Developing Sensors for Multifunctional Applications

Ashok Kumar and N.M. Ravindra

Over the past two decades, research and development in sensors has increased significantly, as demonstrated by the growth in financial investment by the manufacturing sector, the number of papers published, and the number of active researchers worldwide.

Sensor science and technology are growing rapidly in response to an ever-increasing demand for faster, cheaper, smaller, and more sensitive means to monitor the chemical, biological, and physical world around us. Sensors can have a global impact in many areas such as environmental cleanup, industrial process control, emission monitoring, aeronautical and space systems, planetary exploration, nonproliferation of weapons, screening for explosives and contraband, home and workplace safety, and medical diagnosis and care, just to name a few. Sensors provide many of the functions of analytical instrumentation, but with reduced cost, size, and power consumption, along with the ability for real-time, in-situ measurements.

Optimization of industrial processes using computer control algorithms requires real-time information of the various process parameters. The degree to which a process can be optimized depends upon the quality and quantity of information received, and this can be enhanced by development of efficient, advanced and cost-effective sensors.

In this month's *JOM-e* supplement (the papers are exclusively on *JOM's* web site and not in the print version of the issue), we are pleased, on the behalf of the TMS Electronic, Magnetic & Photonic Materials Division, to present an exciting set of papers focussing on the infinite capabilities and applications of a variety of sensors. In doing so, the fundamental science and technology that form the foundation of these new frontiers of science are not neglected.

The first article (*www.tms.org/pubs/journals/JOM/0010/Rosenthal/Rosenthal-0010.html*), deals with the subject of infrared analysis of thin film materials. Rosenthal, Xu, Charpenay, Cosgrove, and Ravindra describe improvements in Fourier transform infrared (FTIR) reflectometry used to characterize the thickness and optical properties of thin films commonly employed in advanced integrated circuits (I.C.s). As the semiconductor industry develops smaller, faster, more energy efficient integrated circuits, specifications for layer composition and thickness are changing radically. The authors explain how infrared spectroscopy provides two additional ways to characterize films with complex chemistry. The first is a high sensitivity optical reflectometer design that measures thin films while suppressing reflected back lighting. The other is a model-based approach fitting to extract dielectric function of a layer from the reflectance spectrum. The authors found that these combined techniques can help FTIR enhance the development and production of materials under consideration for a new generation of I.C.s.

We sincerely hope that this electronic supplement to the journal will be of great use to the sensor community.

Next up is an article from Ivanov on advanced sensors for multifunctional applications (*www.tms.org/pubs/journals/JOM/0010/Ivanov/Ivanov-0010.html*). Sensor engineers today face the challenge of developing advanced sensors for many functions similar to human and animal senses. Since sensors rarely operate in an environment where only one parameter is present, the sensors must be able to process effectively and efficiently many stimuli such as temperature, pressure, and odor in much the same way a human brain does. Employing multifunctional micro-electro-mechanical sensor (MEMS) systems, the author explains how the combination of MEMS and thin film technology can enable sensors to detect chemical, mechanical, and physical parameters at the same time.

Cosandey, Skandan, and Singhal focus on materials and processing issues in nanostructured semiconductor gas sensors (*www.tms.org/pubs/journals/JOM/0010/Cosandey/Cosandey-0010.html*). The article explores advances in developing an electronic "nose" capable of detecting mixed gases and even odors. Divided into three parts, the article examines the selectivity and sensitivity of semiconductor oxides, reviews synthesis methods for producing nanostructured thin-film semiconductor oxide materials, and summarizes the challenges facing the implementation of this new technology.

Kumar studies piezoelectric crystal detectors and bio-sensors (*www.tms.org/pubs/journals/JOM/0010/Kumar/Kumar-0010.html*). The article describes the construction of an antibody-based piezoelectric sensor that can detect mycrobacterial antigen in diluted cultures of M. tuberculosis. Such a sensor could be used in agricultural and veterinary applications, along with industrial, mining, explosives, pollution, and other areas. The advantages of this type of sensor include fast response times, low costs, simplicity, minimum sample pretreatments, and high sample throught-put.

Finally, Fergus describes the use of chemical sensors in the control of molten metal during processing (*www.tms.org/pubs/journals/JOM/0010/Fergus/Fergus-0010.html*). Such sensors can provide valuable information about changes in the composition of a molten alloy. Real-time information on these compositional changes can be used to optimize the process for efficiency or product quality. Chemical sensors can be used to improve control in the processing of such molten metals as steel, aluminum, and zinc. In some cases, sensors are commercially available and widely used. In others, the sensors are under development or are too costly. In the course of the paper, the author reviews the status of sensor development for some of these applications.

Using this 21st century superhighway called the Internet, we sincerely hope that this electronic supplement will be of great use to the sensor community in particular and the world of science in general. We thank all the contributors for their hard work that has made this issue possible, and we acknowledge with thanks the editorial assistance of Anand Shenoy, graduate student at the New Jersey Institute of Technology.

Ashok Kumar is with the Department of Mechanical Engineering and Center for Microelectronics Research at the University of South Florida. N.M. Ravindra is with the Department of Physics at the New Jersey Institute of Technology. Both are advisors to JOM *from the Thin Films and Interfaces Committee of the TMS Electronic, Magnetic & Photonic Materials Division.*