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The Fingernail Polish Solvent Sensor

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Abstract – There is an interest in accessing sophisticated subjects in materials sciences using very simple experiments. The present experiment allows one to develop concepts such as sensors, swelling of polymers, electrical resistance and resistivity, percolation and composites, among others, in a very palpable way. The experiment comprehends the preparation and use of a solvent sensor capable of changing its electrical resistance in response to changes in the concentration of acetone vapors. The sensor is prepared by a simple mixture of nail polish and powdered graphite. The measurements of the sensor response are made with a readily available ohmmeter.

In the learning of materials sciences a newcomer is often challenged by the theoretical aspects of some of the main concepts. Many of these concepts, however, are based in very concrete experimental observations. A good approach in situations like these is to show these experiments or, even better, to let the students to do them themselves. A well planned experiment allows the student to establish the connection among the relevant concepts and presents as few elements as possible that can distract the students from them. If the experiment can use everyday materials it is also possible to relate the students more closely to the subject under study. In this sense, an experiment was planned and tested to present the main concepts in the field of materials as sensors.

The idea of sensors as being materials that can respond to changes in their environment presents a large variety of possibilities related to what the detector senses, how the detector detects and also how the measurements of the response are done. The experiment here presented was outlined to explore the working concepts involved in building a solvent sensor whose response is due to the sensor swelling. This response is measured through changes in the sensor's electrical resistance (or conductivity).

A polymer sample can swell when in contact with a solvent that is in some way similar to itself. This happens only when the Hildebrand solubility parameters of both solvent and polymer are similar (a necessary but not sufficient condition). If the solvent is in a vapor state this swelling is limited, being controlled by the difference between the chemical potential of the solvent in the sample and in the sample surroundings. The consequence is that the swelling degree is proportional to the solvent vapor pressure.

When an electrically conductive powdered material is dispersed in an dielectric polymer matrix, in an adequate amount, many pathways are established that allow an electric current to pass through the sample [1]. When the sample swells many of these pathways are broken, increasing the sample resistance. This behavior is depicted in Figure 1.

The everyday materials chosen for building this sensor were colorless fingernail polish (mainly nitrocellulose) and powdered graphite (21 phr), a lubricant for key locks. The components were weighted, mixed and disposed over a pair of electrodes. After solvent evaporation, the sensor was exposed to acetone in various concentrations and its resistance was measured with an ohmmeter. Figure 2 shows the experimental setup while Figure 3 shows its response to acetone concentration.

The simplicity, clear response and the amusement caused by the employed materials make this experiment a very valuable resource in teaching some aspects of materials sciences.

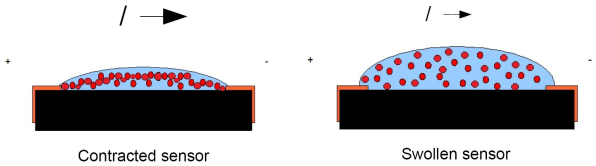

Figure 1: Solvent sensor - working principle

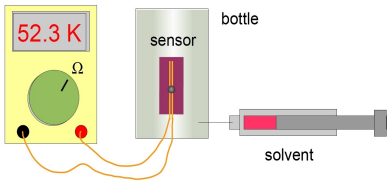

Figure 2: The experiment

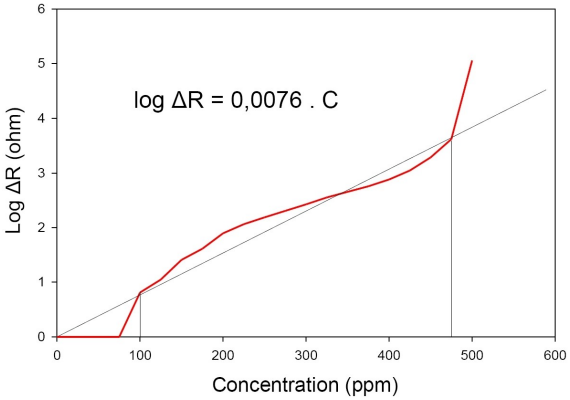

Figure 3: Sensor response to acetone concentration

[1] Souza Jr, F. ; Michel, R.; Soares, B.; Polymer Testing, 2005, 24, 998-1004.