A Table Top Static Gas Sensing Unit: Model No. TPD-BARC-16CH


Technical Physics Division

Table Top Static Gas Sensing Unit (Model: TPD-BARC-16CH) has been designed and developed. This unit is suitable for monitoring or recording the response of 16 sensing elements simultaneously under controlled conditions of operating temperature and gas environment. The indigenous software has also been developed that interfaces the instrument to a personal computer or Laptop. Moreover, the resistance of the sensing elements under investigations is recorded and displayed as a function of time. The unit can measure the resistance variation from 1 G to 1 K or 1 M to 1 Ω. The developed product is unique and no such similar product is available in the market. Importantly, the instrument is useful for the measurement of response curves of chemiresistive sensors.

Keywords: Multiple Sensors Testing Unit, Gas Sensors, Operating Temperature, Data Acquisition

Introduction

Gas sensing is one of the most widely investigated activities of the materials research [1]. With the advent of nanoscience and nanotechnology novel materials with superior performances are being routinely synthesized [2]. Development of gas sensors based on these materials demands a thorough investigation of these materials under controlled conditions of operating temperature and gas environment [3-4]. Further, to speed up the process for optimization, simultaneous measurement of multiple sensors under identical conditions is desired but it often requires a very long time. In order to speed up the parameter optimization e.g. sensitizer, its concentration and annealing schedule, it is essential to have a system possessing the capability of recording the response curves under identical conditions of operating temperature and gas environment. To address this need, Technical Physics Division (TPD) has developed a Table Top Static Gas Sensing Unit (Model: TPD-BARC-16CH), which can monitor the responses of 16 sensing elements simultaneously. The developed unit is suitable for monitoring or recording the response under controlled conditions of operating temperature and gas environment. Some of the salient features of this product are;

### Technical Specifications of the Unit

| Unit: TPD-BARC-16CH | 230 V, 50 Hz AC  
|                     | Light weight (<2 kg), portable |
| Test Chamber 1:     | SS-304  
|                     | 28 mm  
|                     | 50 mm  
|                     | Array  |
| Test Chamber 2      | SS-304  
|                     | 81 mm  
|                     | 48 mm  
|                     | Individual  |
| Technical Parameters: | MΩ to Ω or GΩ to kΩ  
|                     | RT to 300 ± 2°C  
|                     | Arduino IDE compatible with Labview Simultaneous  
|                     | Adjustable, maximum 4 points/sec  |
• Uniquely positioned product: No such unit in the market is available containing both data acquisition and testing facility in one unit.
• Light weight and portable.
• Six order changes in the resistance can be measured (G - K).
• Two separate test chambers for multiple sensor array (10-16 numbers) and individual sensing element (maximum 7 numbers) testing, respectively.
• Operating temperatures can be tuned in the range from room temperature (RT) to 300oC.
• Real time monitoring with direct interface to personal computer or Laptop.
• Indigenous software, provision to select and deselect the sensing element.

The unit essentially comprises of the following two parts:
• Sensor test chambers and
• Data acquisition unit

**Sensor test chambers**

As shown in figure 1, the unit is equipped with two test chambers containing heaters and readers. The heater temperatures are controlled using potentiometer on the temperature control circuit in the housing below test chambers.

**Test chamber 1**

In this, two sensor arrays comprising of 5 sensing elements each with two heaters and two readers are provided. It consists of a Teflon disc containing an array (20 x 2) of gas tight electrical feed-through with a spacing of 1.5 cm (figure 2). For measurement of resistance of a sensor array of dimensions 1.5 cm x 3 cm, it is advised to connect heaters at the two edges along with readers. Heaters are made by connecting two Pt-100’s in parallel to each other, while reader is just a single Pt-100 whose resistance value as measured using digital multimeter is an indicator for the operating temperature.

The rest of the feed-throughs are connected to the data acquisition card located in the housing below.

**Test Chamber 2**

It consists of seven Teflon heads fixed in stainless steel (SS 304) disc as shown in figure 3 (a). The Teflon heads are provided with 6 pins (phosphor bronze) for electrical connections. Out of these 6 pins, two are used for sensing element, two for the connection of heater and the rest two for the reader as shown in figure 3 (b). The heater wires are connected to the temperature control circuit, reader wires to the 8-pin band change switch and the two sensing element wires to the data acquisition card. Here also, the heater is realized by connecting two Pt-100’s in parallel. The heater and the reader Pt-100’s are physically connected adjacent to each other so as to form a platform on which the sensing element can conveniently be rested. The heater and reader wires are connected to the phosphor bronze pins in such a way that a direct contact with the Teflon base is avoided.

Figure 4 shows the photograph of the wiring behind the test chambers. Herein color code has been followed, red color wires are used for heater, orange for reader and other colors for the sensing element. As is evident all the heater and reader are routed to the temperature control circuit and the 8-pin band change switch (digital...
multimeter) via a general purpose printed circuit board (PCB).

The stainless steel test chambers are provided with two values (inlet and/or outlet). The test volume of the chambers is 250 sccm (standard cubic centimeter). By injecting the known amount of test gas in the chamber through an inlet value provided with septum the concentration of the test gas can be controlled. For recovery measurements, the sensor chamber cap or top needs to be opened subjecting the sensors to the ambient environment. Importantly, the test chambers can be customized to specific needs of the user. Two pairs of either test chamber 1 or 2 can be used with necessary modifications of the wiring or connections.

**Operation of the Instrument**

Figure 5 shows the Home screen with various fields. There are three main tabs Data Acquisition (DAQ), settings and retrieval. There are 16 channels (0-15) displaying the resistance values (in k) of the 16 sensing elements. The color of each channel is different and hence can be used to locate the channel on the screen. The individual sensing element can be selected or

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**Fig. 3:** (a) Photograph of Test chamber 2 with 7 Teflon heads containing heater, reader and sensing elements, (b) Photograph of single Teflon head showing the connections made to sensing element, heater and reader.

**Fig. 4:** Inside view of the unit showing connections or wiring between different components of the unit.
deselected as per the requirement in the channel selector. In the settings, tabs options are provided to control or calibrate the data acquisition values (resistance) by setting the multiplication factor (x factor). By default it is set at 1.39. It is also possible to control the data acquisition speed by setting the Analogue to digital Converter (ADC) values. By default it is set at 30, it can be brought down to increase the data acquisition speed. The retrieval window is also provided to retrieve the previously saved data for comparison or reference, as and when required. The files can be recalled by pressing the retrieve data knob and locating the files through drop down menu.

**Measurement of Response Curves**

Once the sensors are mounted and the operating temperature is fixed, the chamber is closed and a settling time of 15 min is provided. Now, the known concentration of the test gas is injected using an air-tight syringe in the test chamber and the variation in the resistance as a function of time is recorded and monitored. Upon injection of the test gas, the resistance of the sensing element will increase or decrease depending upon the sensing element and the nature of test gas. For example, for n-type metal oxides like SnO₂, ZnO, and TiO₂, the resistance will decrease or increase when exposed to reducing (H₂S, NH₃) or oxidizing gases (NO₂, CO₂), respectively (Figure 5 (a) and (b)). Opposite is the case with p-type materials i.e. with holes as majority carriers. By default the files are saved as “.xls” file (excel) with the name as date and time of measurement. With columns showing the different channels and the rows depicting the resistance values. The first column is the time displayed in seconds. Moreover, the files can easily be accessed and transferred or copied to the other software as per the user requirement.

In order to demonstrate the working of the instrument a multiple sensor array (MSA, 12 sensing elements) based on ZnO nanowires has been tested for its response towards different gases and the results are shown in figure 6. For this ZnO nanowires were deposited using a
hydrothermal method [3] and an array of (4 x 3) sensor films were realized by modifying the nanowire film with sensitizers namely Al, Ti, and Au layer. Figure 6 shows the response curves of all the 12 sensing elements towards increasing concentration of NO₂ between 1 and 50 ppm. The data was acquired using the instrument and plotted using the origin software.

As shown in figure 6, the 12 sensing elements were tested under identical conditions and accordingly it becomes easier to compare the response curves and the related parameters namely response time, recovery time, sensor response values in a single run. This implies that in a single exposure, it is possible to generate more information that can be used to tune the parameters to realize a better sensing material. Thus the result clearly demonstrates that the present system is capable of speeding up the parameter optimization in order to achieve the required sensing characteristics.

Conclusion

A uniquely versatile import substitute product namely a table top static gas sensing unit has been successfully developed, tested and implemented for addressing needs of a client base comprising of universities and other Research & Development institutes. The developed system can record response curves from the 16 sensing elements simultaneously. Two independent test chambers, one for the sensor array and the other for the individual sensing element have been provided. The operating temperature can be tuned right from RT to 300°C. The unit can measure the six order change in resistance from 1 GΩ to 1 KΩ or 1 MΩ to 1 Ω. Importantly, the product demonstrated its utility in speeding up the parameter optimization to achieve required sensing characteristics.

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References