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CARBON ANALYZER FOR URANIUM METAL
REPORT ON HOMI BHABHA CENTENARY
BRNS-GND UNIVERSITY WORKSHOP ON
MOLECULAR/ORGANIC ELECTRONIC DEVICES (MOED-2009)
“ELAC-2010”

4th ISEAC Triennial International Conference on ElectroAnalytical Chemistry and Allied Topics

Under the auspices of Indian Society for ElectroAnalytical Chemistry (ISEAC), the above International Conference would be held at Toshali Sands, Puri, Orissa (www.toshaliresort.com) during March 16-20, 2010. The Conference will be preceded by Short Courses on ElectroAnalytical Chemistry and Materials Characterization on March 14-15, 2010. The Conference would cover recent advances in various ElectroAnalytical Techniques and their applications in Chemistry, Physics, Biology, Material Science, Nuclear Technology etc. Scientific Programme of the Conference would include Invited Talks, Contributed Papers as Posters Presentations, Panel Discussions and Oral Presentations by (M.Sc., Ph.D.) Research Scholars). Manuscripts of the papers are to be submitted strictly by January 29, 2010. Further updates about this Conference would be available on www.iseac.org. For any other details, please contact:

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URL: http://www.barc.gov.in
DEVELOPMENT OF AN IR BASED CARBON ANALYZER FOR URANIUM METAL

Analytical Chemistry Division

ABSTRACT

A carbon analyzer for measurement of carbon content in the mg kg$^{-1}$ range in uranium metal, has been designed and fabricated. The set-up is based on the measurement of carbon dioxide, liberated subsequent to combustion of carbon, present in the sample in oxygen atmosphere. This analyzer consists of a furnace for sample combustion, a pneumatic flow control section, an IR detector with associated electronic hardware, micro-controller based data acquisition system and dedicated windows-based supporting software for data processing, storage and analysis. The system was standardized, method of analysis was validated and deployed, for routine analysis of carbon in uranium samples.

Introduction

One of the major activities of the Analytical Chemistry Division is the analysis of carbon content in uranium metal samples received from the Quality Assurance Division and the Uranium Extraction Division. For this purpose, an apparatus based on a classical low-pressure method [1] as well as another TCD-based Carbon Analyzer, developed in-house, were used. Low pressure method involves a tedious procedure such as the preparation of acetone-liquid nitrogen slurry. In addition to this, vacuum lines, molecular sieve trap and delicate glassware are also used. On the other hand in the TCD-based analyzer, molecular sieve trap, solenoid valves and helium as carrier gas are used. To provide an improved alternate instrumental technique, a Carbon Analyzer based on IR detection system has been designed, developed and fabricated. This instrumental set-up eliminates several tedious procedures mentioned above as well as it does not require a molecular sieve trap. It uses oxygen for combustion as well as a substitute for the expensive helium carrier gas. The new setup greatly reduces the analysis time (approximately from 45 minutes to 5 minutes) and uses simplified pneumatic control. The principle of operation is based on the conversion of carbon content in the metal sample into carbon dioxide, by combustion of carbon in the sample in oxygen atmosphere, in a quartz combustion tube and then its detection by using the IR detector. The limit of detection achieved by the system is 10 mg kg$^{-1}$.

Instrumentation

The instrumental set-up consists of three parts, namely, the pneumatic flow control section (Part 1, Fig.1), the sample furnace (Part 2, Fig.1) and the electronics hardware section consisting of detector electronics and data acquisition system (Part 3, Fig.1).

Pneumatic flow control section

The simplified pneumatic flow control section (Part 1, Fig.1) consists of an oxygen gas regulator, needle valve, flow meter, injection port, dust filter and moisture...
Fig. 1: Schematic of the IR-based carbon analyzer

Trap. The required oxygen flow rate of 300 mL min\(^{-1}\), set at an inlet pressure of 0.5 kg cm\(^{-2}\), provides the oxygen rich atmosphere for the sample, placed in the quartz combustion tube located inside the sample furnace.

**Sample furnace**

A resistively-heated, axially movable furnace maintained at 650 ± 5 °C is used for sample combustion (Part 2, Fig. 1), as CO\(_2\) is the only product in this temperature region [3]. An axially placed, long (length = 100 cm and dia = 4 cm) quartz combustion tube, houses a silica boat in which uranium sample is placed. The IR cell is mounted inside a detector oven which is maintained at a constant temperature of 45 ± 0.5°C. The IR cell consists of an IR source, a chopper, an optical filter (4.26 μm), a gas cell and an IR detector. The associated electronics include a constant current power supply for the IR source which is a heated nichrome wire maintained at 850 °C, a chopper control, a pre-amplifier and a signal conditioning stage. The signal output from the IR cell, proportional to the CO\(_2\) concentration, is fed to the data acquisition hardware. The data acquisition hardware is built around a Philips P89C51RD2 [4] flash micro-controller with an external Analog to Digital Converter (ADC) based on ICL7135 (4½ digit dual slope integrating type) and an RS-232C based serial interface for PC connectivity. A character-based custom communication protocol is used for system communication.
Windows-based software

The Windows-based front-end software has been developed with a Graphical User Interface (GUI) for interactive data acquisition and analysis. It facilitates real time graphical display of the acquired data (IR detector O/P vs. time) with auto-scaling features for both detector signal and time axis, Start and Stop of acquisition, Storage and Retrieval of data files, Peak Identification with information, like peak area, height and time.

System operation

The photograph of the Carbon Analyzer is shown in Fig. 3. The pneumatic flow diagram shown in Part 1, Fig.1 is self-illustrative. The oxygen gas, at a flow rate of 300 mL min⁻¹, set by the corresponding flow controller, flows through the combustion furnace. A long quartz tube, placed in the furnace, with a gas inlet and outlet at opposite ends serves as the combustion chamber. A ceramic boat, in which the sample to be analyzed, is kept at the centre of the quartz tube. The sample when brought to the hot zone of the furnace, burns immediately due to exothermic reaction between uranium and oxygen with a glow of light. The carbon content in uranium sample undergoes combustion under this condition and the CO₂ released in the process is made to pass through the dust filter and the moisture trap. Then it passes through the IR detector, where the selective absorbance of characteristic IR radiation (4.26 μm) by CO₂ takes place. The detector output proportional to the IR absorbance is monitored as a real time graphical display on the PC screen, using the Windows-based supporting software. As the liberated CO₂ reaches the detector, a signal appears and increases with time. It reaches a maximum and then starts decreasing. When it reaches a background level (base line), it indicates that evolution of CO₂ has ceased, as all the carbon present in the sample has been burnt. The integrated signal, in the form of measured peak area, is proportional to the concentration of carbon content in the sample.
Standardization of the system

The system response has been calibrated by injecting known volumes of pure (99.99%) CO\textsubscript{2}. The area per microgram of carbon, calculated for CO\textsubscript{2} volume, is obtained from the measured peak area for the injection of known volume of CO\textsubscript{2}. Fig. 4 shows the calibration graph obtained for different volumes of injected CO\textsubscript{2} gas, from which carbon content is calculated.

The system reproducibility was found to be within 2%. The method was validated measuring CO\textsubscript{2} released in the combustion chamber, by decomposing a known amount of dried calcium carbonate diluted with dry silica, pre-heated at 500 °C in oxygen flow for 4 hours. Knowing the stoichiometric value of CO\textsubscript{2} released, the area per microgram of carbon was obtained from the analysis of the peak.

Sample analysis

The uranium turnings are cut into small pieces of about 0.2 g and the surface is cleaned by boiling it in 1:4 nitric acid followed by washing with distilled water. The cleaned samples are dried under an IR lamp. An accurately weighed amount is transferred into the ceramic boat and heated at 650°C in an oxygen flow of 300 mL min\textsuperscript{-1}. The evolved CO\textsubscript{2} is measured by recording the IR response. The output as a function of time obtained for a uranium sample is shown in Fig. 5. The results obtained for uranium samples analyzed using the IR analyzer were compared with those obtained using a Low Pressure method which is an absolute technique, where the amount of carbon in the sample was computed, using gas laws. It is evident from Table 1 that the two methods show good agreement in the carbon values.

Conclusion

The indigenously developed Carbon Analyzer offers several advantages over the traditionally used Low Pressure Method namely increased sample throughput, ease of operation and elimination of glass wares as well as hazardous chemicals. This analyzer has been deployed for routine analysis of uranium samples for carbon content.
Table 1: Comparison of results

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>IR analyzer</th>
<th>Low Pressure Method</th>
</tr>
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<tbody>
<tr>
<td>N-3811</td>
<td>340</td>
<td>330</td>
</tr>
<tr>
<td>N-3815</td>
<td>360</td>
<td>400</td>
</tr>
<tr>
<td>N-3820</td>
<td>680</td>
<td>650</td>
</tr>
<tr>
<td>N-3822</td>
<td>790</td>
<td>790</td>
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The authors thank the sincere efforts of Ms. Sujata S. Jadhav, Ms. Granthali Kamble and Mr. B.W. Shirsat of Analytical Chemistry Division. The authors are grateful to Dr. P.V. Ravindran, former Head, Electrochemical & Thermal Methods Section of Analytical Chemistry Division, Dr. S.V. Narasimhan, Associate Director Chemistry Group and Dr. T. Mukherjee, Director Chemistry Group, for their keen interest in this work.

References


Fig. 5: Output plot with Uranium sample
The Homi Bhabha Centenary BRNS-GND University Workshop on Molecular/Organic Electronic Devices (MOED-2009) was successfully held at the Physics Department, Guru Nanak Dev University, Amritsar and its Conference Centre at Dalhousie, during September 22-25, 2009. The theme of the workshop was discussion of the latest developments in the field of molecular/organic semiconductor based devices.

Dr. J.V. Yakhmi, Associate Director, Physics Group, BARC, inaugurated the workshop. In his inaugural speech, he pointed out that molecular/organic semiconductors, being lighter, more flexible and less expensive than inorganic counterparts, are fast becoming alternatives to inorganic semiconductors. In addition to this, molecular/organic semiconductors are creating the possibility of new applications, such as printed electronics, smart windows, electronics papers, molecular computers etc. He also emphasized that molecular electronics in future would extend the scaling limits of Si-based microelectronics down to few nanometers.
A total of thirteen eminent speakers from different parts of the world delivered lectures during the workshop. Various issues pertaining to the realization of electronic devices using organic/polymer semiconductors were discussed in detail, during this workshop. Prof. Robert M. Metzger from USA delivered a talk on “Unimolecular Electronics”, which dealt with the rectification in the donor-acceptor type single molecules. Dr. Jörg Kröger from Germany discussed on how molecular electronics could be explored with a scanning tunneling microscope. In particular, he discussed the molecular switches and conductance of single-atom contacts. Prof. A.J. Pal from IACS, Kolkata presented a talk on organic/inorganic hybrid systems for electronic memory devices. Prof. (Ms.) Maria Anita Rampi, Italy, discussed how current flowing through metal-molecules-metal junctions could be controlled through an appropriate gating. Prof. K.S. Narayan, JNCAR, Bengaluru, presented a talk dealing with studies of spatially resolved photocurrent from molecular structures, using near-field techniques. Dr. Philippe Leriche, France, explained molecular engineering of conjugated systems to fabricate devices using molecules. Dr. S.K. Gupta, BARC, discussed in detail, about the deposition of molecular monolayers by self-assembly and electrodeposition techniques and their electrical characterization. Prof. Gilles Horowitz, France, delivered a talk on the improvement of the characteristics of organic thin film transistors, by tailoring the interfaces. He also spoke about the commercialization of flexible electronics in the very near future. The talk of Prof. Hideyuki Murata, Japan, dealt with interface engineering of organic electronics devices, using MoO$_3$ layer. Dr. Maya Lukas, Germany, discussed conductance of self-sustained molecules on metal surfaces, investigated by scanning tunneling microscopy. Prof. Leeor Kronik, Israel, presented an excellent theoretical talk dealing with the understanding of the electronic properties at organic/inorganic interfaces from first principles. Dr. Mukesh Joshi, RRCAT, Indore, presented a talk on the physics of polymer-based optoelectronics devices. Dr. D.K. Aswal, BARC, presented an overview on the development of gas sensors, using both molecular and conducting polymer semiconductor films.

A total of 58 contributory papers were received, out of which 49 participants made Poster presentations. A panel of referees comprising of Prof. Hideyuki Murata, Dr. Maya Lukas and Dr. Jörg Kröger evaluated the poster papers. The following papers were awarded prizes.

(a) First prize: “Fabrication of white organic light emitting diodes by controlling the position of the thin layer of red dye in the hole transport layer” presented by Gayatri Chauhan, National Physical Laboratory, New Delhi.

(b) Second prize: “Effect of short chain molecules on metal–molecule-semiconductor junction”, presented by Mohamed Ikram, Karnatak University, Dharwad, Karnataka.

(c) Third prize: “Synthesis and characterization of σ–π molecules for hybrid nanoelectronics” presented by P. Jha, BARC, Mumbai.

During the concluding session, all the three Poster Prize winners made oral presentations of their work. Other participants echoed the view that this workshop not only updated their knowledge about the latest developments in the field of molecular/organic electronics devices, but also helped them to interact directly with pioneers in the field. It was felt that BRNS should organize such workshops regularly.
The National Symposium on Growth of Detector-grade Single Crystals (NSGDSC-2009) was held during November 19-21, 2009, at the Training School Hostel, Anushaktinagar, Mumbai. Around 125 participants from all over the country attended the symposium. There were 14 invited talks and about 40 contributed papers including 12 oral presentations.

The inaugural function was chaired by Dr. S. Banerjee, Director, BARC with Lt. Gen. (Dr.) V.J. Sundaram as the chief guest. In his welcome address, Dr. Banerjee informed the audience about the genesis of the symposium, and the recent growth of large size, detector-grade, silicon single crystals, in BARC. He also dwelt on the optical crystal growth facility in the centre. Lt. Gen. Sundaram in his speech, emphasized the need to grow high quality single crystals in the country, to meet the demands in the area of defense and space research. Dr. R. Muralidharan, Director, SSPL New Delhi gave the inaugural lecture on the research presently being carried out on the growth of single crystals at the SSPL.

The invited presentations on the first day at the morning session, were mainly on the facilities of single crystal growth in BARC. Dr. Sadhana Mohan gave an overview of the silicon single crystal growth activity in HWD, BARC and Dr. Sangeeta spoke on the effect of non-stoichiometry, on the growth and optical properties of crystals, grown using the Czochralski technique. The other invited presentations were by senior scientists from different universities and institutes. Prof. H.L. Bhat of IISc, Bengaluru gave a delightful presentation on the growth of cesium-lithium-borate single crystals and factors controlling the growth of good quality crystals. Dr. Bhagavannarayana made a presentation on the characterization of crystals by a high resolution X-ray diffraction technique available at the NPL, New...
Delhi. There was a poster session wherein about 20 posters were displayed by the participants of the symposium.

The second day began with oral presentations by researchers followed by an elaborate talk on the Sankaranarayanan-Ramasamy technique, for the unidirectional growth of large size oriented crystals, that was given by one of the inventors of the technique, Prof. P. Ramasamy. Prof. K. Byrappa described the growth of nano-diamond crystals using hydrothermal techniques. Dr. Thamizhavel of TIFR delivered a talk on the growth of new types of intermetallics (magnetic and superconductor materials) employing the high temperature solution technique. Dr. S. Moorthy Babu of the Crystal Growth Centre, Anna University, talked about the growth of InSb crystals, using modified Bridgman method for detector applications. In the last session, four oral presentations were given by the participants. There was also a poster session on the second day and about 20 posters were displayed by the participants of the symposium.

The third and final day began with an oral presentation session and four participants presenting their work. This was followed by an invited talk by Dr. V. Natarajan on the use of piezoelectric crystals, for applications in under water experiments. Dr. D.B. Gadkari explained the detached growth of crystals in a vertical directional solidification technique. Prof. Mihir Joshi of Saurashtra University talked about the doped KDP crystals with improved non-linear optical properties. Dr. Jayavel delivered a talk on the relaxor ferroelectric crystals. Dr. I. Bhowmik delivered an interesting talk describing his work on the growth of lithium tantalate crystals. Thus, a wide spectrum of topics was covered in the invited lectures.

An exhibition was also arranged on this occasion and different crystals such as silicon, cesium-iodide, bismuth-germanate, calcium-fluoride, lithium-tetra-borate, gemanium, Nd:YAG etc. grown in BARC were displayed. A few participating business concerns displayed instruments useful in the processing of single crystals, for studies and device fabrication.

The concluding session was chaired by Dr. G.P. Kothiyal and a detailed discussion took place on the roadmap ahead in the area of single crystal growth in the country. Dr. S.C. Gadkari, the convener of the symposium invited Prof. P. Ramasamy, Prof. K. Byrappa, Dr. R. Jayavel and Dr. V. Natarajan to the podium for a panel discussion. The decreasing number of crystal growth researchers and a lack of funding from the government agencies were the main topics. Dr. Sadhana Mohan, the Co-convener invited the participants, to collaborate with BARC-projects for common interests through BRNS funding. Further, it was agreed upon, that this kind of symposia are required to increase the awareness of crystal growth among young researchers and increase the quality of research. Dr. A.K. Chauhan, Secretary of the symposium thanked all the participants and delegates for making the symposium a successful event.
OBSERVANCE OF VIGILANCE AWARENESS WEEK IN BARC

As per the Directives of the Central Vigilance Commission, a Vigilance Awareness Week was observed in BARC from 3rd November - 7th November 2009. In addition to taking of the Vigilance pledge by the officers and staff members on 3rd November 2009, various programmes like Essay Competition, Poster Competition and Quiz Competition were organized, as part of the Vigilance Awareness Week. At the concluding session, held on 6th Nov. 2009, an address on “Anti-corruption and Vigilance” was arranged at BARC, Trombay, by inviting Mr. P. Kandaswamy, IPS, DIG (CBI). The session concluded with distribution of prizes to the winners of the competitions.

The Vigilance Awareness Week, celebrated for the first time in BARC, was well appreciated by the employees/ participants and has generated interest among all employees, on the need to maintain probity and transparency in public life.

At the Concluding session of the Vigilance Awareness Week (from left to right): Mr. S. Goverdhan Rao, Head, Personnel Division, BARC, Mr. P. Kandaswamy, IPS, DIG, CBI, Mumbai, Mr. G.P. Srivastava, Director, E&IG, BARC
A one-day National Theme Meeting on Electrodynamics experiments with Left Handed Maxwell (LHM) Systems was held on the 17th August, 2009, at TSH-BARC. The meeting was inaugurated by Dr. Srikumar Banerjee, Director BARC; sponsored by BRNS-DAE; and organized by RRPS, Reactor Control Division, E&I Group, BARC. This new and unique topic was discussed in detail in the theme meeting. The LHM team comprising of Prof. Subal Kar Calcutta University, Ms Tapashree Roy, Research Scholar Calcutta University, Mr. Arijit Mazumder Scientist-SAMEER and Mr. Shantanu Das Scientist BARC, presented a unique LHM Electromagnetic crystal, to Dr. Srikumar Banerjee Director, BARC. It was designed by Labyrinth Resonator (LR) and Thin Wires (TW) - to have negative refractive indexed metamaterial-LHM (in the range of minus 1 to minus 3 at around 30GHz Ka Band. This meta-material was designed and fabricated for the first time in India, by the LHM team.

Dr. Srikumar Banerjee, Director, BARC, gave an encouraging inaugural talk on this very new science topic; stating the difference between matter and metamaterials (artificially structured), the science of which is still developing and can lead to a possible new theory. The physics of this subject is still an at infant stage. During his welcome address, Mr. G.P. Srivastava, Director, E&I Grp., spoke about a memorandum of understanding between BARC, SAMEER & Calcutta University, on a National Programme on Left Handed Maxwell Systems. This basic experimental and theoretical platform envisaged by this MoU, would be useful for developing future LHM components in mid-IR to visible region and in developing several future novel devices, to have “two-handed” Electro-Magnetic interactions, in this very high frequency regime. Left-handed system is counter-intuitive, which leads to reversal of Snell’s law, leading to negative refractive index-giving concept of ‘plane surface focusing’ beyond diffraction limit. This part, the proposed platform in the joint project development under the MoU; as deliverable, was presented in detail by the LHM team. The reversed Doppler Effect with possibility of RADAR defense applications and reversal of Cherenkov Effect (which has to do with design of suitable detectors and which can make ‘clean beam measurements’ in the particle accelerators), are the future outcomes of this proposed joint endeavour which was presented during detailed deliberations. The topics presented at the theme meeting were, “Introduction to Left Handed Maxwell Systems-and the experiment proposal”, by Mr. Shantanu Das, “Electrodynamics of Left Handed Systems and its applications”, by Prof. Subal Kar, “Design and Fabrication of LHM Structures”, by Tapashree Roy and “Meta-materials: Numerical and Experimental Methods”, by Arijit Mazumder. The detailed deliberations of this ‘new-science' during the ‘discussion sessions’ opened up several novel ideas for eg. exploring the possibility of active LHM meta-materials, re-thinking regarding physics of square root of product of two negative numbers as negative, 3D-structure fabrication, taking this subject to university students-so as to teach it in 'popular science way'-to attract students to electrodynamics, re-thinking on physics of conservation laws to explain this counter-intuitive science and research on optical-magnetism, participation of physicists (of optical-community and quantum optics) with electrical engineering team on LHM-theory and experiments. Interestingly, theoretical deliberations on ‘new-quantum prescriptor for momentum’, were proposed by Mr. Shantanu Das, in order to distinguish wave-vector direction opposite
Photograph of the designed and fabricated meta-material crystal of LHM presented to Director, BARC.

to Poynting’s vector direction in LHM wave equation, which opens up the possibility of having ‘partial’ Left Handed Maxwell Systems. That is, material engineered one with characteristics of both normal Right Handed Material (RHM) and LHM-meta-materials. This discussion session, on several new-science topics on electrodynamics was guided by Dr. S. K. H. Auluck (ATSS-BARC), Dr. B. N. Jagtap (LPTD-BARC), Prof. Krishna Rai Dastidar (IACS Kolkata), Prof. Deepak Ranjan Poddar (Jadavpur University), Prof. Anjan Basu (CARE-I.I.T. Delhi), Dr. K. Madhusudhan Reddy (Scientist-ISRO) and Prof. B. N. Mahalley (University of Nagpur).

Dr. Madhusoodan V. Hosur, SSPD, BARC has been elected as a Fellow of the Indian National Academy. He is a Biophysicist studying biomolecules from a three dimensional structural perspective, using X-ray crystallography as a tool. He has made significant studies on biomolecules, ranging in size from small nucleotide coenzymes to huge icosahedral viruses. At BARC, Dr. Hosur and his colleagues have determined atomic level structures of ribosome inactivating enzymes, gelonin and saporin, which can be developed...
Dr. B.N. Pandey received the 'AARR Young Scientist Award' sponsored by the Asian Association of Radiation Research, for his outstanding contributions in the area of radiation research. The award was conferred on Dr. Pandey during the Second Asian Congress of Radiation Research, held at Seoul, Korea, during May 17-20, 2009.

Dr. Pandey joined the Radiation Biology and Health Sciences Division in 1995, after graduating from the 38th Batch of Biology-Radiobiology Orientation Course (1994-95). He received his Ph.D. in Life Sciences from Mumbai University in 2003. He completed his Post Doctoral Fellowship with Prof. E.I. Azzam at the Division of Radiation Research, Department of Radiology, New Jersey Medical School, Newark, USA in 2004-05. Currently, he is working in the field of Cancer and Radiation Biology. His current research interest involves effect of low and high LET radiation on normal and tumour cells, for cellular radio-protection and improvement of cancer radiotherapy.
Dr. B. S. Kademani, Scientific Information Resource Division, Bhabha Atomic Research Centre has been awarded the prestigious “SIS Fellowship-2009 Award” by the Society of Information Science (SIS), in recognition of his outstanding contribution to the Library and Information Science field. This award was presented to him by Dr. Craig W. Stephens, Vice President, Chemical Abstracts Service, Ohio, USA on 9th December 2009 on the occasion of 26th Annual Convention of SIS held at CSIR-National Chemical Laboratory, Pune.

The paper “Electron Beam Welding and Laser-TIG Hybrid Welding of Mo-Alloy (TZM)” co-authored by Santosh Kumar, Anjan Chatterjee, C. S. Viswanadham, K. Bhanumurthy and G. K. Dey of Materials Science Division won the D&H Secheron Award for the Best Presentation at the National Welding Seminar, 2008 held at Mumbai between February 4-6, 2009.

Mr. Santosh Kumar completed his B. Tech in Metallurgical Engineering from IT-BHU, Varanasi in 1998 and has since been working at the Materials Science Division of BARC.
Mr. J.S. Visvanadham graduated from the 24th Batch of BARC Training School in Physics after an M.Sc. degree from IIT Madras. He also holds a Postgraduate Certificate in Software Technology from TIFR, Mumbai. His research interests include the application of industrial lasers to process nuclear materials, and computer modelling of materials’ behaviour under laser and neutron irradiation. Currently he is with the Laser Materials Processing Section of the Materials Science Division.

Mr. Chebolu Subrahmanya Viswanadham graduated from the 24th Batch of BARC Training School in Physics after an M.Sc. degree from IIT Madras. He holds a Postgraduate Certificate in Software Technology from TIFR, Mumbai. His research interests include the application of industrial lasers to process nuclear materials, and computer modelling of materials’ behaviour under laser and neutron irradiation. Currently he is with the Laser Materials Processing Section of the Materials Science Division.

Mr. Anjan Chatterjee is BE (Met) from Jadavpur University, Kolkata in 1981. He joined the 25th batch of BARC Training School in 1981. During 1982-1999 he was associated with FBTR fuel pin fabrication in Radio Metallurgy Division (RMD) of BARC. Since 1999 he is working in laser cutting and laser welding. He contributed to the design and fabrication of a machine for laser dismantling of spent PHWR fuel bundles. He was awarded KCP award for his paper on laser dismantling of PHWR fuel bundles in NWS 2002. Presently he is working in Laser Materials Processing Section of Materials Science Division. He is working on Laser-TIG hybrid welding of similar and dissimilar materials.

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Dr. K. Bhanumurthy
joined the 24th batch of BARC Training School. His research interest includes interdiffusion studies in metals and alloys, similar and dissimilar materials joining using advanced solid state processes, friction stir welding, materials characterization, phase diagrams study and evaluation. Presently he is Head of the Scientific Information Resource Divn. BARC.

Dr. Gautam Kumar Dey obtained his B. Tech in Metallurgical Engineering in 1979 from the Institute of Technology, Banaras Hindu University. He joined the 23rd batch of BARC Training School and was awarded the Homi Bhabha prize for standing first in his discipline. On completion of training, he joined Metallurgy Division of BARC. He obtained his Ph. D degree from Banaras Hindu University in 1988. He was a postdoctoral fellow at University of Cincinnati from 1994 to 1996. He has been Visiting Scientists at University of Osaka, Japan and Institut fur Festkorperforschung (IFF), Juelich, Germany. He has won several awards for his scientific contributions. Of these mention can be made of the Young Scientist award of Indian National Science Academy (1989), Young Metallurgist Award given by Ministry of Steel and Mines (1989), MRSI Medal given by Materials Research Society of India (2001) and Metallurgist of the year award given by Ministry of Steel (2003) and the Vasvik Award. He is a fellow of the Indian National Academy of Engineering (INAE), Indian Academy of Science (IAS) and Electron Microscopy Society of India (EMSI). He is associate editor of Transactions of the Indian Institute of Metals. Areas of his research interest are Phase Transformation in Zirconium and Nickel Base Alloys, Amorphous Alloys, Rapidly Solidified Crystalline and Quasicrystalline Alloys, Electron Microscopy and Defect Characterization and High Resolution Electron Microscopy. He has more than 200 scientific publications to his credit. He has been designated a Professor in the Homi Bhabha National Institute and is currently the Head of Materials Science Division, BARC.
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