Electroconducting Polymer Film Based Gas Sensor on Thick Film Substrate [1]

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Summary: *In the beginning of the 80's years an essential property of most polymers, which distinguishes them from metals, was their inability to carry electricity. During the past twenty years, a new class of organic polymers has been devised with ability to conduct electrical current. These conducting plastics are still under development for practical applications, such as rechargeable batteries, capacitors, enzymatic biosensors, gas sensors, etc... This paper describes the application of conductive polymers in preparing gas sensors. A new type of gas sensor was developed on thick film electrodes. Different sensor structures were tested, and change in conductivity was measured in the presence of methanol gas.*

Introduction: The electrical properties of any material are determined by its electronic structure. Conducting polymers are similar in that they conduct current without having partially empty or partially filled band. When an electron is removed from the top of the valence band of a conjugated polymer a hole or a radical cation is created, that does not delocalize completely, as would be expected from classical band theory. Only partial delocalization occurs, extending over several segments causing them to deform the valence band. The polaron stabilizes itself by polarizing the medium around. If another electron is removed from the already oxidized polymer, two things can happen: this electron could come from either a different segment of the polymer chain, thus creating another polaron, or from the first polaron level by removing the unpaired electron to create a special dication, called bipolaron. Both polaron and bipolaron are mobile and can move along the polymer chain by the rearrangement of double and single bonds [1] (Figure 1).

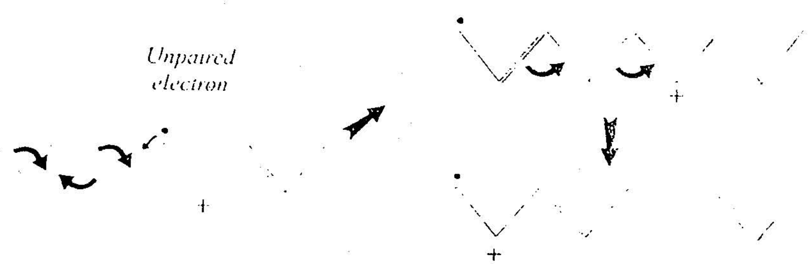

Figure 1. Propagation of a polaron through the polymer chain by rearrangement of double bonds

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ECPs appear very attractive for using in sensors either as sensing components or as matrix for easy immobilization of specific substrates. They easily can be synthesized by a simple electrochemical method, where the doping reaction modulates the conductivity reversibly several orders of magnitude via redox interactions.

The electronic conductivity related to the doping level of an ECP is modulated by the interaction with various substrates. Change in parameter values, such as resistance, current or electrochemical potential, can be registered to measure the sensor response of the studied phenomena.

A variety of devices has been constructed and tested utilizing the reversibility in redox properties of ECP films, coupled with incorporation of electrolyte anions into the polymer film, and dissolution of the incorporated anions takes place in redox reaction. So conducting polymers can be used to sense gases and vapors by monitoring the change in conductance on exposure of the polymer to the sample. The preliminary studies on these materials have shown that they exhibit fast, reversible responses at room temperatures [2,3]. These polymers have a number of distinct advantages in the point of view of gas sensing:

- a wide variety of polymers are available,
- they can be formed by electrochemical polymerization of the monomer under well controlled conditions
- they operate at room temperature.

One disadvantage of these materials is their lack of specificity: they show responses a wide range of different gases and vapors. Lots of ECPs (PMPy, PPy, PTh, PANI) were studied for use in gas sensors. They produce non-selective response to different gases [4-6]. The approach of thick film technology producing gas sensors offers several advantages over applying conventional microelectrodes or other integrated (thin film, and monolithic) technologies as discussed elsewhere [7].

Experimental and results: The sensor electrodes were screen-printed onto alumina ceramic carrier. Pd-Pt-Ag paste was used for the working and the counter electrode. The thickness of the Pd-Pt-Ag layer was about 10μm (Figure 2).

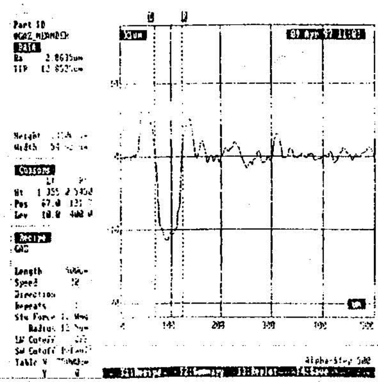

Figure 2. The thickness of the screen-printed metal layer used for the sensor substrate

A 60μm wide gap was cut into the screen-printed metal pad by GRAVILASER™ developed at the Department. Three kinds of electrode structures were studied for optimal use for the electropolymerization (Figure 3).

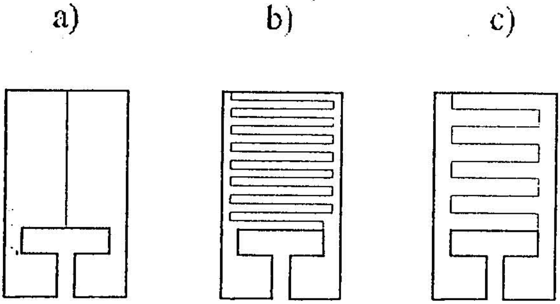

Figure 3. Schematic diagrams of the electrode structures for sensor substrate

The polymerization took place in a 0.1M pyrrole 0.05M dodceyl-sulfate solution by applying cyclic voltammetric method using 0.1M SCE as reference electrode. The cyclic voltammograms of the growth of the polymer film can been seen in Figure 4.

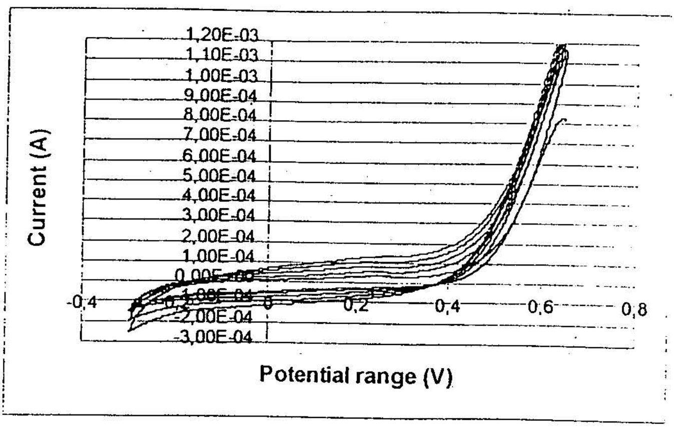

Figure 4. Cyclic voltammograms for the deposition of polypyrrole on the electrode

The preliminary results showed that the polymer film grew over the gap (Figure 5), and the resistance of the layer was in the kΩ range.

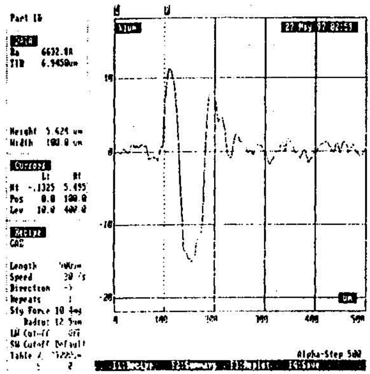

Figure 5. The thickness of the polymer film on thc metal layer was about 4-5 μm

The sensitivity of the polymer film was investigated, and the sensor produced reversible changes in the conductivity in the presence of methanol gas.

Conclusions: The results of the gas sensor showed that thick film technology is suitable to fabricate low cost electrochemical devices. Different ECP films were studied to form chemically sensitive materials.
Three types of electrodes were tested for the gas sensor substrate. Cyclic voltammetric polymerization method was suitable for the immobilization and film formation. It was found that the PPy grew over the gap, thus forming a sensitive resistor. The gas sensor produced reversible change in the conductance in the presence of methanol gas.

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