Chapter 12
Polymer/Metal Oxides Composites on Flexible Commercial Substrates as Capacitive Sensors

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The development of a low level humidity capacitive sensing device working at room temperature, based on a thick layer of iron oxide nanopowders dispersed into a poly(diallyldimethylammoniumchloride) (PDDAC) hydrophilic host matrix deposited on flexible commercial plastic substrates provided with silver electrodes, is reported. The sensor response was tested in a transduction system based on a capacity-frequency conversion of the timing circuit by means of a microcontroller unit. The sensor was investigated in the absolute humidity range from 0% to 1%, showing a good sensitivity and response linearity.

1 Introduction

The development of humidity sensors, working at room temperature, for the monitoring of low humidity levels is an active area of research today due to the great importance of humidity control in many advanced technological applications. Various materials such polymers, polymers mixtures, and polymer/nanoparticles composites, deposited on ceramic or plastic substrates and working as sensing element of humidity sensors, are described in the recent scientific literature [1].

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In this paper is reported our research activity towards the development of low cost gas capacitive sensors and of related characterization system based on a microcontroller and custom electronics.

The devices here presented are based on a thick layer of iron oxide nanopowders dispersed into a poly(diallyldimethylammoniumchloride) (PDDAC) hydrophilic host matrix deposited on flexible commercial plastic substrates provided with silver electrodes. PDDAC is a poly-cationic binder and it has been widely used in combination with metal oxide nanoparticles to produce thick/thin films [2, 3], on the basis of an electrostatic attraction of oppositely charged colloidal particle between the inorganic materials and the polymer [2].

2 Experiments

The sensing material was deposited by drop coating deposition from a water solution of PDDAC and γ-Fe_2O_3 (maghemite) nanopowders. In Fig. 12.1 is reported a SEM micrograph showing the presence of Fe_2O_3 nanoparticles dispersed in the PDDAC host matrix.

The XRD spectrum of the sensing material shown in Fig. 12.2a confirms, by comparison with the diffraction peaks reported in the JCPDS 04–0775 data file, the presence in the PDDAC matrix of the maghemite phase. This is in according with the FT-IR analysis (Fig. 12.2b).

The electrical characterization was performed with an home-made system based on a transduction circuit with NE556 dual monolithic timing devices and a measuring/interfacing one made with an ATMEL AWR Butterfly micro-controller. The transduction system is based on a capacity-frequency conversion of the timing circuit and finally, in a frequency measurement developed by means of the microcontroller unit.

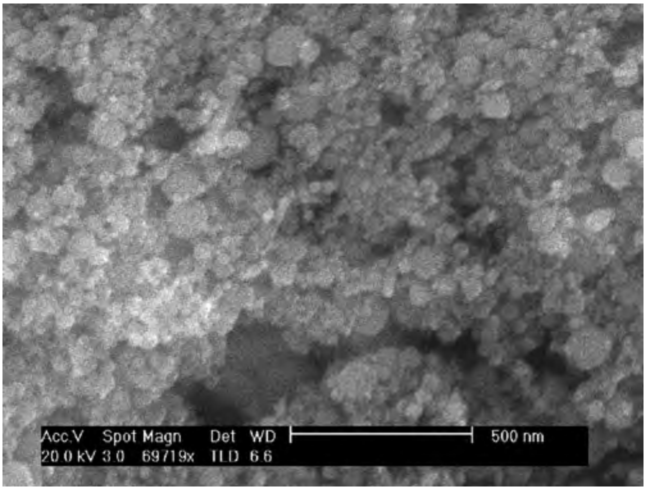

Fig. 12.1 SEM micrograph of the sensing material

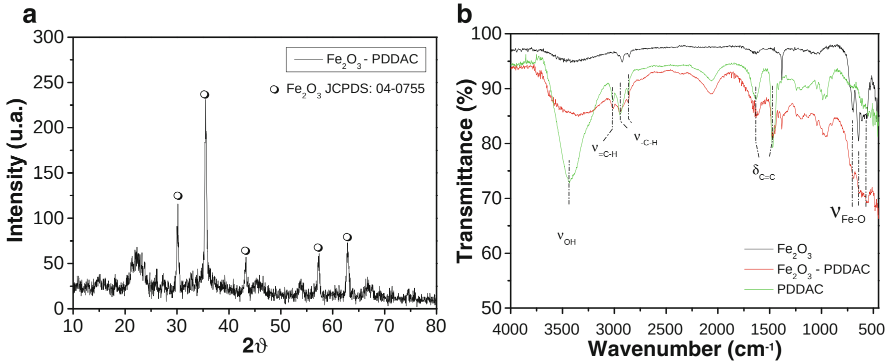

Fig. 12.2 XRD spectrum (**a**) and FT-IR analysis (**b**) of the sensing material

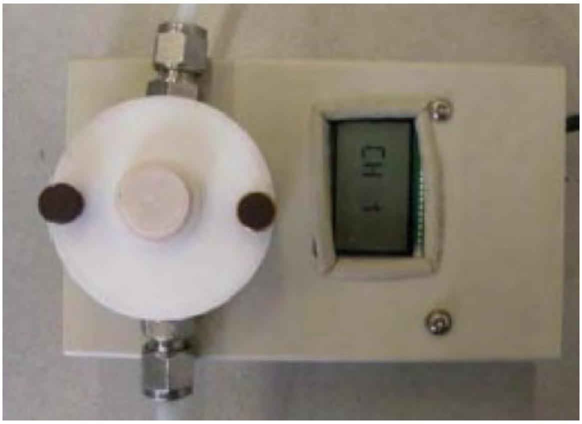

Fig. 12.3 The realized six channel capacitive sensor measurement system

The apparatus shown in Fig. 12.3, is biased by USB Bus and it is interfaced with a personal computer and a Graphical User Interface able to record the frequency and the capacity values of the devices under test.

The system was validated by means of commercial capacitors allowing measurements in a range spanning from 5 pF to 50 nF. The developed system is able to read capacity values of up to six sensors in a single testing procedure. The capacity value of the holder was de-embedded by the capacity ones of the sensors by means of a calibration procedure able to handle the whole sensing array.

3 Results

Humidity sensing test measurements were performed under flux conditions of 50 cc/min, reading the capacity values by varying the water vapor concentration in an absolute humidity range from 0% to 1%.

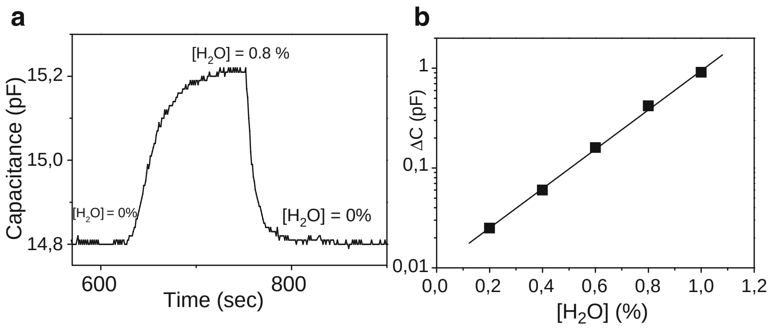

Fig. 12.4 (**a**) Sensor dynamic response to a 0.8% of absolute humidity value. (**b**) Sensor response vs. absolute humidity values

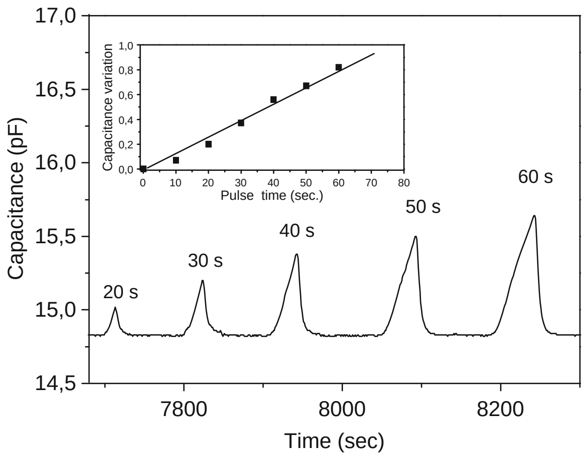

Fig. 12.5 Capacitance response to pulses of water vapour (0.8%) with different time duration. In the *inset*, the correlation between the capacitance variation and pulse time duration is shown

In Fig. 12.4a is reported the sensor dynamic response to a pulse of 0.8% of absolute humidity. It can be noted the well reversible response, with a fast response time and recovery time, in the order of ~ 90 s and ~ 60 s, respectively. In Fig. 12.4b is shown the linear response of the investigated sensor to values of absolute humidity ranging from 0.2% to 0.8%.

Humidity sensing tests were also performed by a pulse method, i.e. maintaining the sensor device in contact with water vapors coming from the bubbler for a lower time than that necessary to reach the complete saturation (Fig. 12.4). In the Fig. 12.5 is reported the capacity values of the sensor tested under pulses of water vapor at a concentration of 0.8% in air with different pulse time, ranging from 20 to 60 s. It can be observed that the capacitance variation increases linearly with pulse time, see inset in the figure, so allowing to find a direct correlation with the humidity concentration.

Providing to establish a suitable calibration, this procedure is particularly effective for practical applications in order to decrease the time between successive pulses, i.e. to increase the number of measurements for unity of time.

4 Conclusion

The development and characterization of a capacitive humidity sensor working at room temperature and of a measurement system able to test sensing arrays composed of up to six sensors, is reported. The sensor was tested in the absolute humidity range from 0% to 1%, showing good sensitivity and linearity. Further activities are in progress to enhance the response of the sensor, by optimizing the sensing materials and the electrodes layout.

References

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