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Fast responding polyaniline based humidity sensor

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Abstract

A humidity sensor based on polyaniline thin films deposited on chlorinated glass surfaces by chemical and electrochemical polymerization is reported. Electrochemically deposited polyaniline on a layer of chemically deposited polyaniline induces a fast response to humidity. The sensor exhibits fast recovery and sensitivity to the full range of humidity and could be employed to measure rapid changes of humidity in ambient air.

1. Introduction

Semiconducting organic polymers have received attention of the researchers due to their versatility easy synthesis and low cost. They have found applications as molecular wires, light emitting materials, solar energy converters and sensors. Polyaniline is one such organic polymer that has been extensively studied. It has been reported that the direct current electrical conductivity of dry polyaniline is dependent on the gaseous environment to which polyaniline is exposed [1]. Applications of polyaniline in hydrogen gas and

moisture sensing have been reported. In these studies electrical contacts to polyaniline thin films have been made by pressing a metal electrode on to polyaniline or by chemical polymerization of polyaniline above the metal contacts. In both cases the metal and the metal junctions are exposed to the reactive environments causing degradation of the quality of the metal-polymer junction. We have observed that polyaniline-Cu junctions undergo corrosion due to acidity of the medium of polymerization. Pressed metal-polymer junctions cannot be made in the case of thin films due to the fragility of the films. Therefore, they require thick layers or pellets of the polymer. The use of thick layers or pellets in gas sensing creates a slow and tailed response due to the diffusion of gas through the matrix of the polymer. Especially this effect is severe in the case of moisture sensing. Once moisture is absorbed, pellets or thick films require substantially long times to recover, making the sensor unsuitable for recording rapid changes in moisture levels. In the present article we report the construction of a thin film past responding polyaniline moisture sensor.

2. Experimental

Thin films of polyaniline were deposited on a glass rod as follows. First the glass rod was refluxed in concentrated HCl for 24 hours. Then it was rinsed with distilled water and dried. The glass was then heated to 400 C in a preheated furnace and kept there for 30 minutes. The hot glass rod was dipped in thionyl chloride for two minutes and then dipped in an aniline solution for another two minutes. Subsequently a layer of polyaniline was deposited on to the glass rod by dipping in a bath containing aniline (0.1M) and HCl (1M) and per-sulfate (0.2M) at room temperature. The chemical polymerization was continued for 24 hours. Two thoroughly cleaned platinum wires were wrapped around the glass rod at a separation of 1.0 mm. This assembly was immersed in an aniline (0.45M)/sulfuric acid (0.5M) bath and a new layer of polyaniline, covering the metal wires and the initial layer was electrochemically deposited at a potential of 1.2V. In this way a highly conducting polymer - metal junction was obtained. The sensor was then calibrated for moisture by exposing it to controlled humidity environments and by measuring electrical conductance using a portable conductivity meter. Humidity controlled environments were prepared by using saturated salt solutions in closed vessels and purging them with nitrogen gas.

3. Results and Discussion

The procedure described above produced an adherent polyaniline film on the glass rod. The film was blue in color indicating the presence of emeraldine salt of polyaniline. Humidity response of polyaniline sensor is shown in Figure 1.

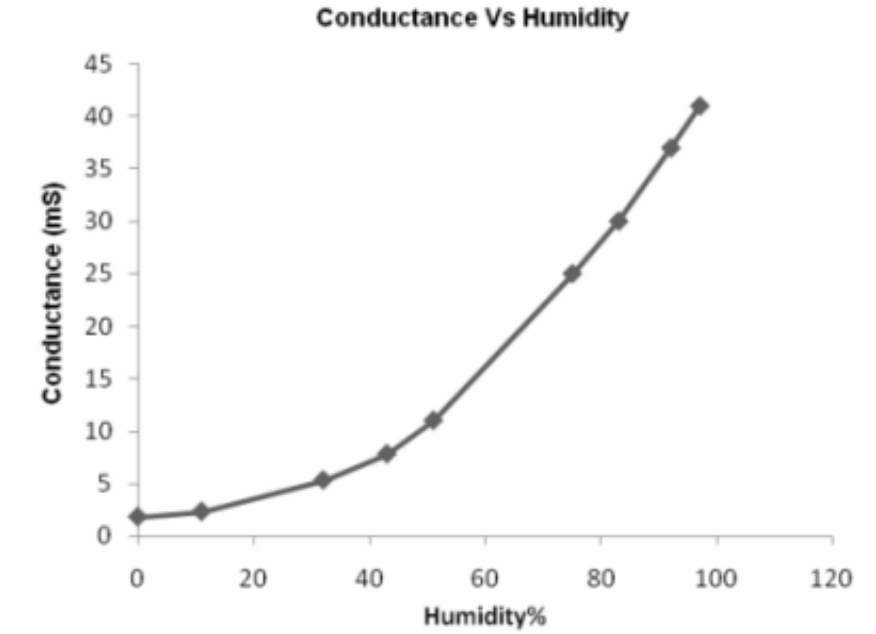

Figure 1. Humidity response of the sensor

It can be seen that the sensor responses almost to the full range of humidity as compared to sensors with limited range reported in literature [2]. The sensor responded and recovered quickly and its response is reproducible (Figures 2 and 3). The conductivity of the polymer film was measured using a conductivity meter and the output signal proportional to the conductivity was recorded using a chart recorder. It can be seen from Figure 2 that the sensor has a fast responses to changing humidity conditions. The alternating humidity conditions were obtained by placing the sensor in a bottle containing dry $CaCl_2$ and then by exposing the sensor to the atmosphere. The full cycle could be completed within 2 minute intervals and the response of the sensor remained reversible.

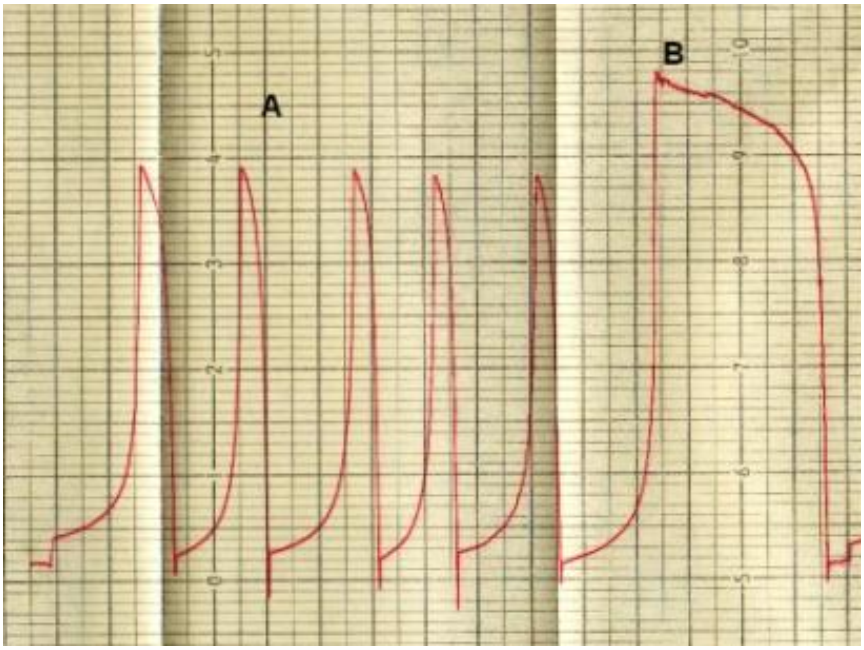

Figure 2. Humidity sensor reproducibility test; A-Cycled between two humidity levels, B-Allowed to come to equilibrium in the atmosphere (Scale X-axis 1 min cm^{-1} and Y-axis 10.0 mV cm^{-1})

The response of the sensor to short pulses of exhaled air (~10 seconds) is shown in Figure 3. The sensor displayed low conductance (Figure 3, A) when exposed to a dry atmosphere (Figure 3, A). This was then exposed to the atmosphere and allowed to come to equilibrium. After attaining equilibrium under atmospheric conditions (Humidity 78% and temperature 31^0C), air was exhaled on to the sensor from a distance of about 20 cm. The response of the sensor was recorded using the conductivity meter coupled to a chart recorder. It can be seen from Figure 3 that the response is quick and reproducible. The conductivity of polyaniline film increased when the sensor was exposed to humid exhaled air. The improved characteristics of humidity sensing can be attributed to the presence of a thin polyaniline film. Literature reported sensors are based on chemically polymerized aniline in pellet form and display slow response and long recovery times.

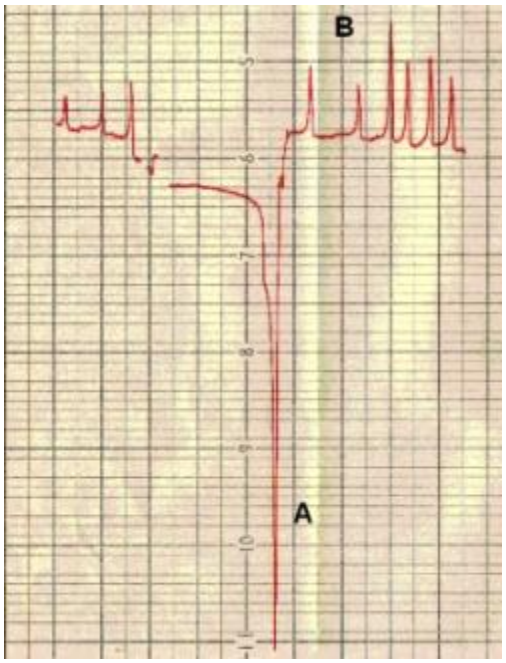

Figure 3. Humidity sensor response to environment; A – dry atmosphere, B-response to exhaled air (Scale X-axis 1 min cm^{-1} and Y-axis 10.0 mV cm^{-1})

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