Exploring the Limits of Detection of Nanoporous-Carbon SAW Coatings

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Surface acoustic wave (SAW) devices respond to the presence of gas-phase analyte in the environment with a measurable frequency response due to an increase in the mass of a sorbent surface coating. This response is a function of the analyte concentration. Nanoporous-carbon (NPC) coatings out-perform other commonly used materials by factors of 10-100x at analyte concentrations 1% of their saturation pressures. NPC grows directly on the SAW quartz substrate at room-temperature with negligible residual stress using pulsed-laser deposition in a highly-controlled process, allowing optimization of the coating with respect to mass density and thickness.

We find that adsorption isotherms determined for analyte concentrations ≥ 1% saturation always conform to power-law functions. This is true for NPC and all polymer coatings that we've studied. Plotting a power-law function on a log-log scale results in straight-lines, as shown in fig. 1 for chlorobenzene. The intercept of these lines at $P/P_{sat} = 1$ represents the SAW frequency loss for a fully-saturated stream. The slope of these lines represents a sensitivity factor that appears to be a function of the materials. Clearly, a lower slope will enable measurement of low analyte concentrations at higher signal-to-noise responses.

Extrapolating this relationship toward infinite dilution may provide a prediction of the limits of detection. This is shown in fig. 2. The y-axis minimum is set one order of magnitude above the signal-to-noise limit of our measurement system. The x-axis limit is set intriguingly at an analyte concentration of parts-per-billion.

While this simple model predicts ppb capability for NPC-coated SAW micro-devices, this must be tested. Using a controlled analyte diffusion gas delivery system, we will systematically study the SAW frequency responses for both NPC and an array of polymer-based coatings, and attempt to determine the limits-of-detection for each coating for a wide variety of volatile organic and toxic industrial chemicals. In addition, we will determine the limit of the power-law functional relationship, if it exists.

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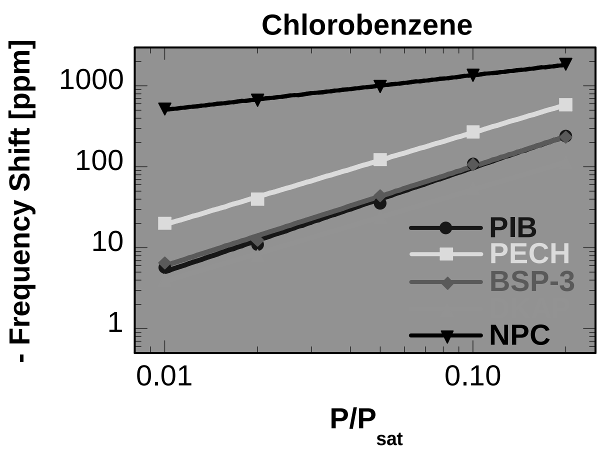

Fig. 1: Log-log representation of the SAW frequency shift for various coatings in response to chlorobenzene from 1 – 20 % of its saturation pressure.

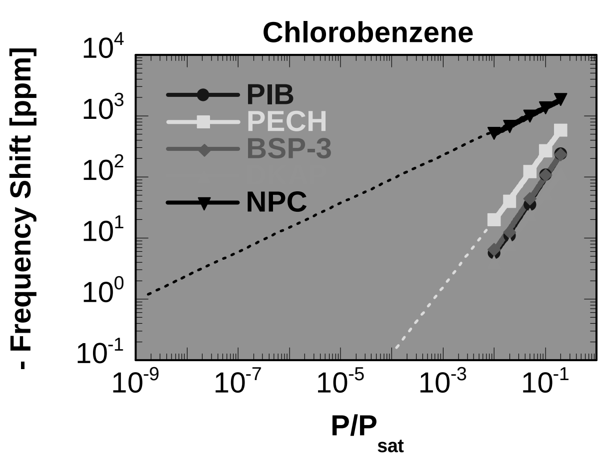

Fig. 2: Extrapolation of power-law functions of isothermal adsorption data to very low dilution limits.