Effects of Temperature on Polymer/Carbon Chemical Sensors

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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 experiments 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 dependencies 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.

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Small CO₂ Sensors Operate at Lower Temperature

Lower operating temperature translates to lower power demand.

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Solid-electrolyte-based amperometric sensors for measuring concentrations of CO₂ 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 Na₃Zr₂Si₂PO₁₂ deposited mainly between interdigitated Pt electrodes on an alumina substrate, all overcoated with an auxiliary solid electrolyte of (Na₂CO₃:BaCO₃ 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.

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 SnO₂, which is an n-type (electron-donor-type) semiconductor that provides additional electrons for reduction reaction at the working electrode to detect CO₂. This use of SnO₂ as a CO₂-sensor material should not be confused with the use of SnO₂ in a related development described in “CO₂ Sensors Based on Nanocrystalline SnO₂ Doped With CuO” (LEW-18247-1), NASA Tech Briefs, Vol 32, No. 10 (October 2008), page 44. The SnO₂ 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 SnO₂. Concentrations of CO₂ 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