Mechanisms of Response in Conductometric Polymer-Carbon Composite Sensors

M. A. Ryan, A.V. Shevade, M.L. Homer, A.K. Kisor, A.M. Manfreda, B.L. Lin

Jet Propulsion Laboratory
Pasadena CA 91109 USA

Polymer-carbon composite sensors are used in the sensor array of the electronic nose now under development at the Jet Propulsion Laboratory [1]. By selecting different polymers as the basic sensing matrix, it is possible to make an array of sensors which respond to organic and inorganic compounds which may be present as contaminants in the recycled air of the crew quarters in spacecraft. The sensors are made conducting by casting films of the insulating polymers mixed with carbon particles. Networks of carbon in the film provide conductive pathways.

The electronic nose using these sensors is used to follow changes in the air composition. The mechanism of sensing in polymer-carbon composite sensors is primarily swelling as analytes sorb into the sensor and shrinking as they desorb. When analyte molecules are sorbed into the film, the swelling causes some of the conductive pathways to be interrupted, increasing the resistance [2]. Sensor response is monitored as change in resistance, and additional compounds in the environment generally result in higher resistance in the film.

Molecular models of the swelling behavior of polymers used in these films correlate well with measured responses. Both modeled swelling and measurements of resistance changes show that the concentration of water in the environment has a strong influence on the response of the film.

At a constant background concentration of water, the response of the film to some analytes is not linear with analyte concentration. Similarly, at a constant background concentration of those analytes, the sensor response to water is not linear with water concentration. Figures 1 and 2 show modeled and measured response for isopropanol in a film of polyethylene oxide at different water and analyte concentrations. The calculated swelling is for pure polyethylene oxide; the measured change in resistance is in a film of polyethylene oxide and carbon composite.

In addition to the non-linear behavior of response of some polymers with some analytes, it has been found that resistance may decrease when the polymer-carbon composite sensor is exposed to certain analytes. This response is clearly not caused by swelling.

In this paper, we will discuss the mechanisms of response in polymer-carbon composite sensors, including swelling, the non-linearities of swelling which are caused in part by the non-linearity of partial molar volumes of analyte in water, and increased resistance in the composite film caused by mechanisms such as ionization of the analyte in water in the polymer matrix.

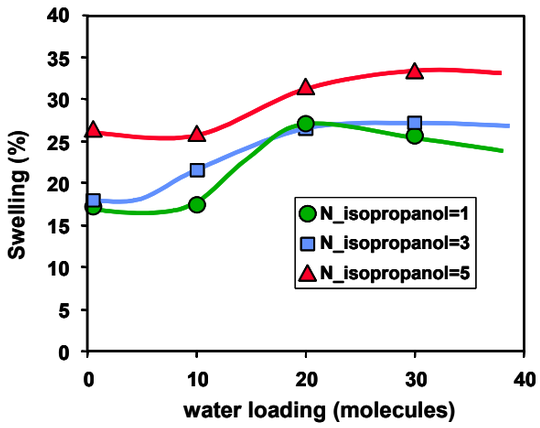

Figure 1. Modeled swelling of PEO on addition of 1, 3, or 5 molecules of isopropanol to a film containing 10, 20, or 30 molecules of water at 300 K.

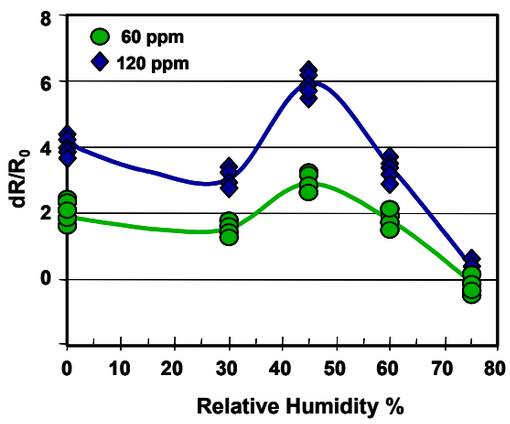

Figure 2. Measured change in resistance of a PEO-carbon film exposed to 60 and 120 ppm isopropanol at 0, 30, 45, 60, and 75 % relative humidity at 300 K.

REFERENCES

1. M.A. Ryan, M.L. Homer, H. Zhou, K. S. Manatt, V. S. Ryan, S. P. Jackson, Proceedings of the 30th International Conference on Environmental Systems; Society of Automotive Engineers, 00ICES259 (2000).

2. E.J. Severin, B.J. Doleman and N.S. Lewis. *Anal. Chem.*, **72**, 658 (2000).