

Development of a Passive Capacitive HF Sensor

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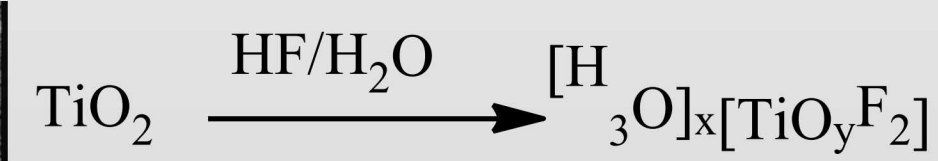
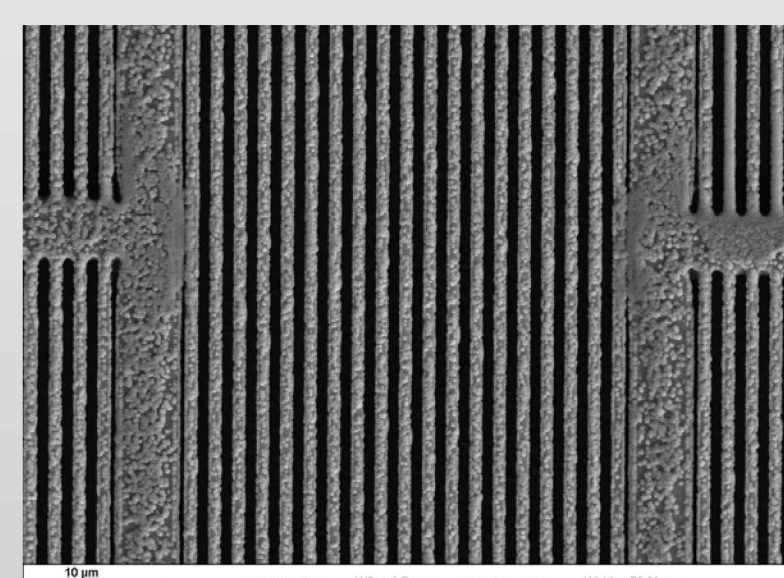
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Objective: Development of a capacitive sensor to passively monitor an area for the presence of hydrogen fluoride (HF) gas and provide a cumulative record of HF exposure.

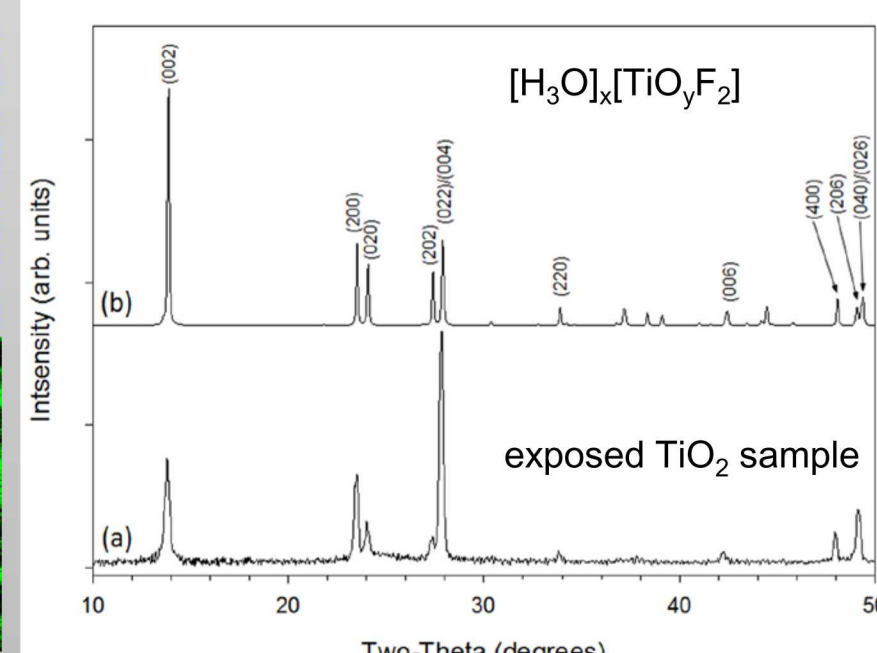
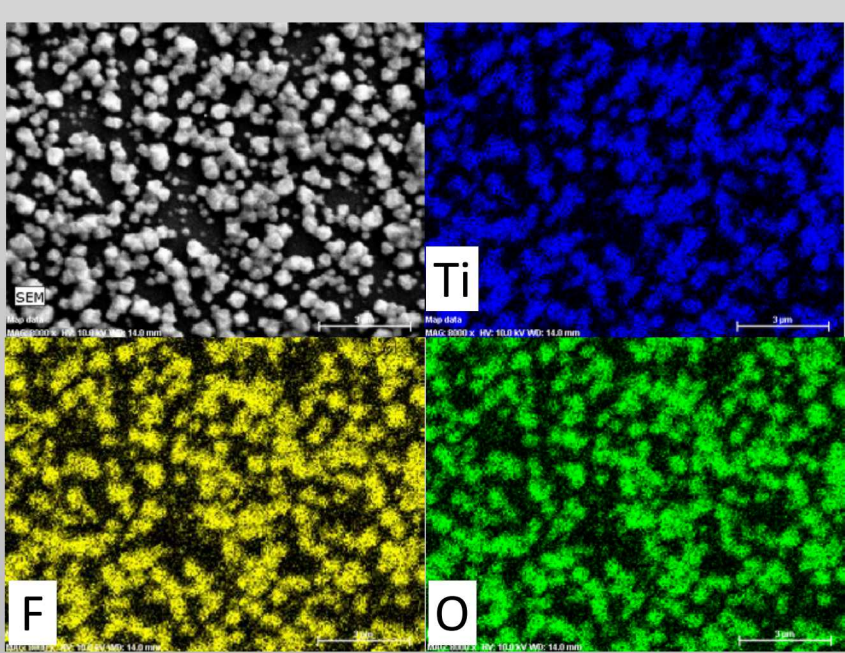
Introduction: Hazardous chemical detection is an important capability for a variety of industrial and manufacturing processes. Hydrogen fluoride and hydrofluoric acid are commonly used in a wide range of industrial processes. Currently available commercial approaches for chemical monitoring are based on active detection systems that must be powered, or are passive technologies that typically require offsite, and ultimately delayed, analysis. Although many different technologies are available there remains a need for robust passive devices that can provide long-duration cumulative sensing of HF in challenging environments, where hazards, accessibility, or space limit the use of active devices.

Results: Materials R&D

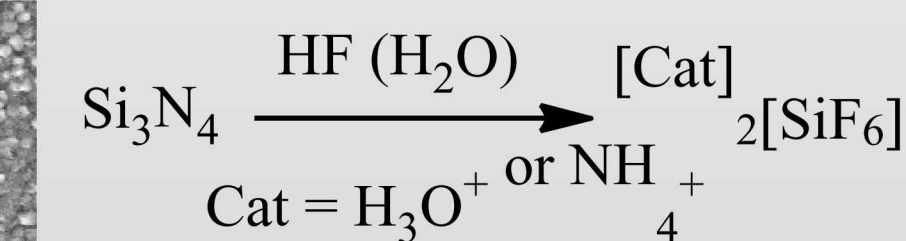
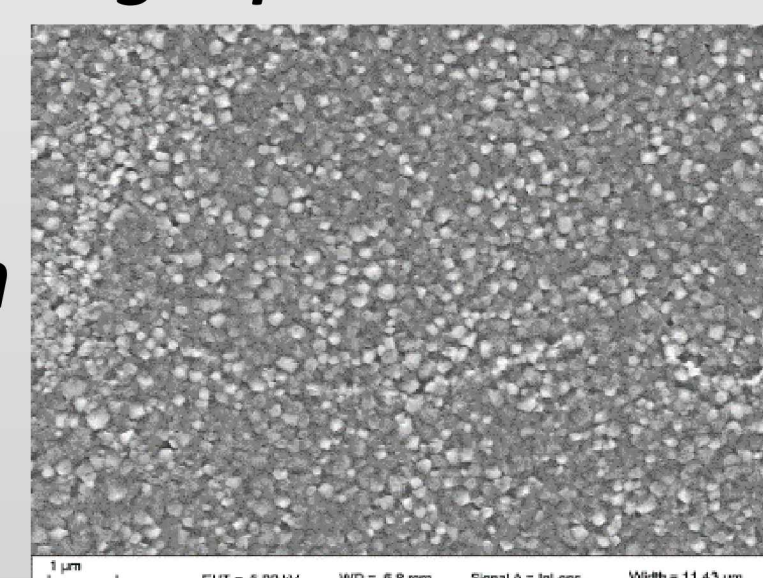
amorphous TiO₂



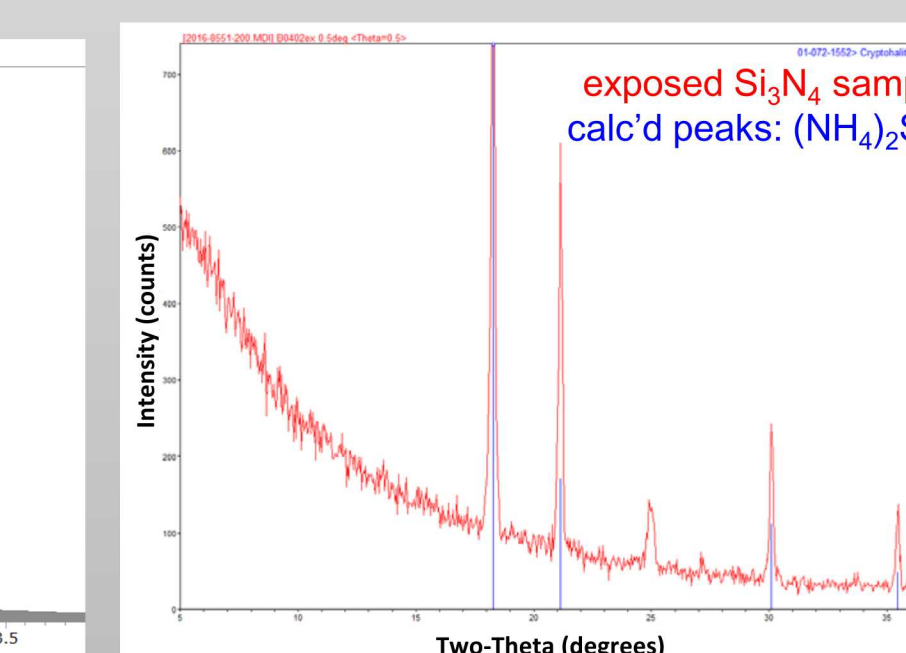
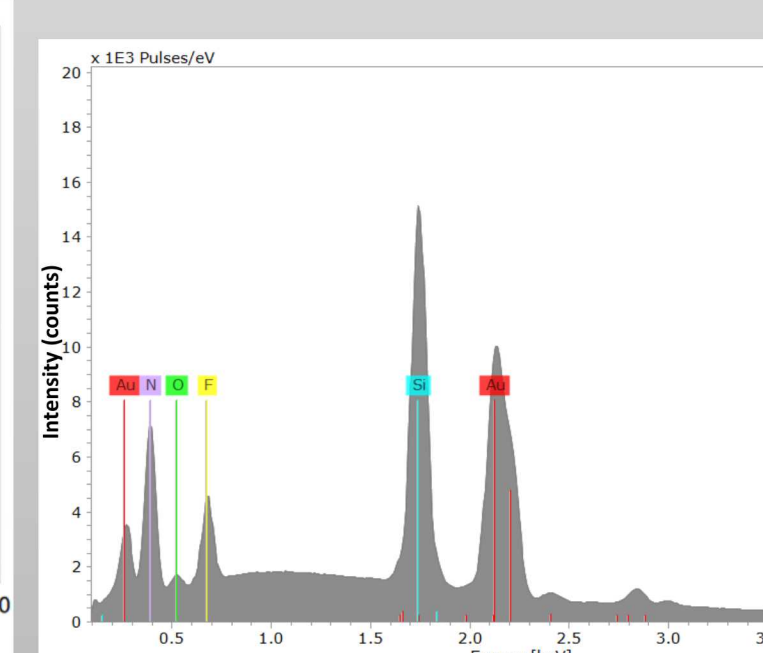
No detectable reaction under dry/low humidity conditions.



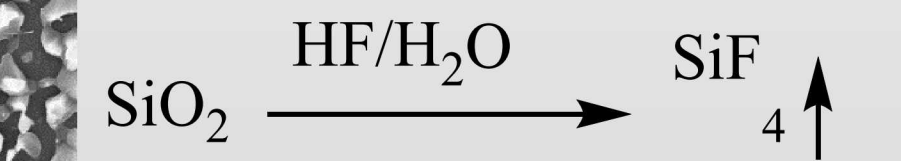
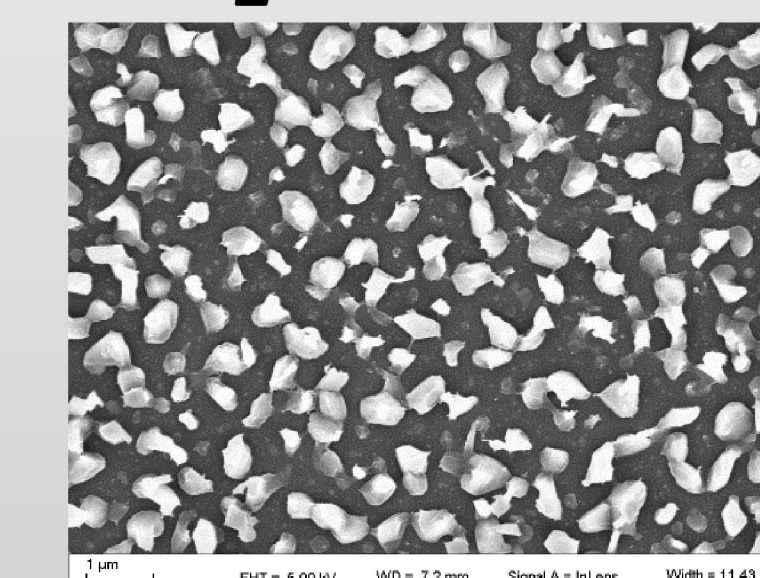
Si₃N₄



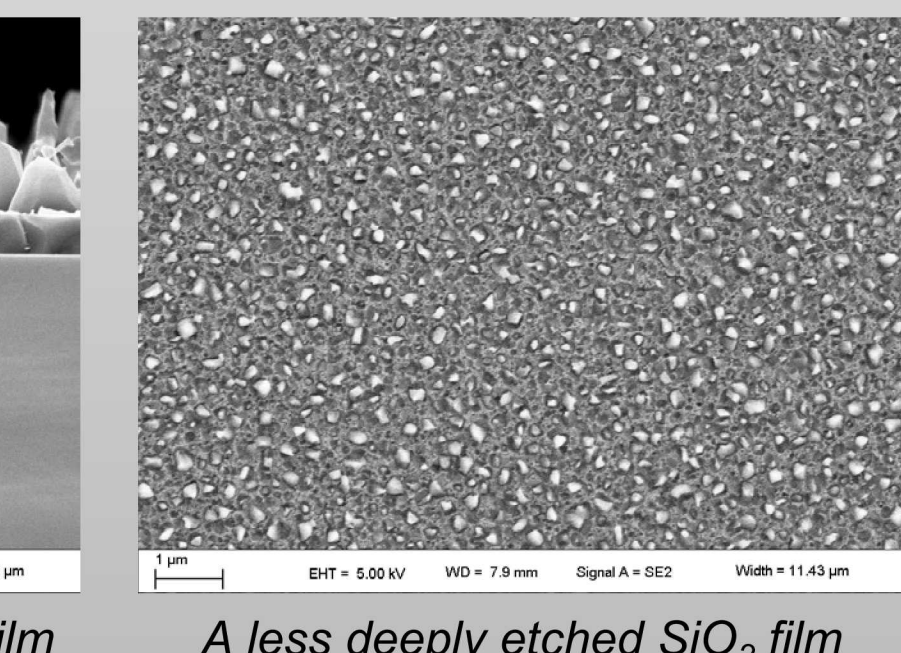
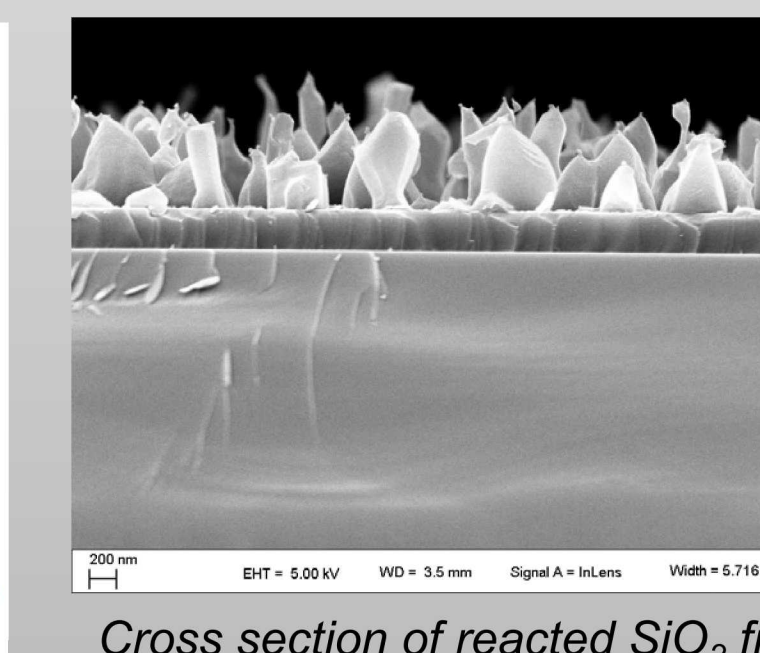
Si₃N₄ reacts even under dry conditions.



SiO₂



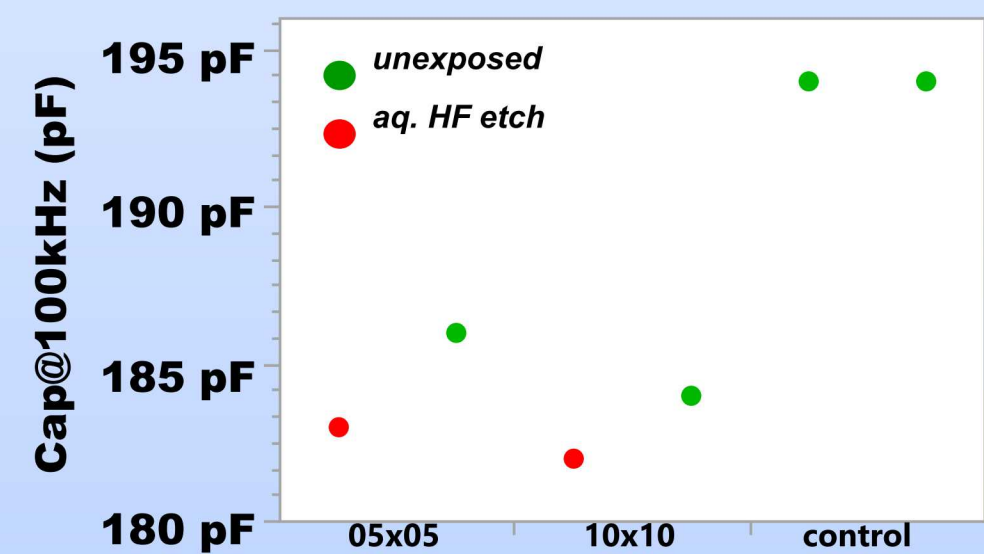
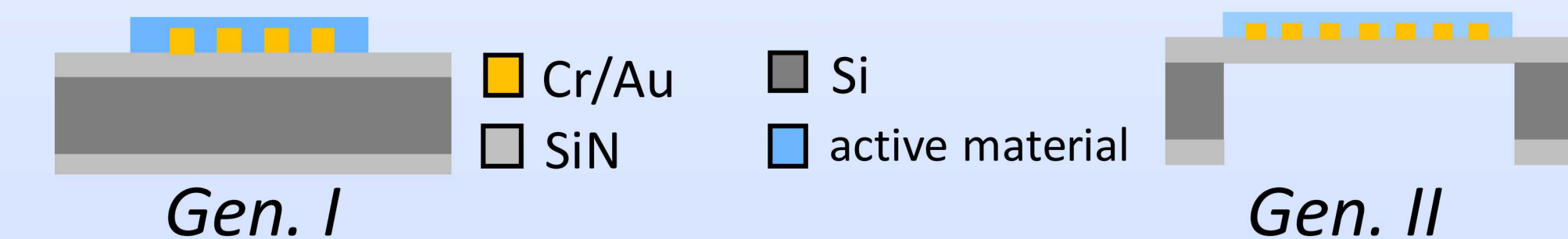
SiO₂ is etched away, leaving no reaction product behind.



Cross section of reacted SiO₂ film

A less deeply etched SiO₂ film

Results: Capacitive Sensor Design

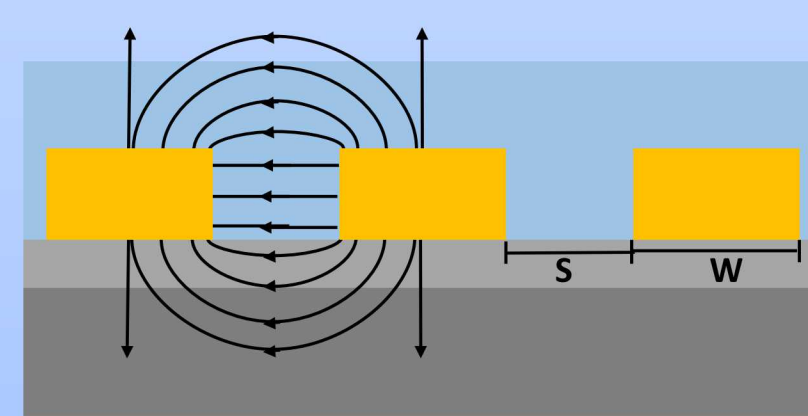


Gen I: Complete etch of SiO₂ only results in 2-3pF change in capacitance.

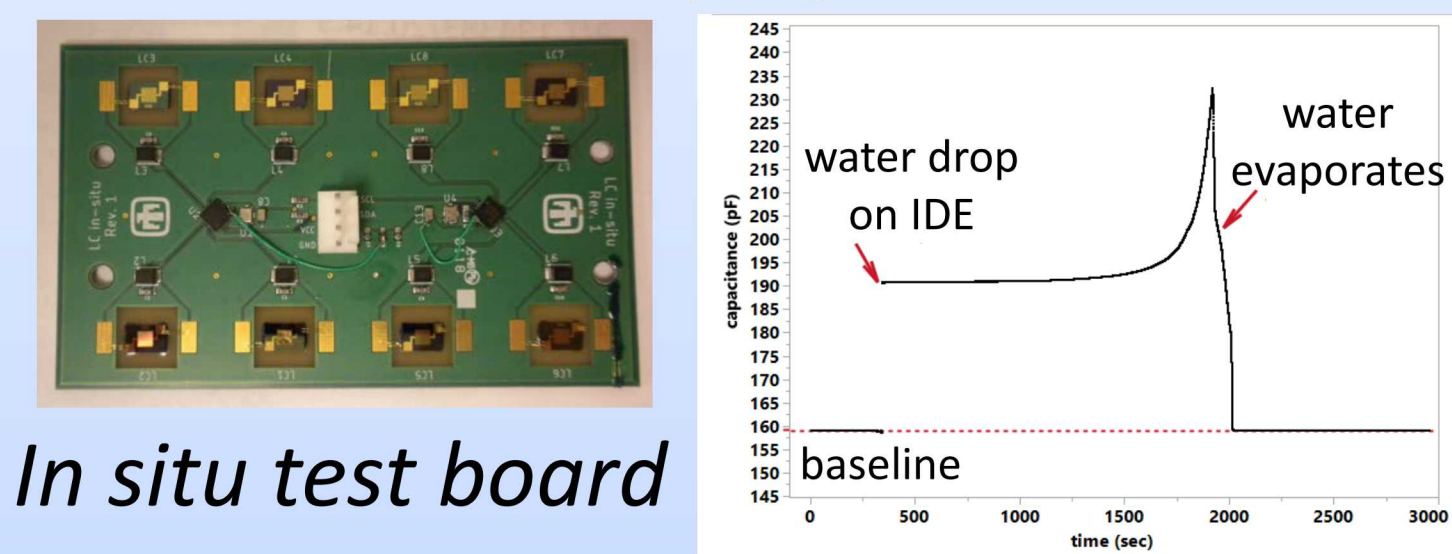
Small relative change due to parasitic and substrate capacitance

Gen II: Suspended design

- Reduces parasitic capacitance due to mirror charge formation
- Increase relative ΔC on exposure

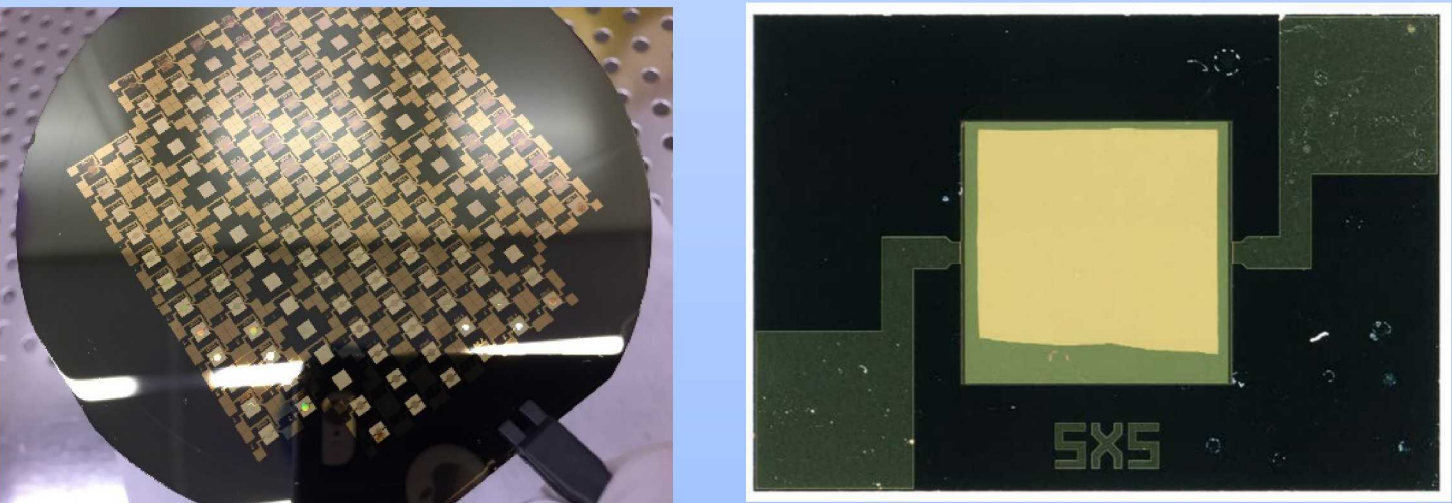


Developing in situ testing to monitor real-time sensor performance



Chip size relative to a dime and SEM of IDE area (Gen. I)

Wafer (L) and individual tag (R).



Results: Materials Sensitivity

Exposure parameters evaluated qualitatively by SEM. Parameters include: HF concentration, exposure duration, and relative humidity during exposure.

Si₃N₄

HF	Time	no RH	10-15%	25-40%
<10 ppm	Short (6 h)			
	Medium (14 h)			
	Long (24+)			
>10 ppm	Short (6 h)			
	Medium (14 h)			
	Long (24+)			

No detectable change
Detectable change

SiO₂

HF	Time	no RH	10-15%	25-40%
<10 ppm	Short (6 h)			
	Medium (14 h)			
	Long (24+)			
>10 ppm	Short (6 h)			
	Medium (14 h)			
	Long (24+)			

TiO₂: The reaction with HF is much slower than the reactions with Si₃N₄ or SiO₂, but TiO₂ is sensitive to low concentrations over long duration exposure times.

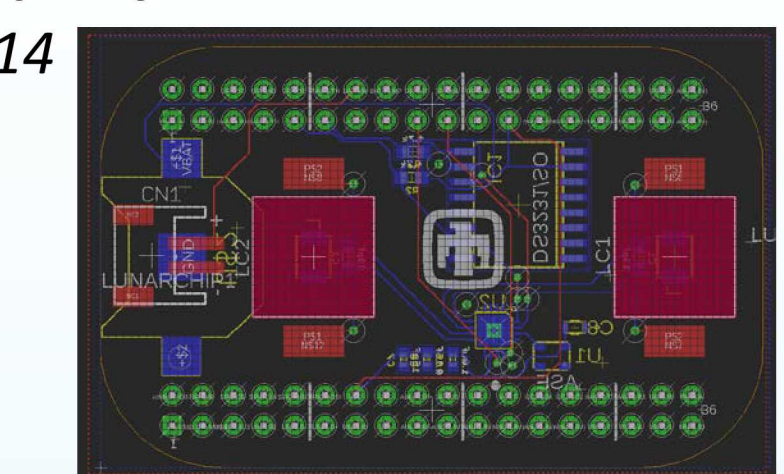
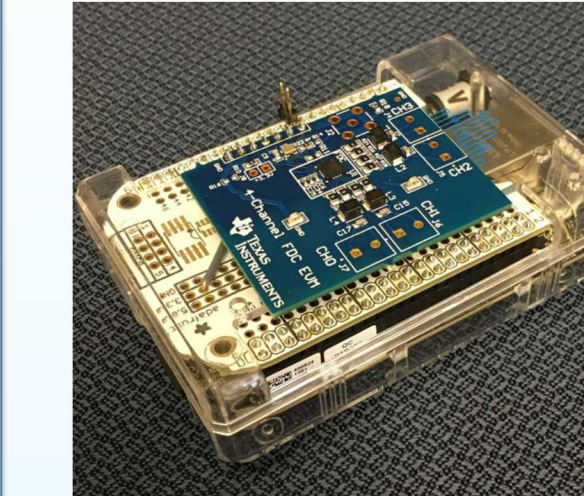
All three materials have advantages for different CONOPS. Future work will leverage multi-material tags to function in a broad range of exposure conditions.

Future Work:

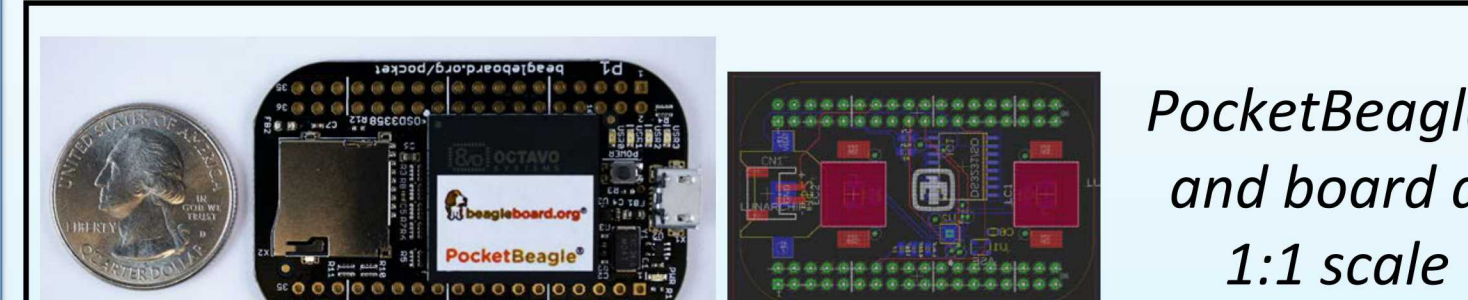
Characterize dose/response with in situ capacitive sensors and readout. Characterize response linearity vs. concentration and environmental conditions.

Integrate with BeagleBone® platform for prototype deployable device.

BeagleBone® with FDC2114 Evaluation Module



Board design for integration with PocketBeagle®



PocketBeagle® and board at 1:1 scale

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