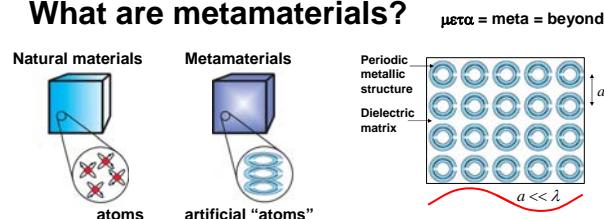


# Terahertz Metamaterials on Thin Silicon Nitride Membranes

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## What are metamaterials?

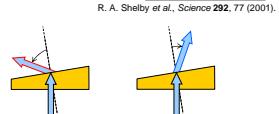


**Metamaterials** are artificial materials with designed electromagnetic properties that go **beyond** those of naturally occurring materials.

### Example: Negative Index of Refraction

Microwave prism - a quasi 3D structure formed of double split-ring resonators and wire arrays.

R. A. Shelby et al., *Science* 292, 77 (2001).

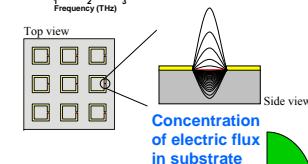


Negative index material  
Normal material  
No equivalent fabrication process at higher frequencies

### Application: Biosensing

Transmission  $\propto \frac{1}{1 + \frac{\omega_{res}}{\omega}}$

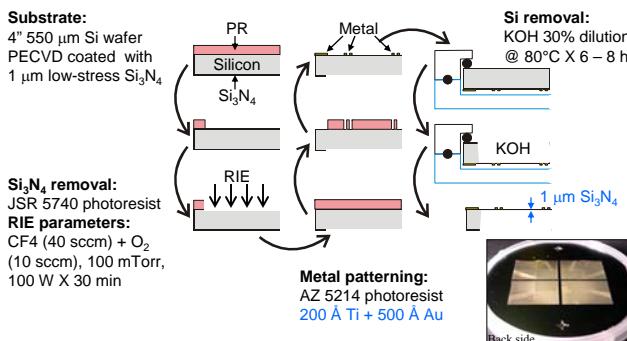
Detection scheme: Modify the dielectric in the gap to modify the resonance.



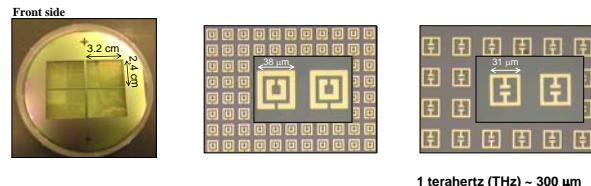
## Why metamaterials on membranes?

- They provide a path towards 3D metamaterials.
- Impose symmetry on the electric flux distribution.

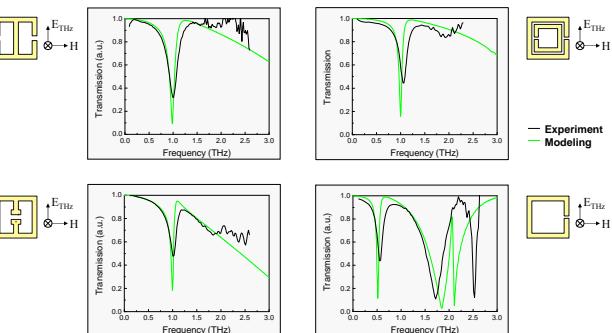
## Fabrication



## Planar metamaterials on SiN membranes



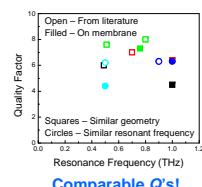
### Experiment and electromagnetic modeling of THz transmission spectra



Differences may be attributed to:

- Constant dielectric permittivity used in EM modeling.
- Effect of higher-order modes.

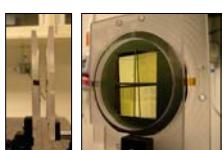
## Comparison to thick substrates



From the literature:  
Substrate materials: Quartz, GaAs, Si  
Thickness range: 1.03 mm - 640 μm

- Consider effect of coupling between resonators.
- Metallization thickness 70 nm vs. (3 μm - 200 nm).

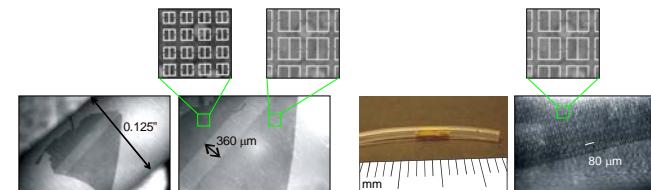
## Stacking



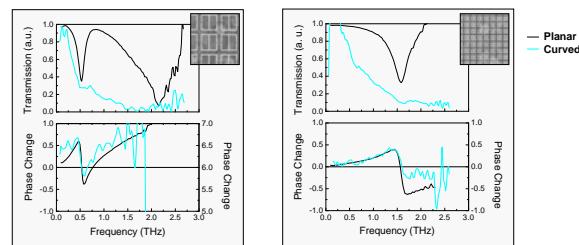
Limited to two layers due to substrate thickness.

Membrane removal allows multilayer stacking.  
Can also make curved metamaterials!

## Curved metamaterials on SiN membranes



### THz transmission spectra of a metamaterial covered membrane on a Teflon tube



- Small decrease in transmission at resonance.
- Uniformly decreasing background in transmission.
- Clear resonance in phase change data.

## Conclusions

- Fabricated THz metamaterials on large-area, free-standing, 1 μm Si<sub>3</sub>N<sub>4</sub> membranes.
- Obtained comparable quality factors to those fabricated on thick substrates so they can still be used for sensing.
- Implemented a double layer THz metamaterial scheme.
- Identified a route for membrane liftoff.
- First implementation and characterization of curved THz metamaterials.

## Future work

- Characterize THz metamaterial bilayer.
- Implement membrane liftoff technique.
- Study curved THz metamaterial's response.

## Acknowledgements

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## References

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