Organic membranes for the permeation of target gases to enhance selectivity in low-cost metal oxide gas sensors.

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As hydrogen (H_2) becomes increasingly integral to Europe's energy strategy, accurate detection is crucial for both safety and cost efficiency. While metal oxide (MOX) gas sensors are sensitive and affordable, they often lack the necessary selectivity in multi-gas environments, leading to unreliable hydrogen concentration measurements. My PhD research focuses on improving the selectivity of MOX sensors by incorporating organic membranes that effectively filter out non-target gases. The core innovation in this work is the use of nanostructured polymers, specifically cellulose nanocrystals (CNC), to develop these membranes. Even when applied in very thin layers, CNC membranes exhibit superior gas barrier properties, making them highly effective at filtering non-target gases while allowing for a rapid sensor response.
We quantitatively characterized the membranes using a quadrupole mass spectrometer (MS) along with a custom setup designed for gas permeability measurements. By creating a step change in gas concentration and monitoring both transient and steady-state transport, we accurately determined the diffusivity and permeability of the membranes to various target gases.
To integrate the membrane into TO-39 bonded sensors and evaluate its effects, we explored various packaging methods. Initially, we used machined caps and FDM-printed PVDF caps. In these iterations, the membrane was synthesized in situ by dropcasting and evaporation, but adhesion issues with the housing led to inconsistent results. Recently, we transitioned to SLA resin-printed caps with embedded self-standing membranes, which ensure uniform thickness and maximize surface area for enhanced hydrogen permeability. Through this iterative approach, we achieved greater control over membrane uniformity, established a reproducible and efficient manufacturing process, and significantly reduced leaks.
To test the sensors, we used a custom setup that included mass flow controllers (MFCs) for gas mixing and delivery into a sensor chamber, with a custom PCB providing power and enabling sensor data readout. This setup allowed for precise control over gas exposure, ensuring reliable sensor characterization.