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Humidity sensing effect of doped metal salts based on polyvinyl alcohol complex materials

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Abstract :

Organic polyelectrolytes have suggested as humidity sensing materials, however they lack in durability as they are easily attacked by moistures. Polyvinyl alcohol(PVA) is a common hydrophilic polymer having an –OH group at an alternate carbon in its back-bone but with changing humidity an impedance response is low. The simple PVA humidity sensor lacks durability and also shows high impedance. To overcome this problem, cross-linking of polyvinyl alcohol was done with 4-styrene sulfonate in presence of metal ions. The humidity sensor materials were obtained when polyvinyl alcohol was cross-linked with 4-styrene sulfonate in presence of some ions at a temperature of 140°C for about 1 hour and when polyvinyl alcohol, 4-styrene sulfonate (sodium salt hydrate) and metal ions were taken in a weight ratio of 10:3:4 respectively. The polymeric mixture of the three materials made in water was printed on an SiO_2/Si substrate prefabricated with interdigitated gold electrodes and was cured at a temperature of 140°C. The results demonstrate that the logarithm of the resistance decreased linearly with increase in %RH in a range of 10-90% RH. Other factors viz. stability, sensitivity and response time for the fabricated sensor were also determined.

Key words: humidity sensor, polymer electrolyte, polyvinyl alcohol, metal salt ion

Introduction

Monitoring the environment humidity mainly for comfort and many industrial processes is of immense importance and these days automated control systems are gaining importance in environmental control. In recent years, the use of humidity control systems has greatly increased in many domestic applications where humidity sensors are used to maintain a comfortable humidity level and for cooling.

A wide variety of sensing materials for humidity have been studied. Ceramics, particularly metal oxides have been extensively used, but many problems are encountered in the fabrication of humidity sensors. Their periodic regeneration is necessary as prolonged exposure to environmental humidity leads to formation of chemically stable hydroxides on their surfaces, that causes irreversible change. Recently, much attention has been paid towards organic polymeric materials to develop humidity sensors for commercial purposes, because of their low-cost and easy fabrication as films on sensing devices.

Polyvinyl alcohol is a cheap and common hydrophilic polymer which shows moisture sensitivity. However, simple fabrication of the polyvinyl alcohol film as humidity sensor, lacks durability and shows very high impedance. Cross-linking polyvinyl alcohol with some organic electrolytes not only maintain its humidity sensing property but also increases its durability against attack of moisture. The work is to develop some cheap and durable polymeric materials that can be used as sensitive humidity sensor.

Experimental

PVA with the low molecular weight (MT 500) was dissolved in water in 1:10 ratio and was allowed to swell for 24h at room temperature. Varying amounts of 4-styrene sulphonate, sodium salt(SS) dissolved in water were added to a known volume of PVA solutions, mixed thoroughly and were allowed to stand for ~ 10min. 1mM solutions of inorganic electrolytes viz. alkali metal chlorides, alkaline earth metal chlorides and transition metal chlorides were prepared by dissolving appropriate amounts of the salts in water. Varying amounts of 1mM solutions of the metal salts were added to a mixture of PVA-SS solutions and mixed thoroughly, thus giving series of solutions for each metal salt(Paste). A SiO_2/Si wafer

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substrate with each chip size 7.2mm×7.5mm was fabricated by screen printing method with gold electrodes having inter-digital as shown in Fig 1. The polymeric mixtures (the paste) made as above, were then coated on the sensor chip by screen printing and were cured at different temperature between 140°C for different time intervals.

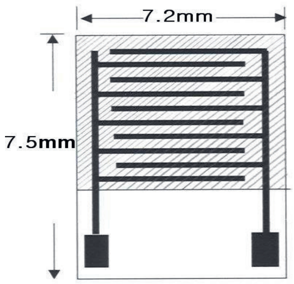

Fig. 1. Schematic view of the sensor chip

Results and Discussion

Fig 2. shows the results obtained for the response of impedance measured at 1 V, 1KHz and 25°C versus % RH with the fabricated polymeric films containing various inorganic electrolytes when taken in a molar ratio of PVA:SS:metal salts 5:2:2 and cured at 140°C for 1h. Alkali and alkaline earth metal salts showed a gradual fall in impedance against humidity Maximum sensitivity was shown with karium ions among all tested electrolytes.

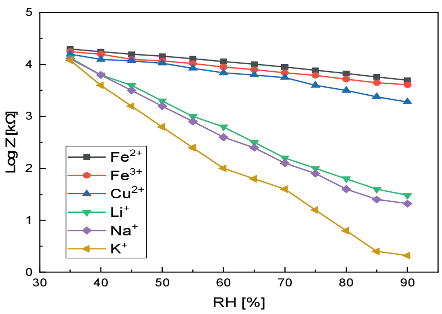

Fig. 2. A plot of impedance to metal salts

It was observed that though the increasing metal ion concentration increased the sensitivity but as the ratio of PVA:metal salts increased above 5:2 the films showed partial water-solubility, thus were sensitive to moisture attack affecting the stability of the films. As is evident from Fig 2, maximum sensitivity was shown when ferrous chloride was present in the films.

The stability of the films was determined by checking their insolubility in water and long exposure of the films in a maintained moisture for at least ~100h. Overall, the best results for sensitivity and stability of the films were obtained when a molar ratio of PVA:SS:metal salts was fixed at 5:2:2 in case of ferrous and ferric and 10:4:3 ration for copper(II) and cobalt(II) salts. Since the polymer electrolyte essentially has a property of dissolving in water, it can be weak hardness in the high humidity atmosphere and condensation. In this study, PVA was sulphonated to improve the above problem and further stabilized and durability by addition of metal ion. Soaking in water the device for a certain period of time, and then measuring the humidity characteristic at each time, we examined the change of the humidification characteristic with the soaking time. Fig3. shows the humidity characteristics after 6 hours and 24 hours soaking.

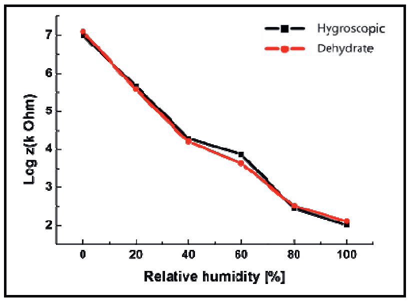

Fig. 3. The characteristic of sensing by soaking

Since this humidity sensor has ion conduction in the polymer electrolyte membrane, its impedance has temperature dependency. The humidity characteristics at 15°C, 30°C and 45°C are shown in Fig 4. The humidity of the electrolyte is a slight proportional to the temperature. As the temperature decreased, the impedance was lower due to low humidity capacitance. As the temperature increases, the capacity increases and the impedance becomes higher.

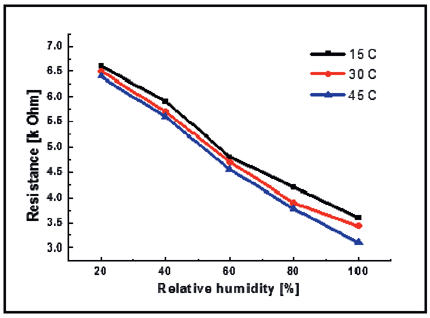

Fig. 4. Dependence of temperature on the relative humidity

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