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ELECTRODE SPACING AND HUMIDITY RESPONSE IN CARBON NANO-ONION OXIDIZED NANOHORN POLYVINYLPYRROLIDONE COMPOSITES

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Introduction

Relative humidity (RH) influences air quality, storage conditions, and industrial processes. The previous resistive RH sensors used binary CNO/PVP [1], GO/CNHox/PVP at 1/1/1–1/3/1 mass ratios on 10 µm interdigitated electrodes [2] and CNO/PVA at 1:1 and 2:1 [3]; for CNO/PVP, the steeper high-RH response begins near 50 % RH [3]. Electrode gap is known to change the response regime and stability of humidity sensing films [4].

The present work differs from [1–3] in three respects: (i) the layer is GO-free and CNO-rich (84 wt% CNO), with CNHox only as a 1 wt% additive; (ii) the transition to the high-slope regime shifts to ≈80 % RH, extending the low-slope range compared with CNO/PVP; and (iii) the interelectrode gap (25 vs. 50 µm) is examined as a design variable for the same formulation, which [1–3] did not address.

Materials and methods

PVP (15 mg) is dissolved in 10 mL dimethylformamide/isopropanol (3:1, v/v) by ultrasonication (2 h); CNO (84 mg) is dispersed for 6 h and CNHox (1 mg) is added with 4 h ultrasonication at 50 °C (84/15/1 wt% CNO/PVP/CNHox). The dispersion is drop-cast onto Si/SiO_2 substrates with gold interdigitated electrodes separated by 25 or 50 µm, treated at 200 °C for 3 h under vacuum and dried at 100 °C for 2 h. SEM and Raman spectroscopy (Witec Alpha-SNOM 300 S, 532 nm) are used for characterization.

Resistance is obtained at constant current while RH is changed in 10-point steps.The two response regimes are identified from the change in slope of the R–RH curve. Four 25 µm devices are compared using R_t/R_0.

Results and conclusions

SEM indicates uniform CNO/CNHox dispersion. Raman D and G bands (≈1353 and 1590 cm^{-1}) give I_D/I_G = 0.62 (CNO), 2 (CNHox) and 0.82 (composite); a band near 1650 cm^{-1} supports PVP incorporation.

Table 1 - Quantitative comparison of the two interelectrode gaps

Quantity	**25 µm gap**	**50 µm gap**
Resistance domain	4.90–7.15 kΩ	31–40 kΩ
Relative resistance variation $\Delta R/R_{min}$	46 %	29 %
Low-RH regime: fit range	10–80 % RH	10–80 % RH
Plateaus at fixed RH	stable	drift
Return to 10 % RH / cycle match	slower / consistent	faster / mismatch

Normalization removes the geometric scaling: although the absolute resistance domain is larger for the 50 µm gap (Table 1), the relative resistance variation is 1.6 times higher for 25 µm.

The baseline ratio (baseline ratio = R_{min}(50 µm) / R_{min}(25 µm) ≈ 6.3) exceeds the 2:1 gap ratio expected for a uniform film on otherwise identical electrodes, indicating additional, poorly connected junctions across the wider gap, consistent with its drift at fixed RH. Among four 25 µm devices, R_t/R_0 at 20 % RH spans 1.00–1.15 (≈ ±7 % about the mean), with larger spread near 80 % RH.

Both gaps show a linear low-slope regime up to ≈80 % RH and a steeper, approximately linear regime above it. In the p-type CNO network, adsorbed water reduces the whole population and raises resistance; above ≈80 % RH, PVP swelling additionally separates particles and breaks contacts. The later onset than in CNO/PVP (≈50 % RH [3]) is tentatively attributed to the higher CNO content.

The results favour 25 µm gaps for stable readings and require separate calibration of the two regimes; hysteresis, response times and long-term drift remain to be quantified.

References

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