DOI: http://doi.org/10.21698/simi.2026.ab12

OXIDIZED CARBON NANOHORN/NANO-ONION/ CARBOXYMETHYLCELLULOSE COATINGS FOR SURFACE ACOUSTIC WAVE ACETONE SENSING: DESIGN AND SENSITIVITY ANALYSIS

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Keywords: *acetone, carbon nanohorns, carbon nano-onions, carboxymethylcellulose, surface acoustic wave sensor design*

Introduction

Surface acoustic wave (SAW) devices convert vapour sorption into frequency or phase shifts. Polypyrrole nanoparticles [1], MWCNT/CeO_2 composites (≈200 kHz acetone shift on a 434 MHz quartz resonator) [4] and suspended graphene on Love-wave devices (sub-ppb acetone) [5] show the attainable range. Carbon coatings respond by mass loading and acoustoelectric coupling [3]; cellulose binders aid film formation but add humidity sensitivity [6].

This short communication presents the patented ox-CNH/ox-CNO/CMC coating and dual-delay-line device as a *design study*; acoustic sensing data are not yet available. We estimate the mass sensitivity and the sorption needed to detect 25 ppm acetone, and define the control coatings.

Materials and methods

Quartz substrates are cleaned ultrasonically in acetone, ethanol and deionized water (10 min). Carbon nano-onions [2] (nanodiamond annealed at 1650 °C in He) and commercial carbon nanohorns are oxygen-plasma treated and washed (ox-CNO, ox-CNH). CMC (2 mg) is dissolved in 10 mL water at 90 °C (2 h); after cooling and filtration, ox-CNO (4 mg, 6 h stirring) and ox-CNH (4 mg, 4 h) are added (ox-CNH:ox-CNO:CMC = 2:2:1 w/w, 1 mg/mL). The dispersion is drop cast on the sensing path of a two-delay-line quartz SAW device and treated at 90 °C and 2 mbar for 2 h; the second path remains uncoated as reference.

Analysis. For an acoustically thin, rigid layer on ST-X quartz, $\Delta f = (k_1 + k_2)\, f_0^2\, m_A$, with $k_1 = -9.33\times10^{-8}$ and $k_2 = -4.16\times10^{-8}$ m² s/kg and m_A the areal mass [7]; elastic and acoustoelectric terms are neglected. *Planned measurements:* coatings C1 (CMC), C2 (ox-CNO/CMC, 4:1), C3 (ox-CNH/CMC, 4:1) and C4 (ternary, 2:2:1) are deposited to the same coating-induced shift Δf_c, so that responses are compared at matched mass, and exposed to 25–1000 ppm acetone (25 °C, 30–70 % RH, three cycles). The differential shift (coated − reference), attenuation and coating conductivity are recorded.

Results and conclusions

Mass sensitivity. Table 1 gives the theoretical sensitivity $S_m = |k_1 + k_2| f_0$ and the areal mass detectable at 3 Hz (3σ) noise.

Table 1 - Calculated mass sensitivity of ST-X quartz SAW delay lines

f_0 (MHz)	S_m (cm²/g)	$\|\Delta f\|$ per 1 ng/cm² (Hz)	$m_{A,min}$ (ng/cm²)
100	135	13.5	0.22
200	270	54	0.056
434	585	254	0.012

Sorption requirement. Sorbed acetone contributes $K \cdot C_v \cdot h$ per unit area (K, partition coefficient; C_v, vapour concentration; h, thickness), the coating ρh, hence $\Delta f_v = \Delta f_c K \cdot C_v/\rho$, independent of f_0 at fixed Δf_c. For 25 ppm (5.94×10^{-8} g/cm³ at 25 °C), $\rho \approx 1.5$ g/cm³ and $\Delta f_c = 100$ kHz, $\Delta f_v \approx 4.0\times10^{-3} \cdot K$ Hz, so 3 Hz requires $K \gtrsim 760$. The hypothesis that H-bonding sites on the oxidized carbons raise K above that of CMC is tested by C1–C4: the ternary coating is beneficial only if its $\Delta f_v/\Delta f_c$ exceeds those of C1–C3. Because CMC is hygroscopic [6], and the reference line cancels shared thermal drift but not coating-specific water uptake, RH must be controlled or co-measured.

The work establishes the coating route, the dual-path design and quantitative targets (≈10 pg/cm² resolution at 434 MHz; $K \gtrsim 760$ for 25 ppm), which measurements on C1–C4 will test.

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