Effects of Temperature on Polymer/Carbon Chemical Sensors

NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments were conducted on the effects of temperature, polymer molecular weight, and carbon loading on the electrical resistances of polymer/carbon-black composite films. The experiment were performed in a continuing effort to develop such films as part of the JPL Electronic Nose (ENose), that would be used to detect, identify, and quantify parts-per-million (ppm) concentration levels of airborne chemicals in the space shuttle/space station environments. The polymers used in this study were three formulations of poly(ethylene oxide) [PEO] that had molecular weights of 20 kilodaltons, 600 kilodaltons, and 1 megadalton, respectively.

The results of one set of experiments showed a correlation between the polymer molecular weight and the percolation threshold. In a second set of experiments, differences among the temperature dependences of resistance were observed for different carbon loadings; these differences could be explained by a change in the conduction mechanism.

In a third set of experiments, the responses of six different polymer/carbon composite sensors to three analytes (water vapor, methanol, methane) were measured as a function of temperature (28 to 36°C). For a given concentration of each analyte, the response of each sensor decreased with increasing temperature, in a manner different from those of the other sensors.

This work was done by Allison Manfreda, Liana Lara, April Jewell, Margie Homer, Shiao-Pin Yen, Adam Kisor, Margaret Ryan, Hanying Zhou, Abhijit Shevade, and Lim James of Caltech and Kenneth Manatt of Santa Barbara Applied Research for NASA's Jet Propulsion Laboratory.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-40621, volume and number of this NASA Tech Briefs *issue, and the page number.*

Small CO_2 Sensors Operate at Lower Temperature

Lower operating temperature translates to lower power demand.

John H. Glenn Research Center, Cleveland, Ohio

Solid-electrolyte-based amperometric sensors for measuring concentrations of CO_2 in air are being developed for use in detection of fires, environmental monitoring, and other applications where liquid-based electrochemical cells are problematic. These sensors are small (sizes of the order of a millimeter), are robust, are amenable to batch fabrication at relatively low cost, and exhibit short response times (seconds) and wide detection ranges.

A sensor of this type at a previous stage of development included a solid electrolyte of $Na_3Zr_2Si_2PO_{12}$ deposited mainly between interdigitated Pt electrodes on an alumina substrate, all overcoated with an auxiliary solid electrolyte of (Na_2CO_3:$BaCO_3$ in a molar ratio of 1:1.7). It was necessary to heat this device to a temperature as high as 600 °C to obtain the desired sensitivity and rapid response. Heating sensors increases the power consumption of the sensor system and complicates the use of the sensor in some applications. Thus, decreasing a sensor's power consumption while maintaining its performance is a technical goal of ongoing development.

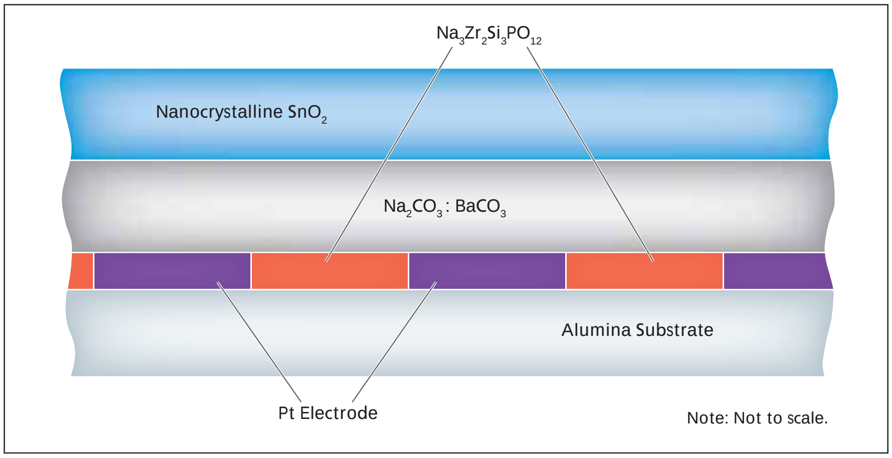


Figure 1. The **Layer of Nanocrystalline SnO_2** enhances the function of the solid-electrolyte layers of $Na_3Zr_2Si_2PO_{12}$ and Na_2CO_3:$BaCO_3$, making it possible to operate at a lower temperature.

A sensor of this type at the present state of development (see Figure 1) has the same basic structure, except that it includes an additional outer layer of nanocrystalline SnO_2, which is an n-type (electron-donor-type) semiconductor that provides additional electrons for reduction reaction at the working electrode to detect CO_2. [This use of SnO_2 as a CO_2-sensor material should not be confused with the use of SnO_2 in a related development described in "CO_2 Sensors Based on Nanocrystalline SnO_2 Doped With CuO" (LEW-18247-1), *NASA Tech Briefs*, Vol 32, No. 10 (October 2008), page 44. The SnO_2 layer makes it possible to obtain the desired sensor responses at a lower temperature (355 °C), thereby making it possible to operate the sensor at lower power. Figure 2 shows the comparison in response between a sensor with and without the armor layer of nanocrystalline SnO_2. Concentrations of CO_2 from 0.5 to 4% in air were also detected at 375 °C.

A sensor of this type can be fabricated in the following sequence:

1. The platinum interdigitated electrodes, typically having width and spacing of 30 μm, are formed on the

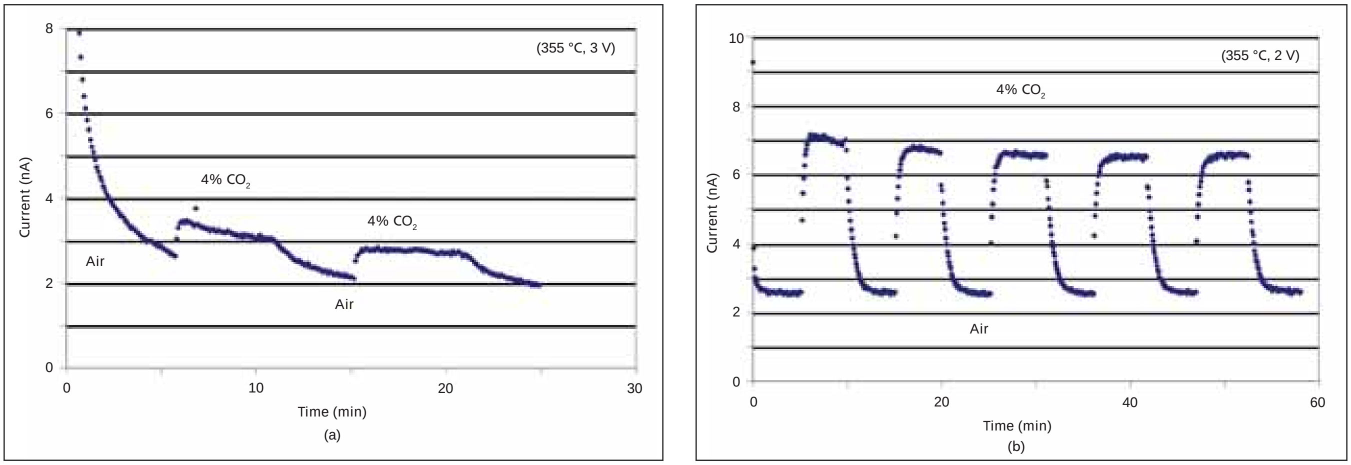


Figure 2. **The Current Response of a CO_2 Sensor** fabricated as described in the text was measured at an applied potential at a temperature of 355 °C. Figure 2(a) shows a CO_2 sensor response without a nanocrystalline SnO_2 coating, while Figure 2(b) shows a dramatic difference enabled by the addition of a coating of nanocrystalline SnO_2.

alumina substrate by use of standard techniques of sputter deposition, photolithography, and liftoff.

2. In a second process involving the use of standard techniques of sputter deposition, photolithography, and liftoff, the $Na_3Zr_2Si_2PO_{12}$ solid electrolyte is deposited mainly between (and touching) the platinum interdigitated electrodes.
3. The workpiece is heated to a temperature of 850 °C for 2 hours.
4. The Na_2CO_3:$BaCO_3$ auxiliary solid electrolyte is deposited on the electrodes and the $Na_3Zr_2Si_2PO_{12}$ solid electrolyte by sputtering through a shadow mask.
5. The workpiece is heated to 686 °C for 10 minutes, then to 710 °C for 20 minutes.
6. The layer of nanocrystalline SnO_2 is deposited on the Na_2CO_3:$BaCO_3$ layer by a sol-gel process.
7. The workpiece is heated to 500 °C for 2 hours.

The workpiece is then ready for use as an amperometric CO_2 sensor.

Research will continue to optimize CO_2 sensor performance, while decreasing the operating temperature and power consumption. The objective of future work is to decrease the power consumption to enable, for example, long-term battery operation of CO_2 sensor systems.

*This work was done by Gary W. Hunter and Jennifer C. Xu of Glenn Research Center. Further information is contained in a TSP (see page 1)***.**

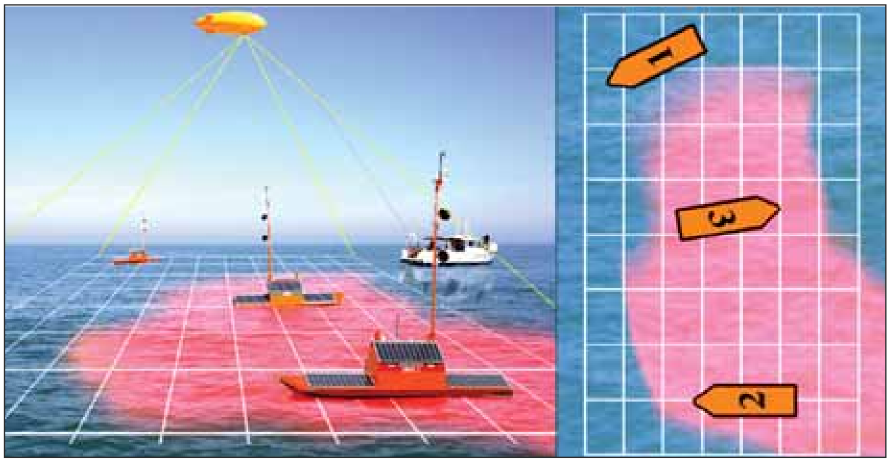
Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18324-1

Tele-Supervised Adaptive Ocean Sensor Fleet

A software architecture and system deploys robotic boats to study ocean surface and subsurface phenomena such as coastal pollutants, oil spills, and hurricanes.

NASA's Jet Propulsion Laboratory, Pasadena, California

The Tele-supervised Adaptive Ocean Sensor Fleet (TAOSF) is a multi-robot science exploration architecture and system that uses a group of robotic boats (the Ocean-Atmosphere Sensor Integration System, or OASIS) to enable *in-situ* study of ocean surface and subsurface characteristics and the dynamics of such ocean phenomena as coastal pollutants, oil spills, hurricanes, or harmful algal blooms (HABs). The OASIS boats are extended-deployment, autonomous ocean surface vehicles. The TAOSF architecture provides an integrated approach to multi-vehicle coordination and sliding human-vehicle autonomy.



A concept of the **TAOSF Field Deployment System** shows an overhead aerostat (an unmanned blimp tethered to a manned field operations vessel) that provides a global camera overview of three OASIS platforms and a patch of rhodamine dye. The overhead map is shown on the right.

One feature of TAOSF is the adaptive re-planning of the activities of the OASIS vessels based on sensor input