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Ternary Oxidized Carbon Nanohorns/TiO_2/PVP Nanohybrid as Sensitive Layer for Chemoresistive Humidity Sensor

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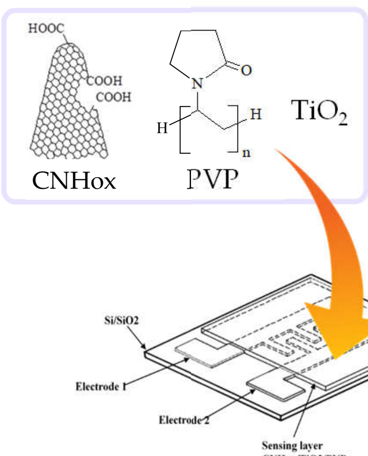
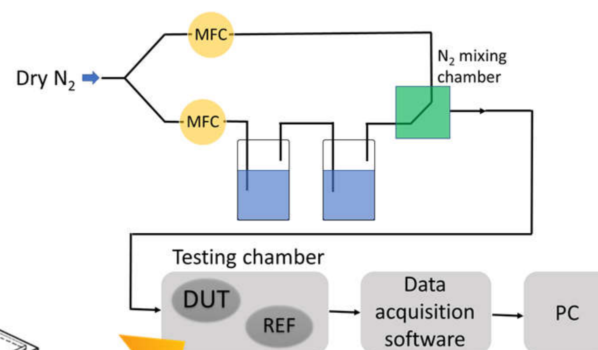
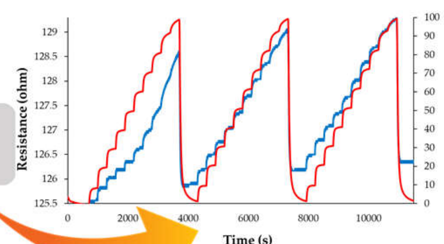
Abstract

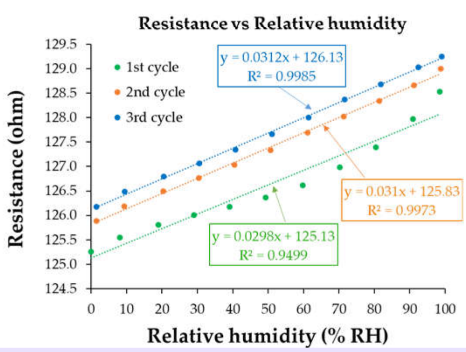
The relative humidity (RH) sensing response of a chemoresistive sensor using a novel ternary hybrid nanocomposite film as sensing element is presented. The sensitive layer was obtained by employing the drop-casting technique for depositing a thin film of nanocomposite between the electrodes of an interdigitated (IDT) structure. The sensing support structure consists of an IDT dual-comb structure fabricate on a oSi-SiO2 substrate. The IDT comprises chromium, as adhesion layer (10 nm thickness), and a gold layer (100 nm thickness). The sensing capability of a novel thin film based on a ternary hybrid made of oxidated carbon nanohorns – titanium dioxide – polyvi-nylpyrrolidone (CNHox/TiO2/PVP) nanocomposite was investigated by applying a direct current with known intensity between the two electrodes of the sensing structure, and measuring the resulting voltage difference, while varying the RH from 0% to 100% in humid nitrogen atmos-phere. The ternary hybrid-based thin film's resistance increases when the sensors were exposed to relative humidity ranging from 0–100%. It was found that the performance of the new chemoresistive sensor are consistent with those of the capacitive commercial sensor used as benchmark. Raman spectroscopy was used to provide information on the composition of the sensing layer and on potential interactions between constituents. Several sensing mechanisms were considered and discussed, based on the interaction of water molecules with each component of the ternary nanohybrid. The sensing results obtained lead to the conclusion that the synergic effect of the p-type semiconductor behavior of the CNHox and the PVP swelling process plays a pivotal role in the overall resistance decrease of the sensitive film.



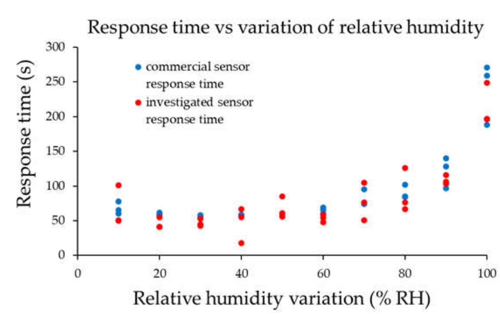


The response of sensor: "RH curve"-blue presented as a function of time for two measurement cycles, when relative humidity was increased in ten steps from 0% RH to 100% RH; "RH curve-red" shows the similar characteristic measured for a commercial, capacitive sensor.





Testing chamber



Conclusions

The RH sensing response of a resistive detector using sensing layers based on a ternary hybrid nanocomposite of CNHox / TiO2 / PVP (2/1/1) was reported. The novel sensitive film used within the design of the chemiresistive sensor exhibited a RT re-sponse comparable to that of a commercial capacitive humidity sensor. The ternary nanohybrid-based resistive sensors' overall linearity – in humid nitrogen when varying RH from 0% to 100% – was shown to beexcellent. The estimated response times were comparable to that of the commercial sensor. Several sensing mechanism hypothesis were discussed according to the possible chemical interaction between oxidized carbon nanohorn, titania, PVP, and water molecules. Although the Grotthus mechanism cannot be excluded, the hole conduction ability of CNHox in conjunction with the swelling of hydrophilic polymer prevails and leads to the overall decreasing conduction of the sensing films.

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