Hydrophilic oxidized carbon nanohorns/PVP/KCl nanohybrid for chemiresistive humidity sensor

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INTRODUCTION

• In recent years, oxidized carbon nanohorns (CNHox) and their nanocomposites with different polymers and semiconducting metal oxides were employed as sensing layers in the design of several chemiresistive relative humidity sensing structures. This paper reports on the fabrication of a resistive sensor and its RH sensing response; as a sensing layerr, we did prepare and use a ternary nanohybrid composite as comprising CNHox (**Fig. 1**), PVP (Polyvinylpyrrolidone), and KCl; these were prepared at different w/w/w ratios (7:2:1, 6.5:2:1,5 and 6:2:2), and named K1, K2, and K3 respectively. PVP is hydrophilic polymer with excellent film forming properties.

•The sensing structure includes a silicon substrate, a SiO2 layer, and interdigital transducer (IDT)-like electrodes (**Fig. 2**). The sensing film was deposited via the drop-casting method on the sensing structure.

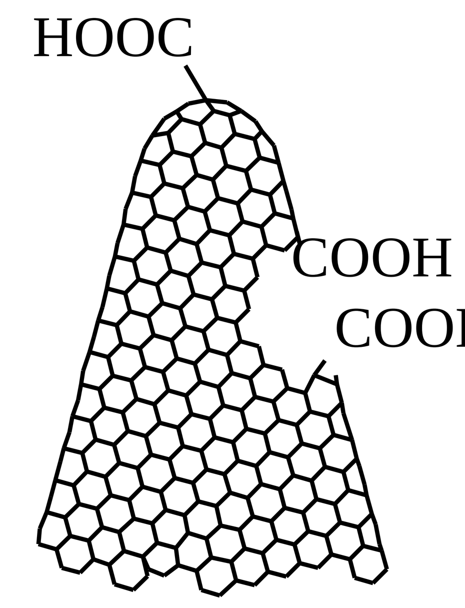


FIG 1 – Structure of oxidized carbon nanohorns (CNH_{OX})

MATERIALS, METHODS, RESULTS

• The test structure consisted of a dual-comb interdigitated transducer (IDT) structure with 100 pairs of Au/Cr fingers, each with a width of 10 µm and 10 µm spacing between two consecutive fingers (**FIG 2**).

• A dispersion formed in isopropyl alcohol of the sensing layer described above, at different w/w ratios, was deposited on the IDT structure by the drop casting method.

•The sensing layers' morphology and composition were investigated through Scanning Electron Microscopy (SEM) and RAMAN spectroscopy (**FIG 3**). The RH capability of the manufactured sensors was investigated by applying a constant current between two IDH electrodes and measuring the voltage at different values of RH. Measurements performed showed that the resistance for one of the sensors (K1) has a linear behavior with the variation of the RH (see **Fig. 4a**), except for the first cycle (RH= 0 up 100 down 0). The response to the RH variations in time was determined using a commercially available state-of-the-art capacitive sensor as a reference (see data plotted in **Fig. 4b**). Two types of sensing mechanisms responsible for the measured RH sensing behavior were identified, which can be discussed in terms of the Hard and Soft Acids and Bases (HSAB) theory.

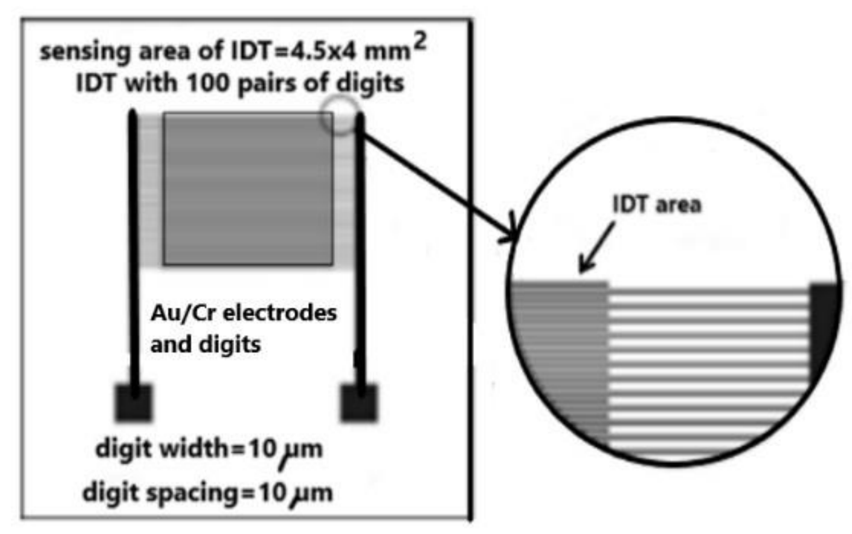


FIG 2 – Schematic layout of the Si chip containing dual-comb IDT transducer. The sensing layer is deposited on the rectangle area of 4.5 x 4 mm^2

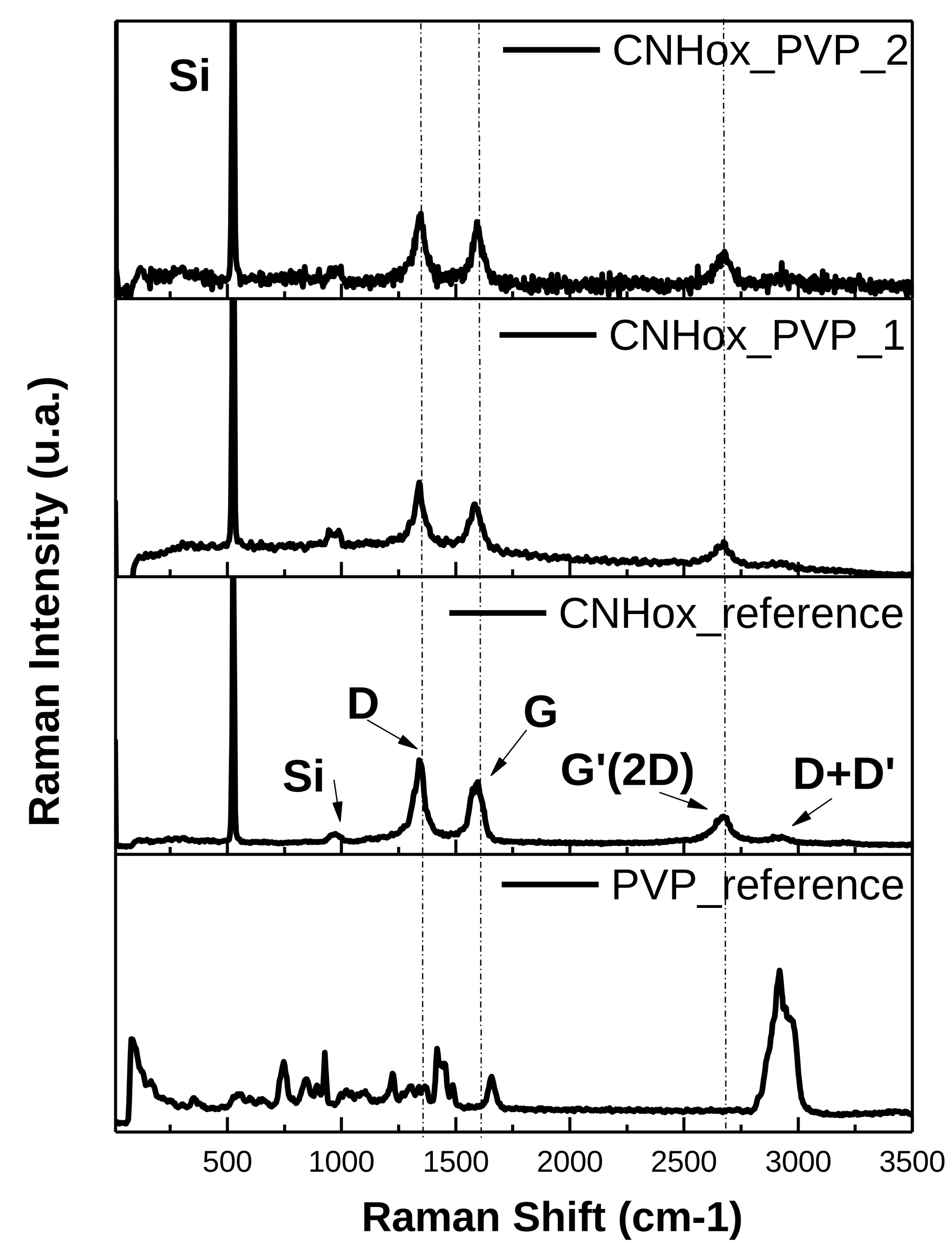
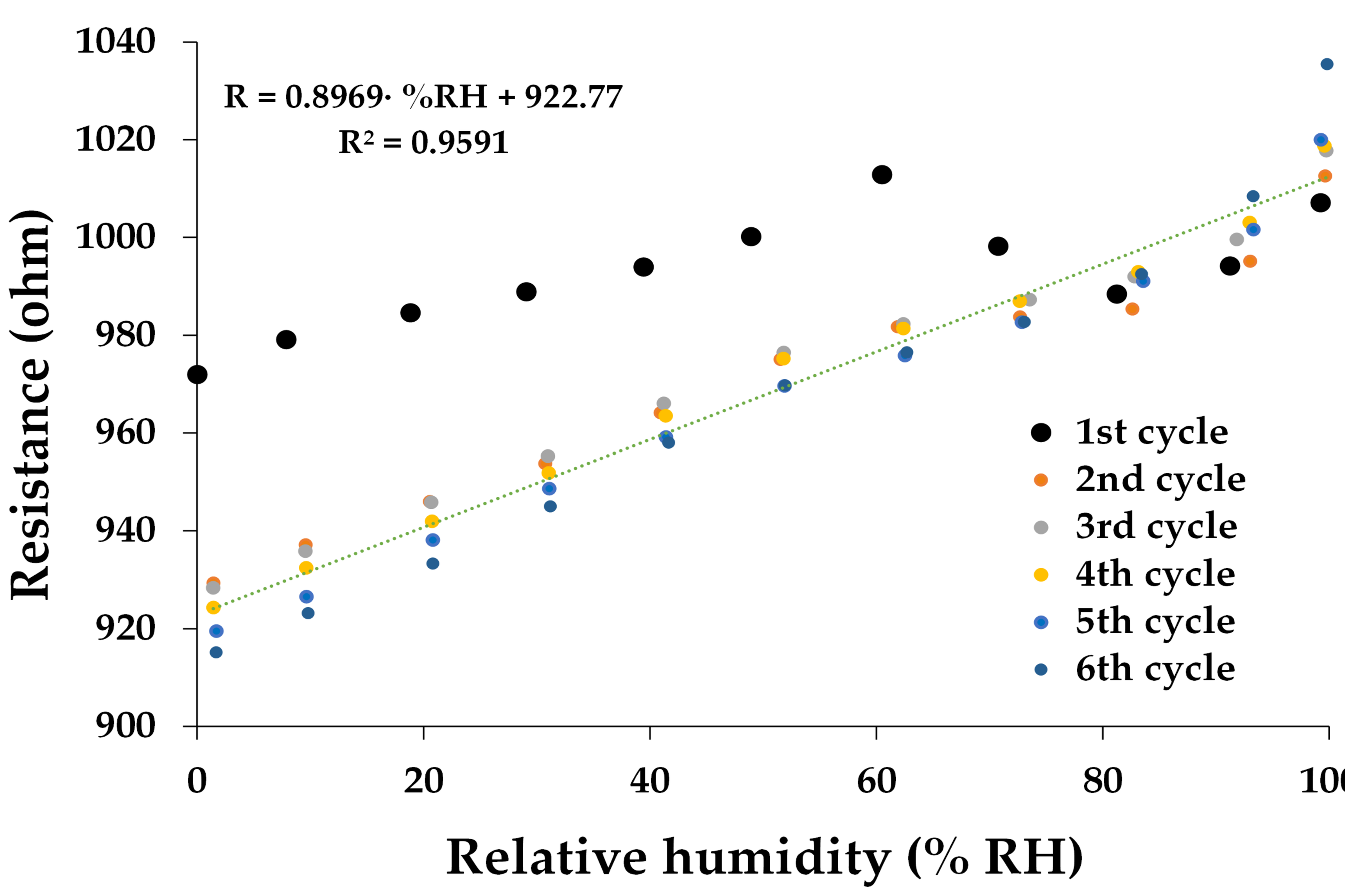


FIG 3 – Raman spectra of CNHox, PVP, and CNHox/PVP nanocomposite



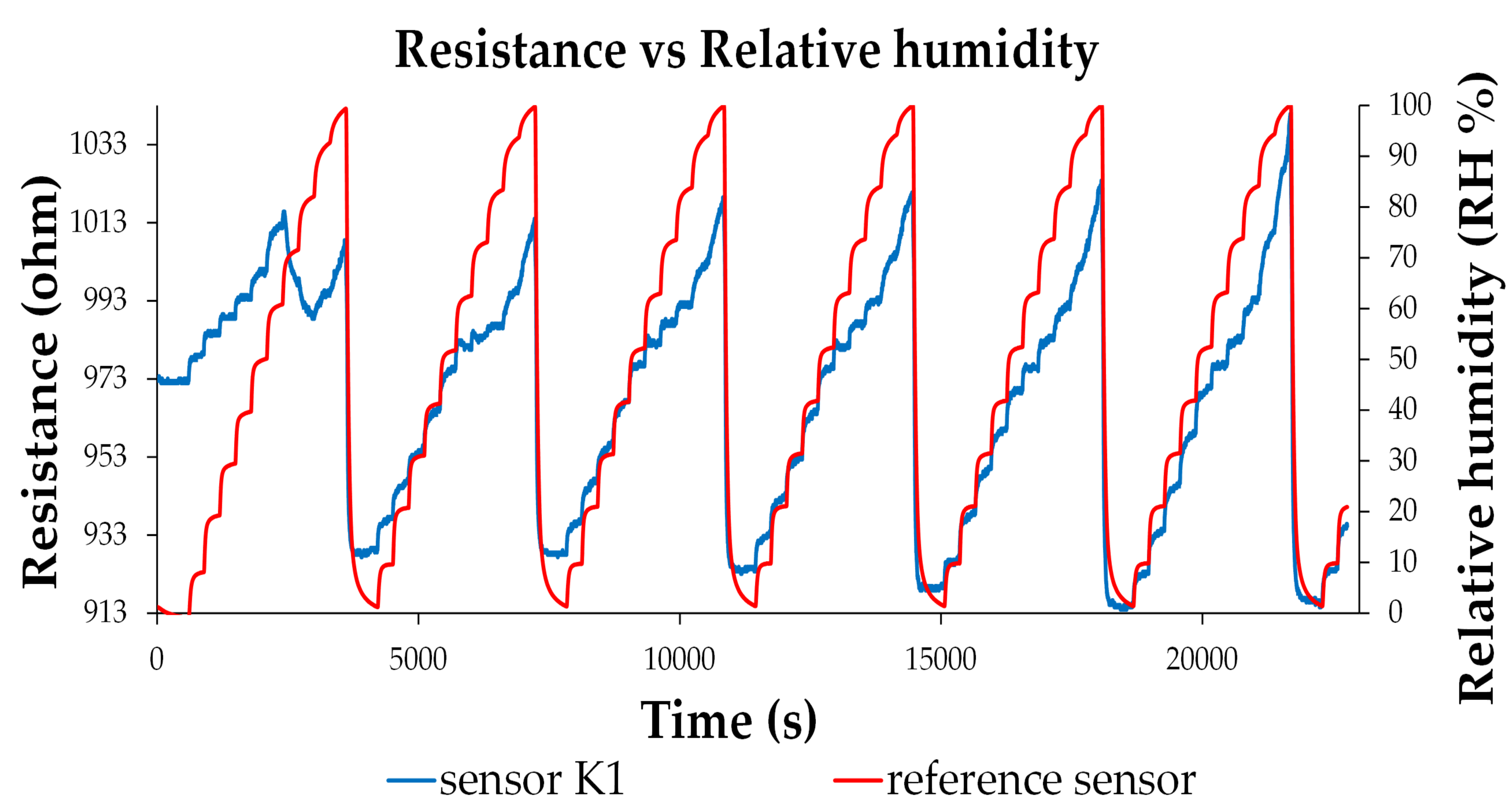


FIG 4 – a. RH response of chemiresistive sensor K1 employing CNHox/PVP/KCl (7:2:1 w:w:w ratio) as sensing layer RT transfer functions of the chemiresistive ethanol sensors employing as sensing layers (left) ox-SWCNH/SnO2/PVP=1/1/1 (mass ratio) and (right) ox-SWCNH; b. Functional response, in time, of the K1 sensor (six complete cycles of RH variation)

CONCLUSIONS

- The resistive RH sensor developed using the nanocomposite CNHox, PVP (Polyvinylpyrrolidone), and KCl, demonstrated a very good sensitivity and time stability, through comparison with an industrial grade, capacitive RH sensor.

ACKNOWDLEGMENT

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