phase. To meet the requirement of nuclear engineering, aerospace, telecommunication and medical diagnostics and body implants these Non-Conventional Machining processes are developed depending upon specific requirements.

Heavy Water plants, using ammonia and hydrogen need Molecular Sieve Trays. These sieve trays have more than one Lakh micro-holes with pore size of 200 micrometer and pore density about 250 per square centimeter. The task was taken up and double-sided photochemical machining (PCM) process was developed. BEL, TATA Press, IDEMI and host of vendors inclusive of Mr. Mitter Bedi, the ace industrial photographer participated in the development process. Sieve trays are shown in Fig 5.

Three-dimensional Laser Lithography:

Conventional photochemical machining (PCM) is used to transfer the two-dimensional image on the 2D substrate; but this process cannot be used for generating intricate structures on the 3D substrate. Therefore a unique technique of 3D laser lithography was conceived, developed and is presently being used for the generation of high-speed fluidic devices. The custom built facility and fluidic devices are shown in Fig 7 a & b.
Micromachining and Related Technology Development

DAE took a pragmatic decision with an eye not only on future but also to tap the benefit of Miniature Micro and Nano-regime exploration and constituted a Steering Group by merging various disciplines of Science & Engineering viz Nanotechnology, MEMS, Sensors and Detectors and High Precision Engineering. The steering group identified the following thrust areas:

- Micro-Nano Systems and Technology
- Sensors and Detectors Development
- Silicon and Nanotechnology Initiative

The developments pertaining to Micro-Nano Systems and Technology are described here. This program was further subdivided into:

- Micro-machining and Nano-finishing Capacity Generation
- Micro-systems Development
- MEMS & Micro Sensor Development program

Micro-machining

A Micro-Nano Engineering Lab was established housing state-of-the-art unique machines in micro domain machining for the first time in the country. These machines are now being used extensively in BARC for development and product research in micro- & nano-domain, Fig. 8 shows these. Table-1 lists the products developed using the available facilities.
**Nano Finishing Technology**

Nano-finishing is a process, used to minimize the irregularities of the surface till nanometric scale. Nano-finishing process is used to arrange cluster of atoms on the surface of material with saturated and stable atoms on the free surface. Therefore, nano-finished components show better mechanical and chemical properties. Since, this process has very small material removal rate, it does not disturb the form of surface.

<table>
<thead>
<tr>
<th>Table 1: Micro-Nano Engineering Products</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Pin Hole Matrix for Synchrotron Beam line calibration</strong></td>
</tr>
<tr>
<td><strong>Process : m-EDM</strong></td>
</tr>
<tr>
<td><strong>Material : Copper beryllium</strong></td>
</tr>
<tr>
<td><strong>Total no. of holes : 70 (in matrix) + 3</strong></td>
</tr>
<tr>
<td><strong>Size 50mm x 50mm x 0.1 mm</strong></td>
</tr>
</tbody>
</table>

Micro Crack Test Specimen for PFBR  
Helical notch on Zirconium Alloy  
Width: 30 μm  
Depth: 45 μm  
Process: Micro-Milling  
&m-EDM

Micro EDM tool and thrust bearing with micro grooves  
Rotate at 4Lakh rpm

Micro Needle Array & Micro Pin Array of 3 x 5 matrix  
Dia. of needles at bottom : 120 micron  
Height of pins : 400 micron  
Pitch : 400 micron

Prototype Micro Chemical Reactor  
ID 0.5mm & Length 10mm

Atomic Cluster Removal of Material  
Micro Drilling on 100 micron human hair of 50 micron diameter

Chemo Mechanical Magneto Rheological Finishing

Magneto-rheological finishing (MRF) process is hybridized with Chemo Mechanical Polishing (CMP) and a novel finishing technology has been developed, Chemo-mechanical magneto-rheological finishing (CMMRF). The process is capable to carry out sub nano finishing. The process has been demonstrated on single crystal silicon substrate, and 0.5nm surface finish is achieved. The process can be developed for 3D sculptured surfaces.

![Image](image3.png)  
**Fig 9: Hybrid Process of CMMRF**

![Image](image4.png)  
**Fig. 10: Material Removal of chemically passivated layer by using magnetically assisted mechanical action**

The process has the ability to finish brittle, hard and soft 3-D shaped materials. Surface roughness value of the finished surface is less than 0.5 nm (Fig 11).
Electrolytic In-process Dress Grinding (ELID)

Electrolytic In-process Dressing (ELID) is a simple and efficient technique that utilizes electrolysis for dressing metal-bonded grinding wheels. During the ELID, the metal bond is slowly corroded and the corrosion product is then mechanically removed by abrasion during the grinding process. The grinding wheels that can produce such a protective layer during electrolysis are more suitable for in-process dressing. The process has the capability to grind any material viz. metals, non-metals, semiconductor and ceramics to obtain surface finish values of up to 10nm. Fig 12 shows the ELID machine and a Si substrate finished with the process having $R_a$ value 10nm.

Sensor Development Programme

**MEMS Pressure Sensors**

Micro Electro Mechanical Systems (MEMS) based sensors and actuators are finding applications in the fields of space, communications, defense, automobiles, biomedical etc. BARC has recently initiated a MEMS development programme and focused on Pressure Sensor development. These MEMS based pressure sensors are based on Piezoresistive effect in silicon, wherein resistivity changes with stress. The four Piezo-resistors are deposited in the substrate in such a way that two resistors would have longitudinal stress while other two would have transverse stress and Si substrate is bulk micro-machined to fabricate the sensing diaphragm of desired size. These resistors are connected in the form of Wheatstone bridge and the differential output voltage changes proportionally with applied pressure. Fig 13 shows a typical pressure sensor at various development stages.

The packaging of sensing chip plays a pivotal role in the development of MEMS sensors. The packaging is required to isolate the chip from the process media. The packaging design (fig 14) & development is basically mechanical engineering in micro & precision domain. Fig 15 shows the MEMS pressure transmitters developed for NPCIL applications. The following critical steps are involved:

- Anodic Bonding to bond the Si chip to glass substrate
- Ultra sonic wire bonding from chip to leads for external electrical connections
- Silicone Oil filling under vacuum to protect the chip from corrosive environment and for pressure transmission
The critical micro-engineering challenges of packaging are:

- Design and fabrication of miniature housing for pressure sensor chip
- Media isolation by using a stainless-steel diaphragm. The diaphragm has to be sensitive on one hand and be of sufficient strength to be able to isolate the chip from mechanical loads.
- Design and manufacture of miniature glass-to-metal seal.

**Opto-Mechanical Sensors**

The Opto-mechanical sensor is based on the principle of a Fabry-Perot Interferometer (FPI). A FPI classically consists of two plane parallel mirrors, and acts as an optical filter in the sense that it transmits selected wavelengths and reflects others depending on the separation between the two mirrors of it as shown in fig 16. In the development process of this sensor, first a micro machined, nano finished metallic mirror is designed & manufactured. This mirror is assembled at the cleaved end of the fiber in order to constitute a Fabry-Perot interferometer at the optical fiber end. This metallic mirror acts as a one of the mirrors of FPI as well as a deflecting element (diaphragm) of the sensor. As this FPI is pressurized, the diaphragm deflects, FPI gap reduces and reflected optical signal changes. The reflected optical signal is calibrated with pressure. Fig 17 shows the setup including opto-mechanical sensor, light source and analyzer. It also shows two different optical signal patterns for two different FPI gap lengths.

**Specification**

- 0-10 bar gauge pressure
- \(\frac{1}{2}\)" NPT(F) pressure port
- SS 316L package
- 4-20 mA current output
- 2-wire electrical connection
- 24-28 V dc power supply
Nanotechnology is at nascent stage of development. Nano science is taking a ‘Bottom-Up’ approach where scientists manipulate atoms and molecules to create nanomaterials and nanostructures. In the ‘Top Down Approach’ Micro-Systems & MEMS are developed to create a platform for nano scale fabrication. Effectively microtechnology is the launch pad for nanotechnology deployment. Presently the National Programme on Nano-technology is heavily tilted towards scientific exploration and development & characterization of nano materials & structures. Micro-Nano-Engineering is relatively a neglected area. Conception, design, manufacture, assembly, testing and characterization of micro and nano systems is at rudimentary state. There is a need to create a suitable Micro-Nano-Engineering Center by DAE and deploy scientists, researchers and engineers of multiple disciplines under one roof. Fig 19 shows the various aspects of engineering that need to be addressed in this Center.

Future Scope

Due to fast changing international scenario and to meet the needs of ambitious nuclear power generation and in allied areas there are two major relevant areas of research & development which must be pursued. These are

- Micro-Nano-Engineering
- Intelligent Manufacturing

Intelligent Manufacturing (IM) is another thrust area for DAE requirements:

- Intelligent-Manufacturing module consisting of flexible machining cell based on intelligent machines with real time- in situ- measurement and feed back.
- Intelligent-Quality Assurance module, measurement and calibration including on-line data transmission and quality auditing rather than batch process (Fig. 20).

IM will ensure very high quality & productivity with minimum human interaction meeting the needs of the department.
Several collaborative projects have been taken up in consultation with leading academic institutes and research laboratories in the country for the development of custom built High Precision Miniature components. Few of the collaborative projects are listed in Fig 21.

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro Machining</td>
<td>IIT B</td>
</tr>
<tr>
<td>Sub-Nano Finishing for Si Mirror</td>
<td>IITK</td>
</tr>
<tr>
<td>Crystal Polishing for Futuristic Bearing</td>
<td>IITB</td>
</tr>
<tr>
<td>LIGA for Micro structures</td>
<td>IITB</td>
</tr>
<tr>
<td>Micro Fluidic</td>
<td>IITD</td>
</tr>
<tr>
<td>Micro Nano Products</td>
<td>BATU, Lonere</td>
</tr>
<tr>
<td>Diamond Turning Technology</td>
<td>CSIO, Chandigarh</td>
</tr>
<tr>
<td>MEMS Sensors</td>
<td>BEL, Banglore</td>
</tr>
<tr>
<td>Nano Finishing of Sculptured surface</td>
<td>IITK</td>
</tr>
<tr>
<td>Bio Medical Implants</td>
<td>IITB</td>
</tr>
</tbody>
</table>

Fig. 21: Collaborative research in Precision Engineering

**Conclusion**

The role of precision-micro-nano engineering and non conventional machining is very critical in nuclear, aerospace, telecom and biomedical fields. With the advent of Nanotechnology, one has to be prepared to accept and adopt the intelligent, integrated and advanced technologies. Development in Microtechnology is the first step in this direction which will be the carrier of Nanotechnology. Robust Micro-engineering capabilities need to be established for future Nano-engineered components and systems deployment in a gainful manner in the department.
ISMAS International Discussion Meet on 
Elemental Mass Spectrometry in Health and 
Environmental Sciences 
(ISMAS / DM / HEAL 2011): Highlights

As a part of International Year of Chemistry 
Celebrations Discussion Meet on “Elemental Mass 
Spectrometry in Health and Environmental Sciences” 
(ISMASDMHEAL2011) was organized jointly by the 
Indian Society for Mass Spectrometry (ISMAS), 
Mumbai and Inter University Accelerator Centre 
(IUAC), New Delhi. The Discussion Meet was held 
at New Delhi during April 14 & 15, 2011.

The Discussion Meet was inaugurated by Prof. S. 
Kailas, Director, Physics Group, BARC on April 14, 
2011. Dr. Amit Roy, Director, IUAC, New Delhi 
president the function and delivered the 
Presidential address. Dr. Sundeeb Chopra, Co- 
Convener from IUAC delivered the welcome address 
and gave an overview of the activities at IUAC. Prof. 
S.K. Aggarwal, President, ISMAS and Chairman of 
the Organizing Committee, briefed on the activities 
of ISMAS and highlighted the scope of 
ISMASDMHEAL2011. Mr. P.G. Jaison, Convener, 
Organizing Committee, proposed the vote of thanks. 
During the inauguration function, the Bound Volume 
of the Proceedings of the ISMASDMHEAL2011 was 
released by Prof. S. Kailas. A special ISMAS 
Souvenir-cum-Bulletin brought out to 
commemorate the occasion, was released by 
Dr. Amit Roy.

There were 70 participants in the 
ISMASDMHEAL2011. The Discussion Meet provided 
a forum for Research Scholars and Scientists from 
Industry and Research Institutes, to discuss their 
experiences and share new developments in the field 
of Elemental Mass Spectrometry with special 
reference to Health and Environmental Sciences. The 
scientific programme of the Discussion Meet was 
covered in 7 technical sessions.

There were 17 Invited Talks by distinguished mass 
spectroscopists from within the country (11) and 
from overseas (6). Invited Talks covered various 
applications of Elemental Mass Spectrometry and 
Accelerator Mass Spectrometry for Biomedical 
applications, drug development, Forensic Science, 
Environmental Science and Geological Science.
Bound volume of the Proceedings of the ISMAS / DM / HEAL 2011 being released by Prof. S. Kailas, Director, Physics Group, BARC, Mumbai. On the dais from left to right: Mr. P.G. Jaison, Convener, Organising Committee, Dr. Amit Roy, Director, IUAC, Prof. S. Kailas, Director, Physics Group, BARC, Prof. S.K. Aggarwal, President, ISMAS and Chairman of the Organizing Committee, Dr. Sundeep Chopra, IUAC.

Invited speakers from overseas included Dr. Korschinek Gunther (Germany), Dr. Tim Ulrich Schulze-König (Switzerland), Dr. John Cottle (Nu Instruments, UK), Dr. R.J. Watling (Australia), Dr. Dirk Schaumloffel (France) and Dr. Bela Kovacs (Hungary).

The speakers from India included Dr. P.V. Bhagwat (BARC, Mumbai), Dr. Ravi Prasad (IOP, Bhubaneswar), Dr. Sundeep Chopra (IUAC, Delhi), Dr. B.R. Chakraborty (NPL, Delhi), Dr. V. Balaram (NGRI, Hyderabad), Dr. M.V. Balarama Krishnan (CCCM, Hyderabad), Dr. K. Chandrasekaran (CCCM, Hyderabad), Dr. J.K. Pattanaik (IISER, Kolkata), Dr.

M.S. Seshshayee (NCBS, Bengaluru), Dr. Vinai K. Rai (PRL, Ahemdabad) and Prof. S.K. Aggarwal (BARC, Mumbai).

There were 9 Contributed Papers presented as posters in two Poster Sessions. During the Discussion Meet, a panel discussion was also held on the topic “Future of AMS in India”. Prof. S. Kailas, Dr. Amit Roy, Prof. S.K. Aggarwal, Dr. Ravi Prasad, Dr. R.K. Choudhary and Dr. Susanta Lahiri were the panelists for the discussion.

ISMAS DMHEAL2011 concluded with a Valedictory Function on April 15, 2011. During this function, the delegates expressed their satisfaction over the technical content and scientific discussions held during the Discussion Meet. A need was felt to have a dedicated “Accelerator based Mass Spectrometry (AMS)” facility and “Electromagnetic Isotope Separator” in the country, in view of their increasing requirements and applications in life-sciences for societal benefit.
BARC Transfers Technologies

Quadrupole mass Spectrometer

Dr. R. K. Sinha, Director, BARC and Director, Knowledge Management Group, BARC has executed the agreement for transfer of know how of “Quadrupole Mass Spectrometer” technology developed by the Technical Physics Division, BARC to M/s Mechvac Fabricators (I) Pvt. Ltd., Navi Mumbai on 17th March, 2011.

The Quadrupole Mass Spectrometer is a versatile analytical instrument capable of compositional analysis of gases and volatile liquids. It consists of an Electron Impact ion source, quadrupole mass analyzer and a detector. QMS is a compact, reliable and low cost analytical tool. It can analyse a mass range of 1-300 amu with a resolution of 1 amu, which is adjustable.

Its applications include Gas compositional analysis from chemical and physical processes, residual gas analysis in Ultra High Vacuum systems, molecular weight and structural identifications in many organic compounds. It can also be coupled to Gas Chromatograph or a liquid Chromatograph for varied analytical problems.

Dip n Drink Membrane Pouch

The technology of “Dip N Drink Membrane Pouch” developed by the Desalination Division, BARC has been transferred to M/s Superklean Environmental Engineers Pvt. Ltd., Mumbai on 6th May, 2011.

The Dip N Drink Membrane Pouch technology is based on the principle of osmosis, which is a natural phenomenon and is deployed for the preparation of membrane pouch for getting sterile drinkable solution from contaminated water using membranes. A low molecular weight, water soluble, non-toxic substance having a high osmotic pressure are filled inside the Membrane Pouch. Based on
The osmosis process, only pure water permeates through the semi permeable membrane and dissolves the nutrient salts filled in the pouches.

Its application is especially useful during disaster management/emergency conditions like floods, Tsunami, earthquakes etc. It can also be used at remote locations where natural water sources are contaminated.
National Fire Service Week: a report

Every year, 14th April is observed as National Fire Service Day. On this day in the year 1944, fire service personnel displayed exemplary courage and devotion to duty as they fought the huge fire that had erupted, following an explosion on a Ship S.S. Fort Sticken berthed at the docks of Mumbai Port Trust. Many fire fighters lost their lives, leaving behind their names etched in the minds of mumbaite forever.

Several programmes were organized by the Fire Service Section, BARC during the Fire Service Week April 14 - April 20, 2011 to create fire safety awareness among employees in BARC Trombay and Anushaktinagar.

On behalf of BARC Mr. A.K. Tandle, Chief Fire Officer placed a wreath on 14.4.2011 at the memorials erected on the grounds of Mumbai Port Trust and at the headquarters of Mumbai Fire Brigade, Byculla.

On 15th April, 2011, Mr. N.D. Sharma, Controller, BARC was offered pin flag to inaugurate fire service week fund raising campaign. Pin flag was also offered to Mr. S.K. Ghosh, Director, Chem. Engg. Group and Mr. Hanmanth Rao, Head, ChED. On 16th April, 2011, two crews from BARC Fire Service Section participated in the Tactical Medley Drill Competition organized by the Govt. of Maharashtra at Cross Maidan, Dhobi Talao, Mumbai. 21 teams belonging to various organization viz. Mumbai Fire Brigade, BPCIL, Mumbai Port Trust, State Fire Training Centre participated in competition. Team ‘B’ of FSS, BARC was awarded the 4th prize and in individual ladder drill 3rd and 7th prizes. On the 17th April, a live Fire Fighting and Rescue Demonstration was organized at the Takshshila Ground for the benefit of Anushaktinagar residents. Around 350 residents witnessed the programme. On 18th April, 2011, Director, BARC Dr. R.K. Sinha was offered a pin flag on occasion of fire service week observance and
fund raising campaign. Director in his message spoke about improvement in communication which was essential between the caller and the responder involving Anushaktinagar residential colony too. He said it was the need of the hour that information regarding operation of different types of fire extinguishers, mode of fire fighting, fire emergency telephone numbers of contact persons during emergency bebe available on BARC Web Site, along with Standing Fire order and do’s and don’ts in case of emergency. On 18th April, 2011, an event on Fire Fighting Equipment Exhibition with fire fighting and rescue demonstration was organized at Hall-2.

On the 19th April, arrangements were made to screen a film on “Preventing Accident at the Home” through cable network at Anushaktinagar. A prize distribution function was also arranged on the 19th, at the Fire Station, BARC, for winners of various competitions conducted among BARC fire service personnel. Mr. S.K. Ghosh, Director, ChEG & Mr. Hanmanth Rao, Head, ChED distributed the prizes to the winners of the various competitions.

This year Rs. 21,407/-only were collected through cash donations during Fire Service Week observance 2011.

On 20th April 2011, the Fire Service Week celebrations culminated with a ceremonial parade at Cross Maidan, Dhobi Talao, in which the contingent from BARC’s Fire Service personnel also participated along with Emergency Rescue Tender & Equipment. Hon’ble His Excellency, Mr. K. Shankarnarayan the Governor of Maharashtra was the Chief Guest.
4th ISEAC International Discussion Meet on Electrochemistry and its Applications (DM-ISEAC-2011): a report

As part of the celebration of the International Year of Chemistry (IYC) declared by IUPAC, the Indian Society for ElectroAnalytical Chemistry (ISEAC) organized the 4th ISEAC International Discussion Meet on Electrochemistry and its Applications (DM-ISEAC-2011) at Mascot Hotel, Thiruvananthapuram, Kerala, India, during February 7-10, 2011. The Discussion Meet was aimed at updating the scientists with the latest developments in the field of electrochemistry and exposing the participants to new developments in electroanalytical techniques and innumerable applications of electrochemistry in different areas.

The Meet was inaugurated on February 7, 2011 by Prof. V. Venugopal, Director, Radiochemistry and Isotope Group, BARC. He spoke about the contributions of Electrochemistry in the nuclear power program of our country and also formally released the Bound Volume containing manuscripts of invited talks and contributed papers. He lauded the focused activities of ISEAC in promoting the potential applications of electrochemistry. Prof. Tulsi Mukherjee, Director, Chemistry Group, BARC gave the presidential address highlighting the importance of electrochemistry and its applications in different areas like nuclear science and technology, material science, biological and health sciences, environmental science etc. He formally released the first issue of the Bulletin of ISEAC acronymed “HEAT”. Prof. S.K. Aggarwal, President, ISEAC, Chairman, Organising Committee, welcomed the delegates and briefed about the activities of ISEAC, since its inception in October 2003. Mr. Saurav K.

Dr. V. Venugopal, Director, Radiochemistry & Isotope Group, BARC delivering the inaugural address. Others on the dias (from left to right) are Ms. Ruma Gupta (Secretary, Organizing committee), Dr. S.K. Aggarwal (Chairman, Organizing committee), Dr. T. Mukherjee (Director, Chemistry Group) and Mr. Saurav K. Guin (Convener, Organizing Committee).
Guin, Convener, Organising Committee, from Fuel Chemistry Division, BARC gave a summary about the various topics of both fundamental and applied Electrochemistry, to be discussed during the Meet. Ms. Ruma Gupta, Secretary, Organising Committee, proposed a vote of thanks.

About 90 participants including 6 overseas speakers participated in the Discussion meet. There were 19 Invited talks, 3 Short lectures, 23 Contributed papers and 10 Research Scholars’ papers presented during the Discussion Meet. All the contributions were spread over 11 Technical Sessions. Invited speakers from overseas included Prof. Christopher M.A. Brett (Portugal), Prof. (Ms) A.M. Oliveira-Brett (Portugal), Prof. John T. Luong (Canada), Prof. Serge Cosnier (France), Prof. Craig E. Banks (UK) and Prof. Emilia Kirowa-Eisner (Israel). The speakers from India included Prof. Sampath (IISc, Bangalore), Prof. J.B. Fernandes (Goa), Prof. K. Girish Kumar (Kochi), Prof. Sushil K. Mittal (Patiala), Prof. P.P. Patil (Jalgaon), Dr. T. Prasada Rao (Trivandrum), Dr. B.P. Reddy (IGCAR, Kalpakkam), Dr. M. V. Sangaranarayanan (IIT Madras), Dr. Ida Tiwari (BHU, Varanasi). Three short lectures were delivered by Dr. T. Ramakrishnappa (UK), Mr. Jonathan P. Metters (UK) and Binh T.T. Nguyen (Singapore). The scientific topics included the Role of electrochemistry in bio-sensors, Room temperature ionic liquids, screen printed electrodes, electrochemical synthesis of nano-particles and carbon nanotubes, graphene as potential electrode material, carbon paste electrodes, micro-electrodes, conducting polymers, pyrochemical reprocessing of metallic fuels, spectroelectrochemistry, and impedance spectroscopy. Besides, there were tutorial lectures on bioelectrochemistry and development of electrochemical biosensors and electrocatalysis.

There was a panel discussion on the recent focus and challenges in Electrochemistry and allied topics. A special session on practical demonstrations of different electroanalytical techniques by M/s Sinsil International, Mumbai was conducted on the first day of the Discussion Meet.

Merit certificates and cash awards were given to the authors of the best poster presentations. Dr. S.K. Aggarwal, Chairman, DM-ISEAC-2011, thanked all the delegates from India and Overseas, as well as sponsors, for their keen interest during the deliberations of the Discussion Meet. In particular, he thanked BRNS (DAE), CSIR and DRDO, ISE for co-sponsoring the Discussion Meet.
Theme Meeting on Very High Energy Gamma Ray Astronomy: a report

A Theme Meeting on Very High Energy Gamma Ray Astronomy was organized by the Astrophysical Sciences Division, during March 28-30, 2011 at the Mt. Abu based Gamma-Ray Observatory. The meeting comprised 15 invited talks highlighting various aspects of progress in the field during the last decade and 17 contributed presentations on various technical issues. Recently detected galactic and extragalactic gamma-ray sources were also discussed in detail. 41 scientists from Tata Institute of Fundamental Research, Physical Research Laboratory, Indian Institute of Astrophysics, Saha Institute of Nuclear Physics and Bhabha Atomic Research Centre, participated in the theme meeting. Discussion during the meeting led to a consensus on strengthening collaboration among various institutes in the country with interest in high energy astrophysics. Need for participation through international collaboration in the setting up of the Cherenkov Telescope Array was also discussed in detail. The meeting was fully funded by the Board of Research in Nuclear Sciences.

Group photograph of the participants of the Theme Meeting
A one-day Theme Meeting on “Thermo-mechanical Deformation of Pressure Tube (PT) under Accident Condition”, was organised by the Reactor Safety Division, BARC on 3rd June 2011 and was held at the Multipurpose Hall, BARC Guest House, Anushaktinagar. The meeting was sponsored by BRNS.

The Thermo-mechanical Deformation prediction of PT is an important aspect of Design Basis Events analysis like Loss of Coolant Accident with unavailability of Emergency Core Cooling System for Pressurised Heavy Water Reactor (PHWR). Pressure tube deforms plastically due to internal pressure and fuel weight during a postulated event scenario. Both ballooning and sagging of PT can lead to pressure tube and calandria tube contact. Further rise in the PT temperature can get arrested as moderator will act as a large heat sink. It is required to predict Pressure Tube (PT) deformation, as it controls the heat flow to moderator. A series of experiments have been carried out, to study the sagging and ballooning behaviour of PT of Indian PHWR, under simulated accident scenario.

The Theme meeting was inaugurated by Shri K. K. Vaze, Associate Director, Reactor Design & Development Group. About 50 participants from BARC, NPCIL, AERB, NFC, IIT Roorkee and Guwahati attended the meeting. There was an invited talk by Shri N. Saibaba, DCE (ZAF & S), NFC on “Manufacturing process of Indian Pressure Tube”. In this meeting, there were talks by experts on experimental and analytical aspects of thermo-mechanical deformation of PT, followed by a discussion on round robin exercise problem for PT ballooning. Dr. Ravi Kumar, Professor IIT, Roorkee gave a talk on “PT Sagging and ballooning experiments conducted at IIT, Roorkee. Dr. P. S. Robi, Professor, IIT, Guwahati gave a talk on PT creep correlations being developed at IIT, Guwahati. There were presentations by experts from NPCIL, BARC and AERB on theoretical simulations of PT deformation using in-house codes. There were also presentations by experts from BARC on Tensile Properties of Zr-2.5wt% Nb Pressure Tube alloy at elevated Temperature and on Post Test Microstructure and Chemical analysis study of Pressure Tube.

In the end, Problem definition of Round robin exercise on PT ballooning was presented. In round robin exercise, participants will be required to predict PT ballooning for experiments conducted at 20, 40 and 60 bar pressure using given experimental data (Pressure and temperature along with required properties of Zr-2.5 wt% Nb). The analysis results submitted by the participants will be evaluated with regard to the measured PT deflection. These analyses will be useful to benchmark the numerical codes and analysis procedures, to predict severe accident scenario for PHWR. It is proposed to hold round robin exercise meeting in the month of December 2011. Concluding remarks on the day’s proceedings were given by Shri H. S. Kushwaha, former Group Director, HSE&G and Fellow, Raja Ramanna Chair.
The Scientific Information Resource Division, Bhabha Atomic Research Centre, Mumbai, conducted ‘Authors’ Workshop’ for BARC Scientists and Engineers on 12th August 2011, at the Central Complex Auditorium. There was an overwhelming response as more than 700 scientists and engineers participated in the workshop.

Dr. K. Bhanumurthy, Head, Scientific Information Resource Division, BARC, welcomed the dignitaries and gave a brief introduction about the workshop.

Dr. R. K. Sinha, Director, BARC inaugurated the workshop. Dr. R. K. Sinha in his inaugural address mentioned that this ‘Authors’ workshop’ was very special and different from other workshops conducted by BARC. He called upon the scientists and engineers of BARC, to publish more in high impact journals.

Dr. David Clark, Sr. Vice President, Elsevier, The Netherlands, the Guest Speaker, spoke on various issues involved in scientific publishing in the electronic era. He gave a detailed step-by-step methodology of publishing in scholarly journals. He explained very succinctly, how one could find out the competencies of individual scientists, institutions and countries, through co-citation analysis. He also highlighted the importance of a scientific publication and citations and the indicators like impact factor and H-index. He touched upon various ethical issues involved in scientific publication such as plagiarism and plagiarism detection tools. Both the talk and the question-answer session were well received.

The function concluded with a vote of thanks by Dr. B. S. Kademani, SIRD.
Nuclear Energy Awareness & Applications (NEAA-2010) Symposium: a report

A two-day symposium on Nuclear Energy Awareness & Applications was held at BARC Colony, Tarapur during 9-10, October 2010. This was organized by the Bhabha Atomic Research Centre Officer’s Association, Tarapur (BARCOAT), in association with the Board of Research in Nuclear Sciences (BRNS). The aim of the symposium was to increase awareness among the general public about the usefulness of nuclear energy. The symposium was attended by more than 400 participants inclusive of local village pramukhs and academicians from schools and colleges in and around Boisar.

The inaugural program began with a welcome address by Shri P. K. Jain, President BARCOAT who said that a symposium of this nature, has been arranged for the first time in the BARC colony at Tarapur premises. The convener of the symposium Dr. Amrit Prakash remarked that the main aim of the symposium was to make the public aware about the usefulness and applications of Nuclear energy. The program was inaugurated by Shri H. S. Kamath, Director, Nuclear Fuels Group. In his inaugural speech, Shri Kamath stressed the need for organizing such symposia. Shri S. Basu, Chief Executive, Nuclear Recycle Board said that it was heartening to see the large number of local public like village pramukhs, principals and teachers of local schools and colleges participating in this symposium, along with the other employees of DAE. Dr. Jose Panakkal, Director, General Services Organization and Head, AFFF stressed the role of BARC Management in organizing such a symposium at Tarapur. Shri R. K. Gargye, Site Director, TMS released the souvenir of the symposium. Shri N. L. Sonar from BARC, Tarapur gave a glimpse of Nuclear energy, radiation and his speech was in Marathi. The next session was on the application of nuclear energy for power production. Eminent speakers from NPCIL gave detail description of reactors for the benefit of participants. Shri S. Maske described Boiling Water reactors and Shri D.D. Akre explained about the power production at TAPS 3&4. The second day started with a lecture of Dr. S. K. Jain, CMD, NPCIL, who described the medical applications of Nuclear energy. Dr. Meera Venkatesh, Head, RPhD, gave a very detailed lecture on Radioactivity as a powerful tool in health care. Dr. Amit Abhyankar from RMC, Mumbai acquainted the audience with the basics of nuclear medicine. The next session dealt with different aspects of nuclear energy such as radiation exposure, its limits etc. Shri G. Ganesh from BARC, Tarapur described the risks associated with radiation exposure. Shri A. Ramu from NPCIL, Tarapur explained the quality assurance aspect in nuclear power plants. Dr. Amrit Prakash talked in Hindi about the awareness and application of nuclear energy. There were two contributory papers from Shri U. V. Deokar about online remote radiological monitoring during operation of Advance Vitrification System and Shri R. K. Sah on Nuclear energy and their agricultural applications.
### BARC Scientists Honoured

<table>
<thead>
<tr>
<th>Name of the Scientists</th>
<th>Saurav K. Guin, Jisha S. Pillai, Rohan Phatak and Suresh K. Aggarwal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Chemistry Division, RC&amp;IG, BARC</td>
<td></td>
</tr>
<tr>
<td>Title of the Paper</td>
<td>Effect of Stabilizing Agent on electrocrystallization of Silver:</td>
</tr>
<tr>
<td></td>
<td>A Mechanistic Study</td>
</tr>
<tr>
<td>Award</td>
<td>Best Poster Award</td>
</tr>
<tr>
<td>Presented at</td>
<td>4th ISEAC International Discussion Meet on Electrochemistry and its</td>
</tr>
<tr>
<td></td>
<td>Applications (DM-ISEAC-2011) held at Thiruvananthapuram, Kerala,</td>
</tr>
<tr>
<td></td>
<td>India, during February 7-10, 2011.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name of the Scientists</th>
<th>Ruma Gupta, Saurav K. Guin and Suresh K. Aggarwal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Chemistry Division, RC&amp;IG, BARC</td>
<td></td>
</tr>
<tr>
<td>Title of the Paper</td>
<td>A Systematic Study on the Electrocatalysis Mechanism of Fe(III)/Fe(II)</td>
</tr>
<tr>
<td></td>
<td>Redox Reaction Mediated by Polyaniline Coated Platinum Electrode</td>
</tr>
<tr>
<td>Award</td>
<td>Best Oral Presentation Award</td>
</tr>
<tr>
<td>Presented at</td>
<td>4th ISEAC International Discussion Meet on Electrochemistry and its</td>
</tr>
<tr>
<td></td>
<td>Applications (DM-ISEAC-2011) held at Thiruvananthapuram, Kerala,</td>
</tr>
<tr>
<td></td>
<td>India, during February 7-10, 2011.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name of the Scientist</th>
<th>Dr. S. K. Sikka</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAE Homi Bhabha Chair Professor</td>
<td></td>
</tr>
<tr>
<td>Award</td>
<td>Prof. Meghnad Saha Memorial Lecture Award (2011)</td>
</tr>
<tr>
<td>Awarded by</td>
<td>National Academy of Sciences, India</td>
</tr>
</tbody>
</table>
ASHOKA TREE

Edited & Published by:
Dr. K. Bhanumurthy,
Head, Scientific Information Resource Division,
Bhabha Atomic Research Centre, Trombay, Mumbai 400 085, India.
Computer Graphics & Layout: N. Kanagaraj and B. S. Chavan, SIRD, BARC
BARC Newsletter is also available at URL: http://www.barc.gov.in

IN THIS ISSUE

• Radiation Processing of Temperate Fruits of Kashmir Valley
• Friction Stir Welding of Aluminium Alloys
• Matrix Assisted Laser Desorption Ionization Mass Spectrometry (MALDI-MS)
• Building Web Based Surveillance, Personnel Tracking and Secure Software Solutions
• Behaviour of Single Piles in Liquefied Soils during Earthquake
• Composite Polyamide Reverse Osmosis (RO) Membranes – Recent Developments and Future Directions
• Precision-Micro-Nano Engineering