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TRIFLUOROMETHYL-ONION-LIKE CARBON-BASED NANOCOMPOSITE AS SENSING FILM FOR LOW-POWER CHEMORESISTIVE HUMIDITY SENSOR

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Introduction

Humidity sensors play a vital role in the medical field, particularly for monitoring relative humidity (RH) in devices such as respirators, incubators, and sterilizers. Accurate RH control is also critical in hospitals, as it significantly affects the survival of infectious agents and viruses, ensuring patient safety. This study explores a novel chemoresistive sensor based on a nanocomposite matrix composed of trifluoromethyl-functionalized onion-like carbon (CF3-OLC) and polyvinyl alcohol (PVA) in a 1:1 weight ratio, offering a promising approach for precise humidity detection and control.

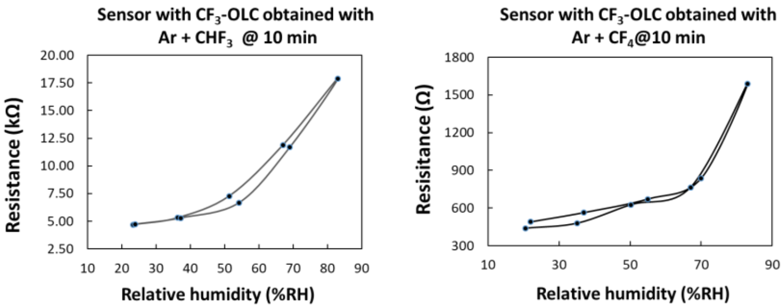
Materials and methods

The CF_3-OLC was synthesized through CF_4-Ar or CHF_3-Ar plasma treatment (4:1 v/v) in a nickel reactor at room temperature and 1 bar pressure. Following this, the CF_3-OLC was dispersed in isopropyl alcohol, while polyvinyl alcohol (PVA) was dissolved in deionized water at 90 °C using an ultrasonic bath for 6 hours. The CF_3-OLC dispersion was combined with the PVA solution, and the mixture was deposited onto the sensing structure using the drop-casting method. The deposited film was then heat-treated at 70 °C under vacuum. Then the mixture was dried at 363 K for 2 hours. The sensor substrate consisted of a 5 mm polyimide (Kapton) sheet with copper electrodes (200 µm width, 5 mm spacing).
The relative humidity (RH) monitoring capability is explored by applying a constant current between the copper electrodes and recording the voltage at different values of the RH level to which the sensitive layer is exposed. The manufactured device was placed in an appropriate testing chamber to measure its resistance change with relative humidity. Dry inert gas (nitrogen) was purged through a series of bubblers

containing demineralized water in order to achieve accurate variations in RH. Different volumes of wet and dry nitrogen were mixed using digital mass flow controllers and delivered to the testing chamber.

Results and conclusions

The surface topography of the sensing film based on the CF_3-OLC/PVA nanocomposite was investigated by scanning electron microscopy (SEM). As depicted, for the whole range of RH, the electrical resistance of the sensing film increased with RH. For low-moderate level of RH, the increase had a moderate slope, while for larger RH, a much steeper increase was obtained. All the experimental results are correlated with type of plasma, exposure time.



(a) (b)

Figure 1. Resistance *vs*. %RH for CF_3-OLC obtained through: a) CHF_3-Ar, and b) CF_4-Ar plasma treatment

Several types of sensing mechanisms are identified and discussed in the view of the recorded data. The hard–soft acid–base (HSAB) principle also supports this mechanism. The hysteresis characteristic of the chemoresistive manufactured device are discussed, also.

The experimentally measured RH sensing response of a chemoresistive sensor using CF_3-OLC and PVA at 1/1 w/w as the sensing film was reported. Experimental results showed that, low and moderate level of RH, the resistance slightly increased with RH, while for larger RH, the resistance increased sharply. Several sensing mechanisms were taken into account and explored, concluding that the p-type semiconductor behavior of the CF_3-OLC and the swelling of the PVA exposed to water explain the behavior of the sensing layer.

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