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Humidity sensor printed on textile with use of ink-jet technology

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Abstract

The paper presents a humidity sensor which was directly printed on textile using the ink-jet printing technology. Fabricated sensors were tested in a controlled environment at 25 °C and 5-95 % of RH. The measured impedance modulus versus humidity for the Nafion sensitive layer shows a non-linear distribution over the range from 40 to 95 % of RH with dependence on measurement frequency. Obtained results show sensor potential for gas humidity monitoring as integrated sensors with “smart” textiles.

"Keywords: humidity sensor; textile sensor; ink-jet printing"

1. Introduction

The textile industry is strongly interested in research on new functional textile materials. A part of these products are emerged from the combination of textiles and electronics, so called "smart" textiles. The potential market is wide e.g. for sports, health care or military.

Applications of different materials are reported for flexible humidity sensor fabrication. Silver naoparticles [2,4,5] or gold [1] are used for electrodes. Humidity sensitive layer is formed with PEDOT-PSS [1], pHEMA [2], CAB [3,4] and Nafion® [5]. Sensors are fabricated mainly on Kapton® polyimide sheets and then woven into textile. The next sensor development step can be done by direct sensor printing on textile.

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2. Sensor design and fabrication

To print all sensor conductive elements (e.g. interdigitated sensor electrodes, the connection traces and the contact pads), the Dimatix DMP 2831 printer was used. The piezoelectric MEMS printing head, equipped with 16 nozzles (the nozzle orifice diameter was 21.5 µm, and the typical jetted drop volume was about 10 pl) allows to adjust the single drop diameter about 50 µm in single shot on the textile but due to sink in process the drop diameter grows to some of 70-100 µm for a few drops placed at the same position. This resolution guarantees continuity of imprinted traces and appropriate low resistivity of the sensor electrodes (some of 50 - 150 Ω). The Ag (silver nanoparticles) ink of U5603 type (from SunChemical) was used with sintering temperature of 200 °C. The sorption layer was deposited with adjustable manual micropipetting devices (drops range from 1 to 5 µl) using Nafion® solution (a sulfonated tetrafluoroethylene).

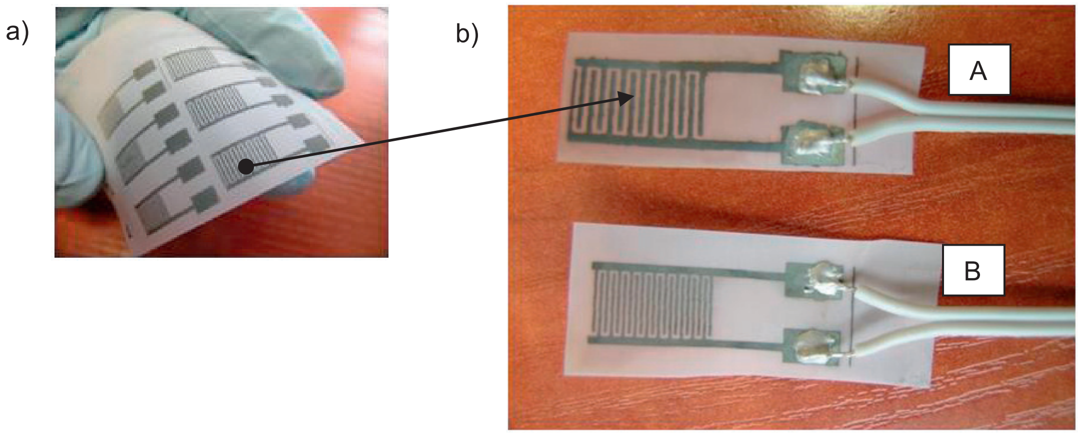

Fig. 1. The humidity sensor electrodes printed on textile with Ag nanoparticles ink: a) textile pattern , b) sensors of pattern A – 400µm x 400µm and of pattern B – 250µm x 250µm.

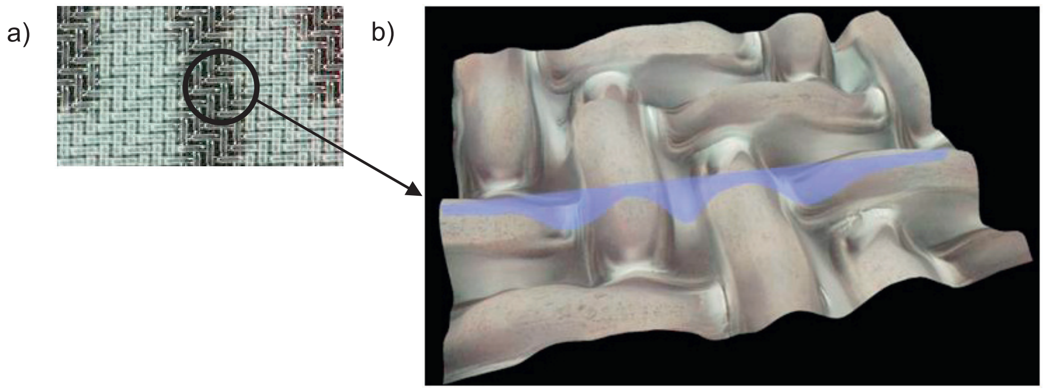

Fig. 2. Fabric threads covered with Ag nanoparticles ink a) magnification of the sensor electrodes, b) the electrode surface profile. Thread diameter and gap are about 22µm and 32µm respectively.

The two patterns of humidity sensor electrodes were printed on textile: pattern A – 400µm x 400µm and pattern B – 250µm x 250µm (fig.1.). Microscopic inspection of threads covered with Ag naoparticles ink and the profile shows good enough continuity of electrodes, even the thread diameter and gap are about 22µm and 32µm respectively (fig.2). The printed electrodes were resistant on textile slight bending and stretching.

3. The measurement results

To characterize the sensor electrical parameters, the measurement stand with gas humidity generator, reference hygrometer, impedance analyzer and temperature stabilized measurement head were arranged (fig.3). Fabricated sensors were tested in a controlled environment at 25 °C and 5-95 % RH.

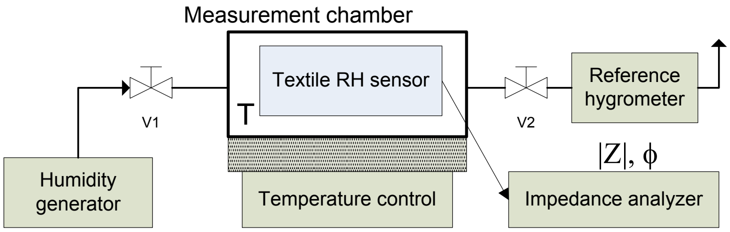

Fig. 3. The measurement stand block diagram.

The sensors impedance modulus dependence on humidity have non-linear distribution over the whole humidity range from 5 to 95 % RH. The pattern B sensor at 1 kHz measurement frequency can measure humidity changes which are higher than 50 % RH while pattern A sensor higher than 65 % RH respectively. Sensitivity of sensor A is similar to sensor B (fig.4). The hysteresis (not shown in the fig.4) was some of 5-10 % RH.

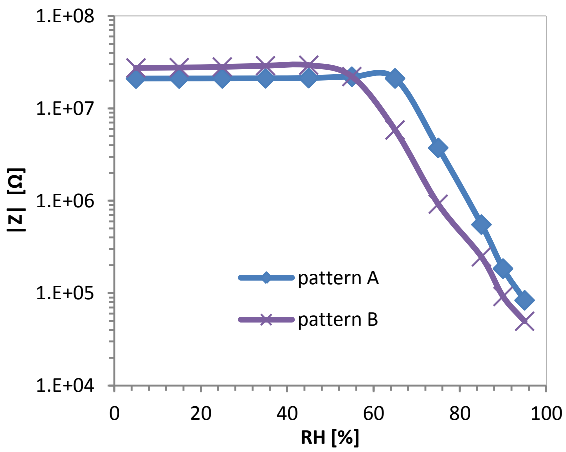

Fig. 4. The sensor impedance modulus dependence on humidity for pattern A and B at 1kHz measurement frequency.

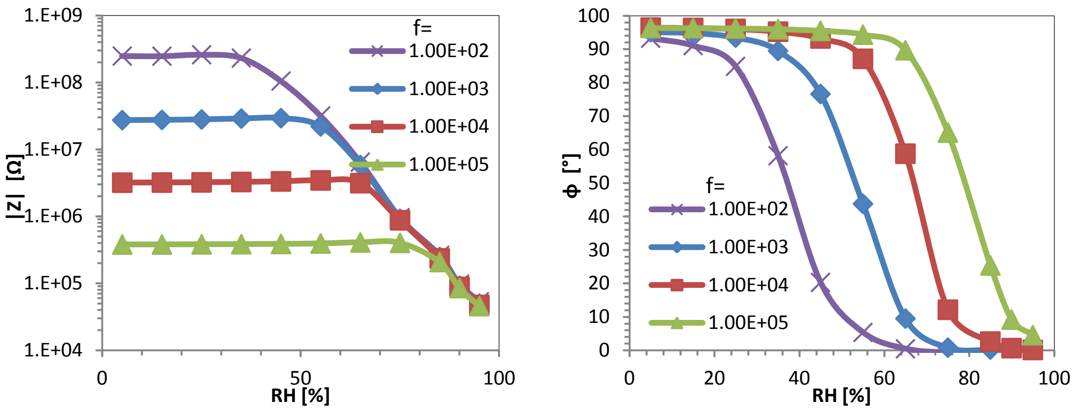

Fig. 5. Sensor (of pattern B) impedance modulus and phase dependence on gas relative humidity for four different measurement frequencies.

The sensor electrical characteristics of (impedance modulus and phase) strongly depend on selected measurement frequency (fig.5). Low measurement frequency (some of 100 Hz) assures covering the widest measurement range (35 – 95 % RH) for the impedance modulus as the sensor output. On the contrary the phase change characteristic is linear in narrow range (some of 20 % RH) of humidity and shifts in accordance to measurement frequency. It means that by proper frequency selecting we can focus in the range of the highest phase sensitivity.

4. Conclusion

The proposed humidity sensors that were directly printed on textile using the ink-jet printing technology have satisfying metrological parameters. They have prospective opportunity of integration with smart wearable electronics used for making so called medical shirt or socks. Further work will focus on sensor long term stability.

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