# Extremely Thin Chemical Sensor Arrays Using Nanohole Arrays

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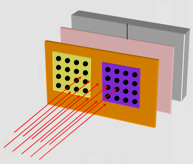
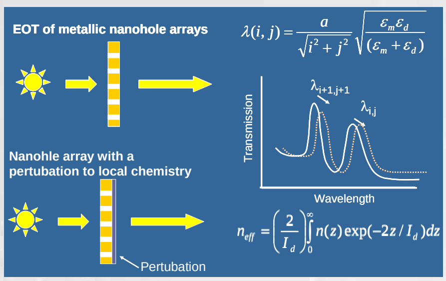
## Problem

Periodic arrays of nano-scale holes have emerged as a plausible platform for compact chemical and biological sensors. These sensors are made by fabricating sub-wavelength holes (~50-200nm for visible light) with spacings of 200-1300nm onto thin metallic layers. Although subwavelength, a disproportionate amount of light is transmitted through these holes by coupling to surface plasmons, in what has been termed "extraordinary optical transmission" . This transmission is sensitive to the microscopic surface chemistry in the vicinity of the nanoholes. By using these nanohole-arrays in transmission mode, with small areas functionalized with specifically designed molecules to ligate desired analytes such as explosives and chemical weapons agents placed directly on top of thin photodiode arrays (<50um), we can realize extremely compact chemical sensor arrays.

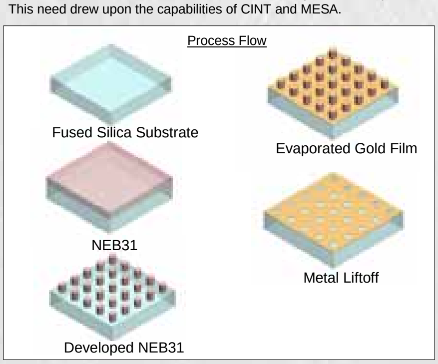


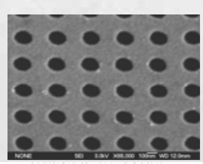


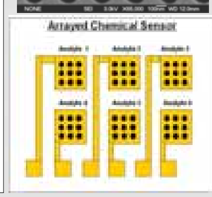

## Approach

### Fabrication at Sandia

The realization of these small sensors relied heavily on the ability to fabricate nano-scale devices. This need drew upon the capabilities of CINT and MESA.



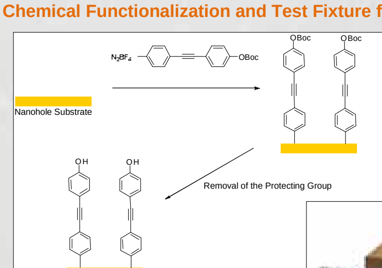






Nanohole arrays were fabricated using negative tone e-beam lithography. The steps for this process are as follows:

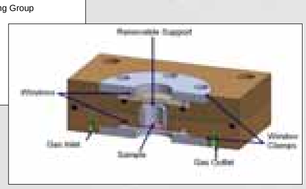
1. A flash layer to prevent charging is applied to the surface of a fused silica substrate.
2. Negative tone resist (NEB31) is spun onto the substrate for the patterning of the nanohole-array.
3. The resist is patterned by an JEOL 9300FS lithography tool and developed leaving behind pillars of resist.
4. 10 Å of Titanium and 500 Å Gold is evaporated onto the surface to form the metallic film.
5. The remaining resist is lifted off with NMP to form the nanohole-array.

### Chemical Functionalization and Test Fixture for Gas Detection

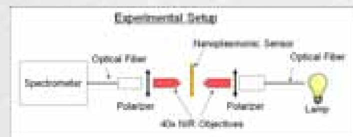


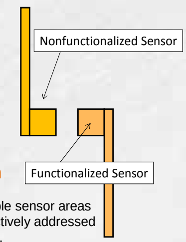

The voltage selective functionalization allows for

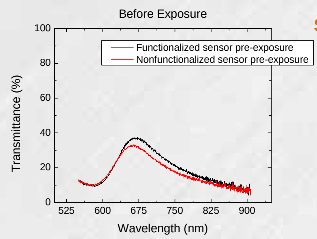
- Very small sensing surfaces
- A variety of chemistries
- Multiplexed Sensing




## Results

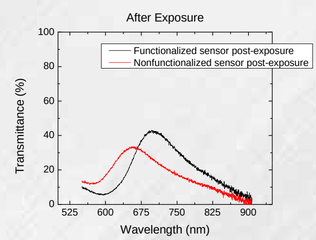


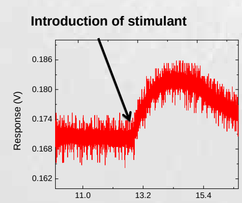

### Spectral Calibration

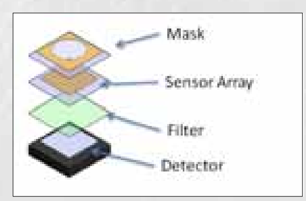
- Single detector with multiple sensor areas
- Each Sensor can be selectively addressed during the functionalization.
- Nonfunctionalized surfaces show no improved adherence to DMMP




### Sensor Prototype

- Illuminated with room light
- Photocurrent changes when sensor is loaded with stimulant
- Future steps underway to make package smaller and include differential sensing




## Significance

There is a lack of compact and thin chem-bio sensors. This approach provides such a solution and could be integrated with processing electronics. Since this sensor relies on light transmission it could also work with ambient light. These types of thin sensors can have multiple applications in national security, surveillance, non-proliferation, and the security of our armed forces.

### Partial List of References

[1] T. W Ebbesen., H. J Lezec, H. F.Ghaemi, T. Thio and P.A. Wolff, "Extraordinary optical transmission through sub-wavelength hole arrays," Nature **391**, 667–669 (1998).
[2] L. Martin-Moreno. et al. "Theory of extraordinary optical transmission through subwavelength hole arrays," Phys. Rev. Lett. **86**, 1114–1117 (2001).
[3] C. Genet and T Ebbesen , " Light in tiny holes," Nature **445**, 42-46 (2007).
[4] Y. Liu, J Bishop., L. Williams, S. Blair and J. Herron, "Biosensing based upon molecular confinement in a metallic nanocavity arrays," Nanotechnology **15**, 1368–1374 (2004).
[5] K.A. Tetz, L. Pang, and Y. Fainman, "High-resolution surface plasmon resonance sensor based on linewidth-optimized nanohole array transmittance," Opt. Lett., **31**, 1528-1530(2006).
[6] Jung, L. S., C. T. Campbell, et al. (1998). "Quantitative Interpretation of the Response of Surface Plasmon Resonance Sensors to Adsorbed Films." Langmuir **14**(19): 5636-5648.

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