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OXIDIZED CARBON NANOHORNS AND FLUORINATED GRAPHENE OXIDE ON POLYIMIDE: A RESISTIVE ACETONE SENSING CONCEPT

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Introduction

Room-temperature resistive acetone sensing has been shown with graphene [1] and, on a flexible support, with Na-doped ZnO/rGO down to 0.2 ppm [4]. Hydrothermally fluorinated graphene oxide (FGO) [2] has detected NH_3 and acetone in the low-ppm range [5], and ternary nanohybrids of oxidized carbon nanohorns (CNHox), with a percolating p-type nanohorn network, detected ethanol at room temperature with 15 s response and 50 s recovery [6].

This short communication presents the patented CNHox/FGO formulation and device route as a *sensing concept*. Sensing and mechanical data are not yet available, so the flexibility of the complete device is treated as a hypothesis; we define the strain levels, controls and acceptance criteria for testing it.

Materials and methods

Kapton substrates are cleaned ultrasonically in acetone, ethanol and deionized water (15 min). Commercial carbon nanohorns are oxidized in Ar/O_2 plasma (2:1 v/v, 5 torr, room temperature, 5 min injection and exposure) and washed. FGO is prepared from 100 mg graphene oxide in 50 mL water by hydrothermal treatment with hydrofluoric acid (180 °C, 30 h), then filtered and washed. CNHox (10 mg) is stirred in 30 mL ethanol for 4 h, FGO (2.5 mg) is added and stirring continues for 6 h (CNHox:FGO = 4:1 w/w). The dispersion is drop cast onto Kapton with linear or interdigitated electrodes and treated at 100 °C and 1 mbar for 12 h; resistance is read at constant current.

Planned validation: acetone 25–1000 ppm in synthetic air at 25 °C and 30–70 % RH; response $S = (R_g - R_a)/R_a$, t_{90} response/recovery and LOD = $3\sigma_{noise}/b$ (b, low-concentration slope); three cycles on three devices; ethanol, 2-propanol, NH_3 and water as interferents. Controls: CNHox alone, FGO alone and non-fluorinated CNHox/GO (4:1). Bending uses cylindrical mandrels of radius r = 20, 10 and 5 mm, then up to 1000 cycles at r = 5 mm, with R_a and S at 500 ppm recorded after each step.

Results and conclusions

Strain analysis. For a thin film on a substrate of thickness t_s bent to radius r, the surface strain is $\varepsilon \approx t_s/2r$. For 125 µm Kapton, r = 20, 10 and 5 mm give $\varepsilon \approx 0.31$, 0.63 and 1.25 %; for 50 µm Kapton, 0.13, 0.25 and 0.50 %, bracketing published flexible carbon chemiresistor tests (90° bending, 500 cycles [7]).

Table 1 - Acceptance criteria for the CNHox/FGO concept

Criterion	Target	Basis
LOD (3σ/b)	≤ 25 ppm	0.05 × EU limit, 500 ppm [8]
Response at 500 ppm	> each control	hybrid benefit
t_{90} response/recovery	≤ 2 min	≪ 15-min short-term average
1000 bends, r = 5 mm	$\Delta R_a \leq 5$ %; S ≥ 90 %	design target
RH effect (30–70 %)	ΔS ≤ 20 %	design target

Expected transduction. The acetone carbonyl can hydrogen-bond to hydroxyl and carboxyl groups of CNHox; electron donation lowers the whole density of the p-type network and raises resistance, with an added contribution from CNHox–FGO junctions. Since excessive C–F formation reduces conductivity [3], FGO is limited to 20 wt%, leaving CNHox as the conducting phase.

The contribution is a simple route to a nanohorn-rich layer on polyimide with a quantitative test plan. The device will be described as a flexible acetone sensor only after the sensing and bending criteria in Table 1 are met.

References

[1] Yang, C.-M.; et al. Enhanced acetone sensing properties of monolayer graphene at room temperature by electrode spacing effect and UV illumination. *Sensors and Actuators B: Chemical* 253 (2017), 77–84. https://doi.org/10.1016/j.snb.2017.06.116.

[2] Wang, Z.; et al. Synthesis of fluorinated graphene with tunable degree of fluorination. *Carbon* 50 (2012), 5403–5410. https://doi.org/10.1016/j.carbon.2012.07.026.

[3] Cheng, S.-H.; et al. Reversible fluorination of graphene: Evidence of a two-dimensional wide bandgap semiconductor. *Physical Review B* 81 (2010), 205435, https://doi.org/10.1103/PhysRevB.81.205435.

[4] Zhang, L.; et al. Na-doped ZnO and RGO composite-based flexible acetone gas sensor operated in room temperature. *IEEE Access* 8 (2020), 171568-171574. https://doi.org/10.1109/ACCESS.2020.3023028.

[5] Amor, I.; et al. Hydrothermally fluorinated graphene oxide chemiresistive sensor for detecting NH_3 and acetone under atmospheric conditions. In: Proceedings of BIOSTEC 2021, Vol. 1: BIODEVICES (2021), 99–106. https://doi.org/10.5220/0010241200002865.

[6] Cobianu, C.; et al. Organic–inorganic ternary nanohybrids of single-walled carbon nanohorns for room temperature chemiresistive ethanol detection. *Nanomaterials* 10 (2020), 2552, https://doi.org/10.3390/nano10122552.

[7] Lawaniya, S. D.; et al. Nitrogen-doped carbon nano-onions/polypyrrole nanocomposite based low-cost flexible sensor for room temperature ammonia detection. *Scientific Reports* 14 (2024), 1-14. https://doi.org/10.1038/s41598-024-57153-4.

[8] Commission Directive 2000/39/EC establishing a first list of indicative occupational exposure limit values. *Official Journal of the European Communities* L 142 (2000), 47–50.