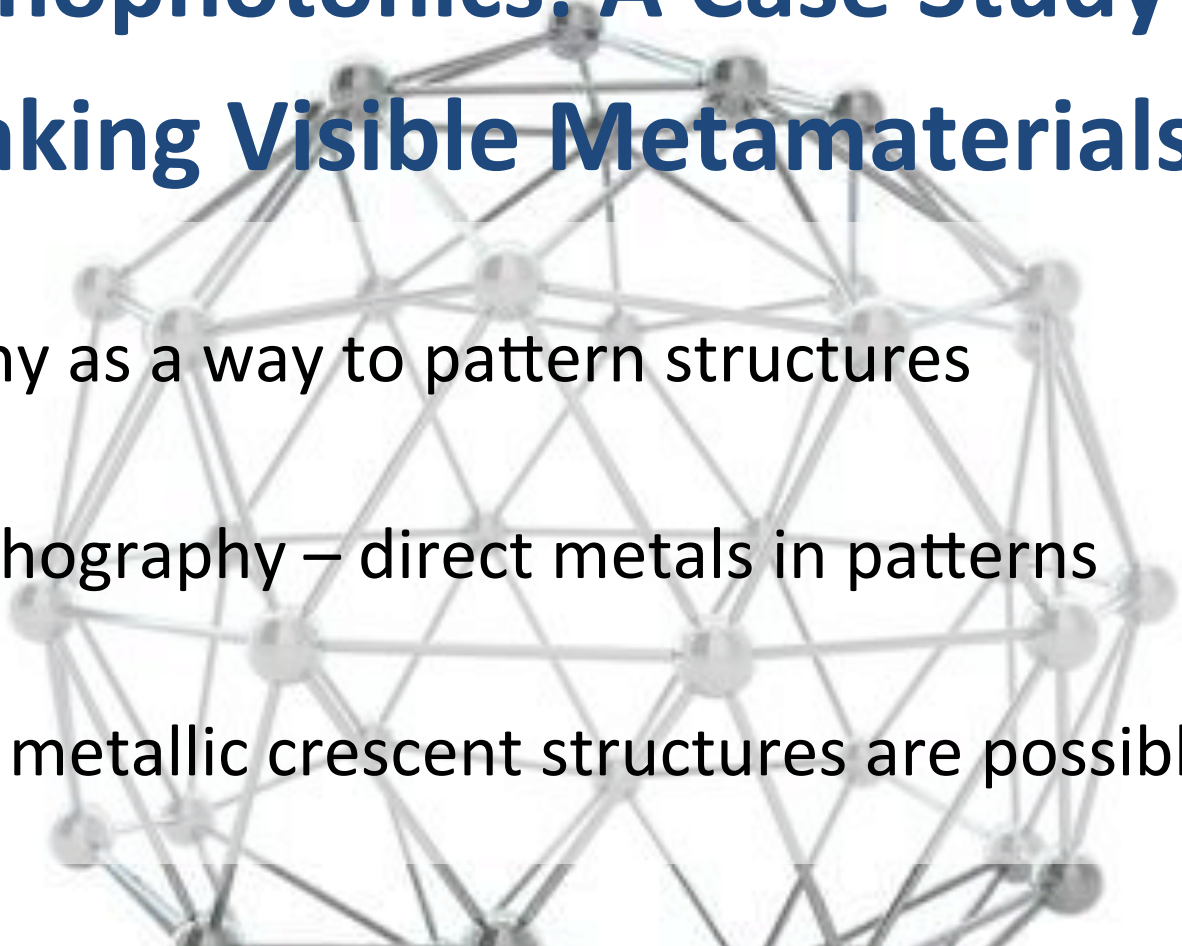


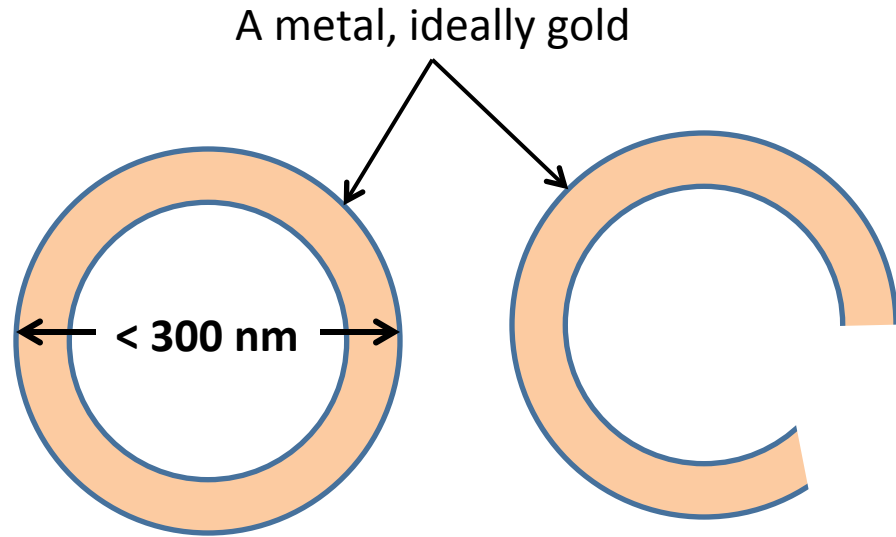
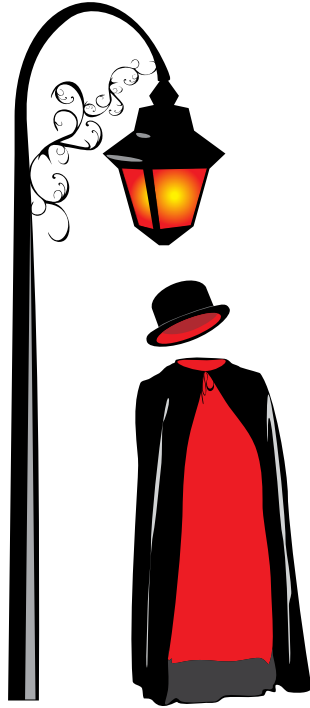
Nanophotonics: A Case Study

Making Visible Metamaterials

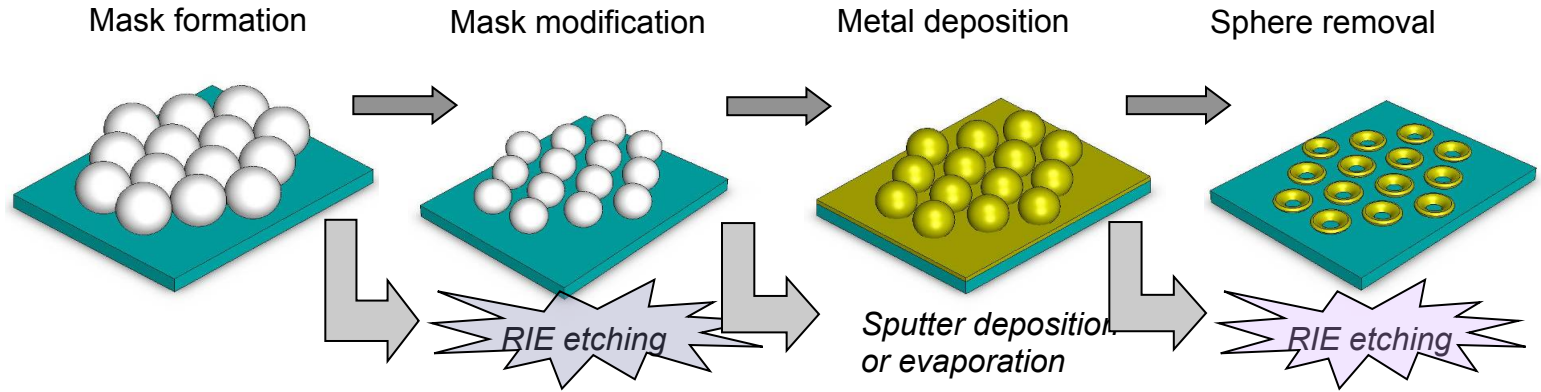
- Soft lithography as a way to pattern structures
- Shaped soft lithography – direct metals in patterns
- Large areas of metallic crescent structures are possible



Our Goal: Rings and C-Structures

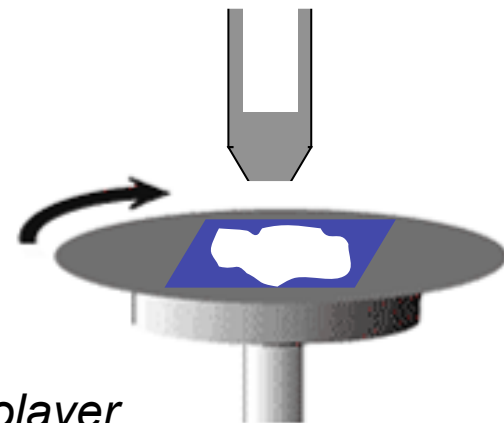


Shaped Soft Lithography

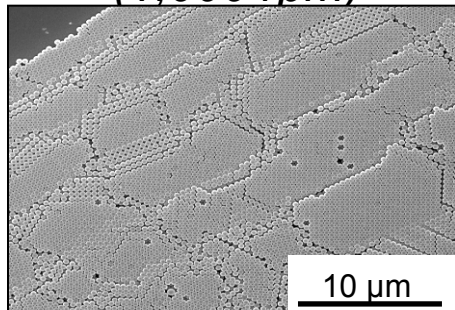


Step 1: Forming the Mask

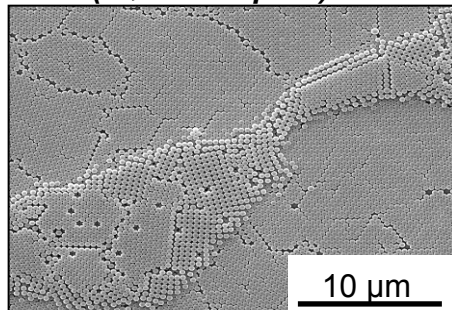
A drop of solution containing polystyrene spheres is placed on the substrate. The fluid is rotated at high speed to spread the fluid by centrifugal force and form a hexagonal closed-packed array of nanospheres. The coating thickness is adjusted by the spinning speed



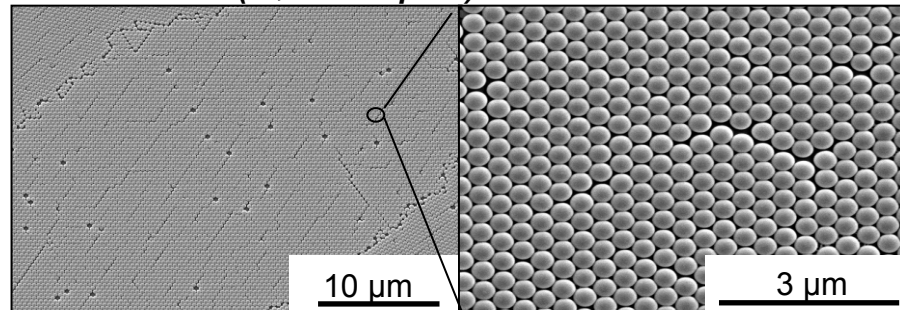
*Multilayer
(1,000 rpm)*



*Double layer
(2,000 rpm)*

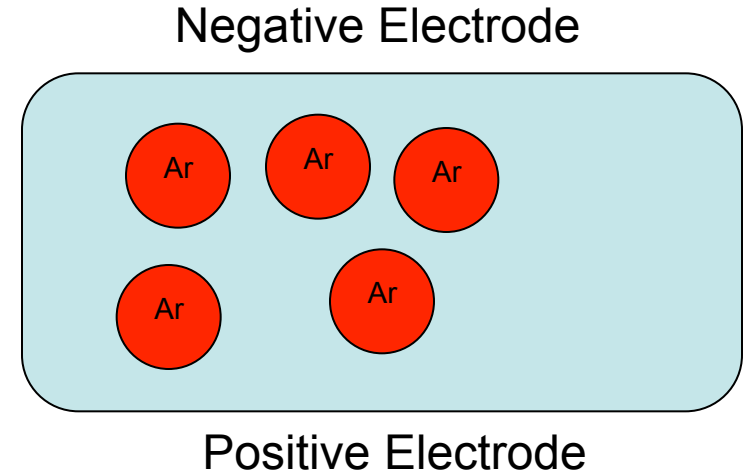
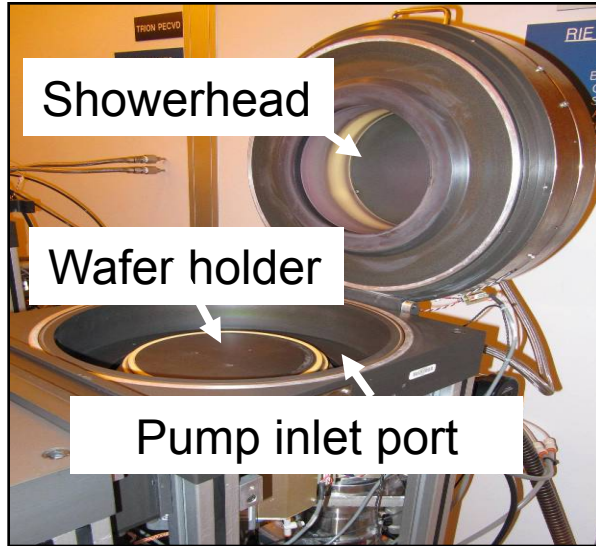


*Monolayer
(3,000 rpm)*



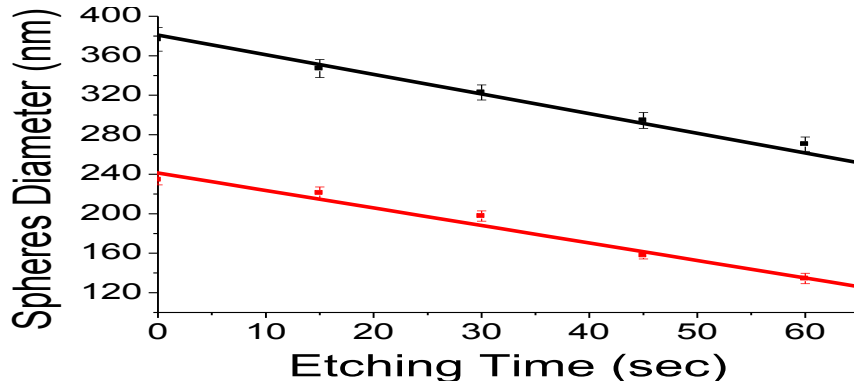
Plasma etching shapes the spheres

Open RIE chamber

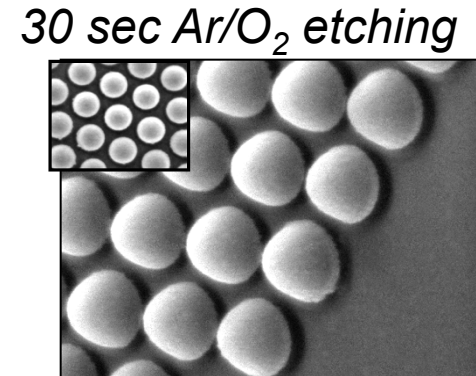
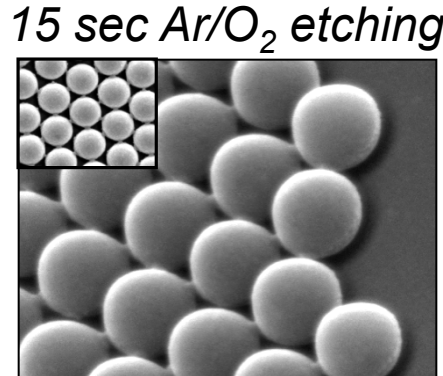
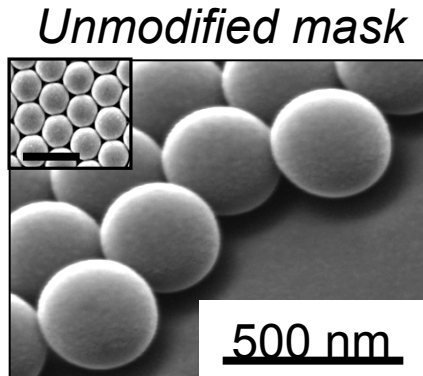
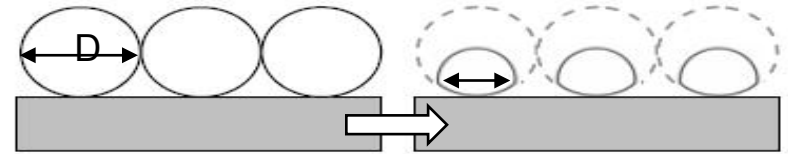


RIE etching uses plasma to remove material deposited on wafers. Plasma is initiated in the system by applying RF (radio frequency) electromagnetic field (13.56 MHz) to the wafer holder. The oscillating electric field ionizes the gas molecules by stripping them of electrons and creating a plasma. Ions drift toward the wafer platter, where they collide with the samples to be etched.

Ar/O₂ plasma etching for mask modification



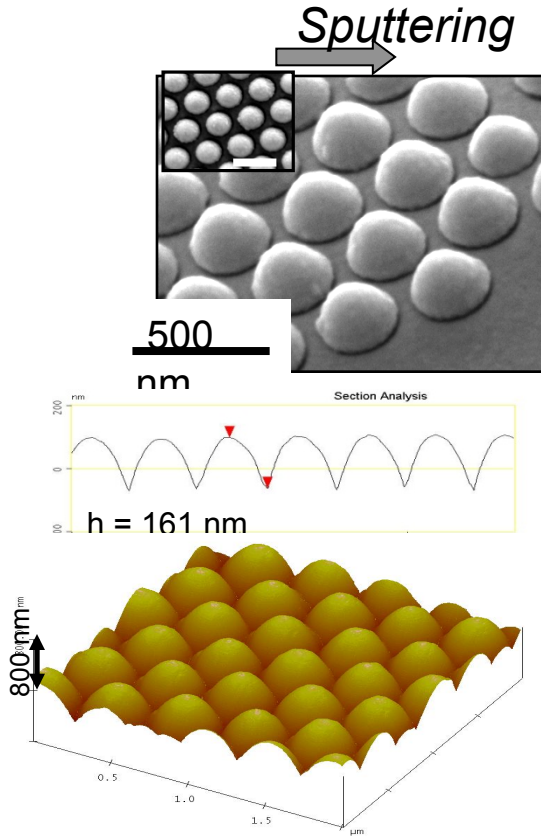
The size of the polystyrene spheres defines the diameter of the nanorings.



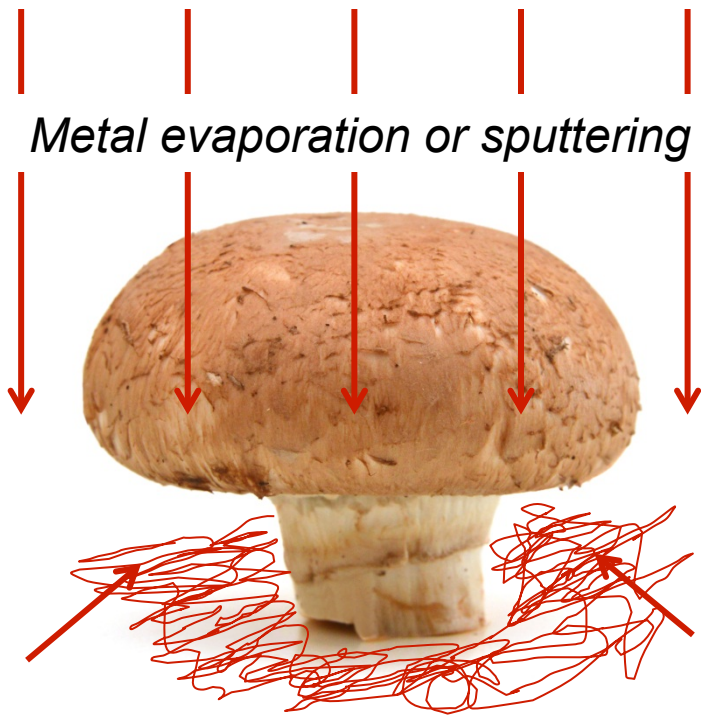
What the etching does



Applying and Removing Metal to the Mask



Laying the Metal Down

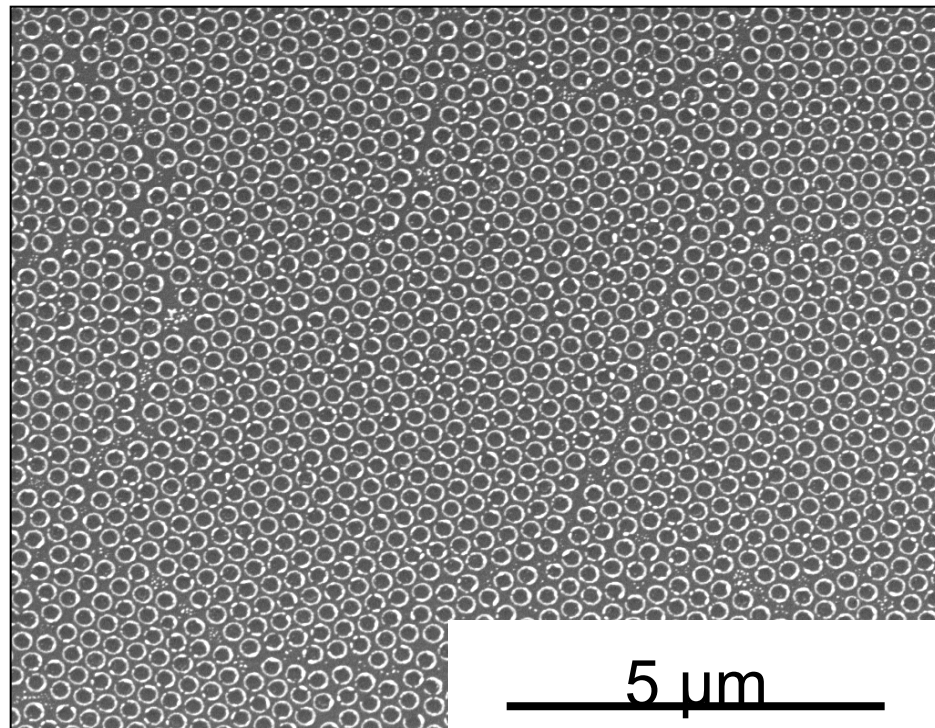
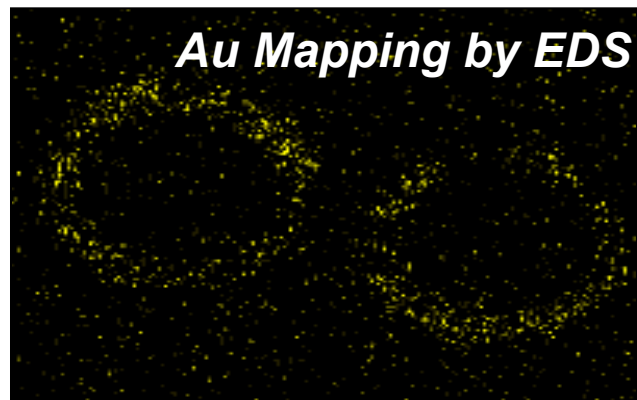
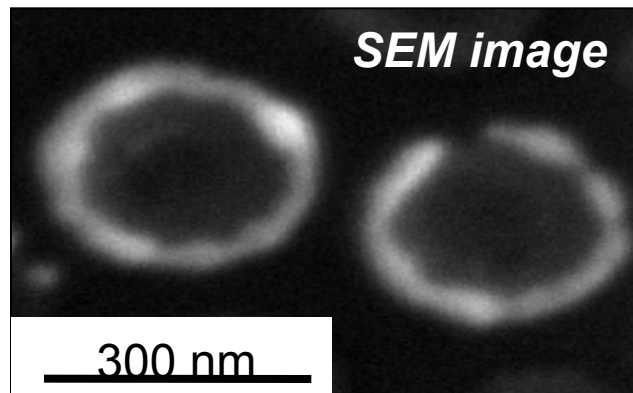


Remove the
spheres



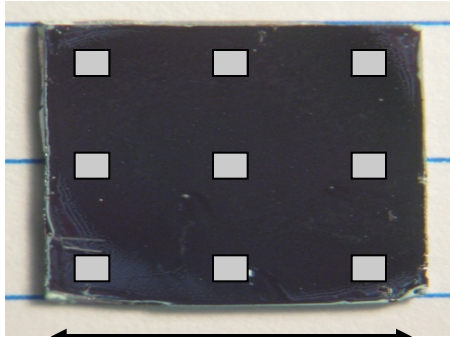
Ions bounce from surface, go under lip

Elemental Analysis of Nanoring Structures



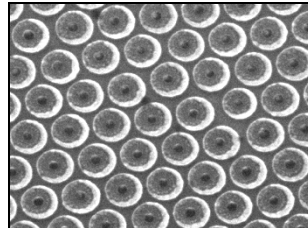
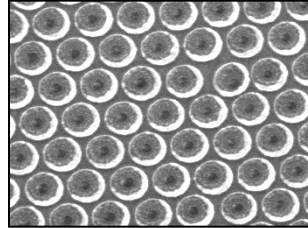
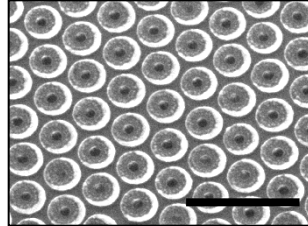
Key Challenge: Non-Uniformity

*Schematic
representation of
analyzed sample area*



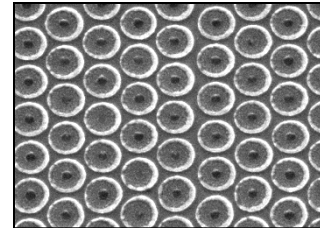
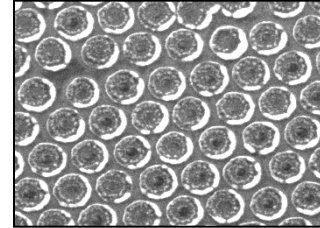
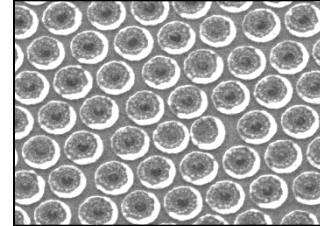
1 cm

Top left corner



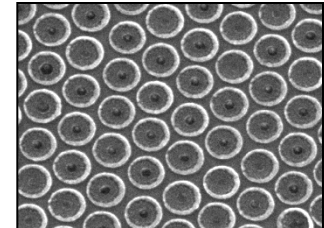
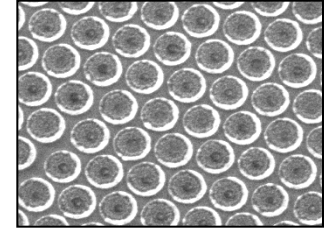
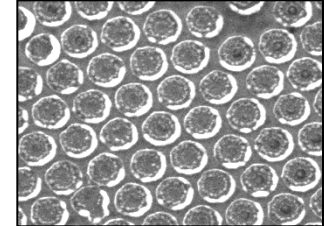
Bottom left corner

Middle

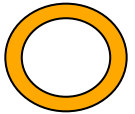


Middle

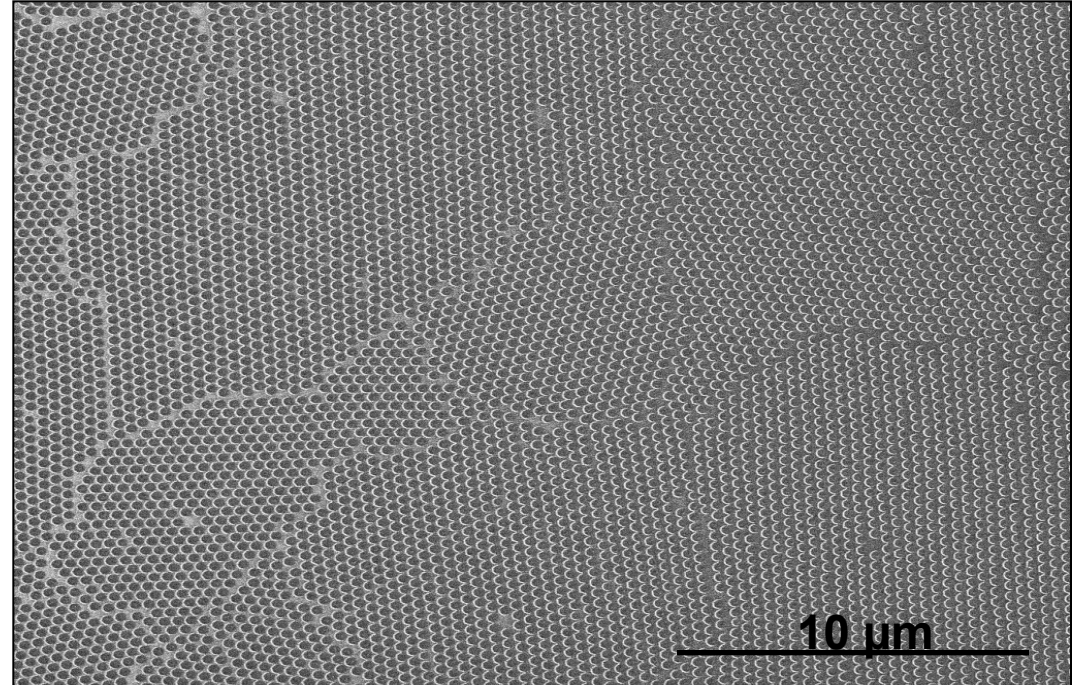
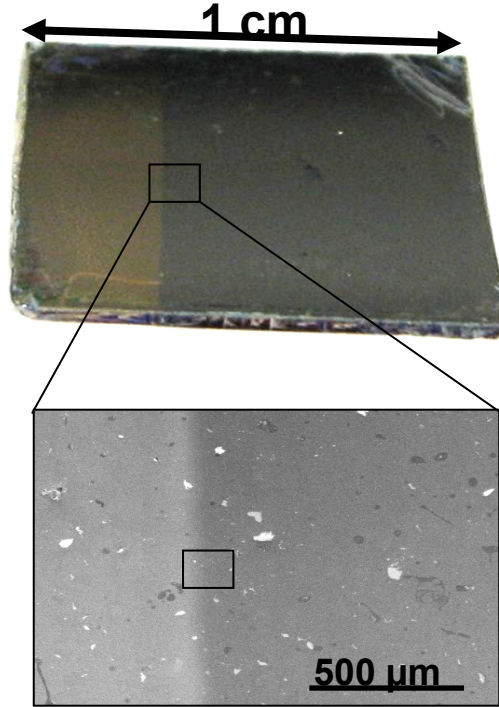
Top right corner



Bottom right corner

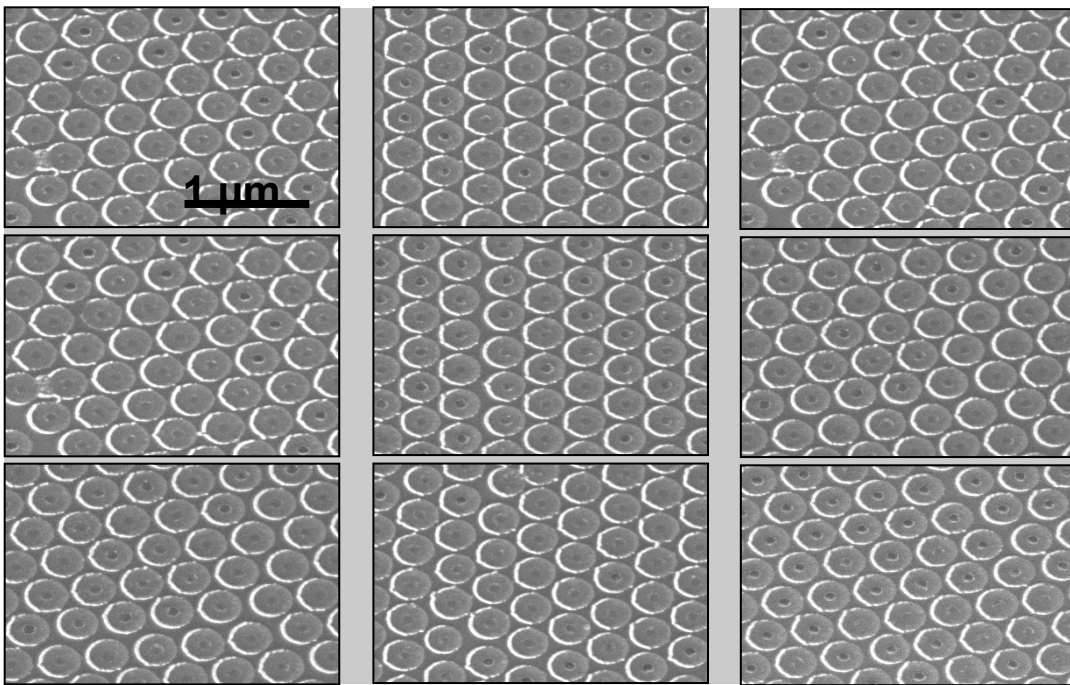
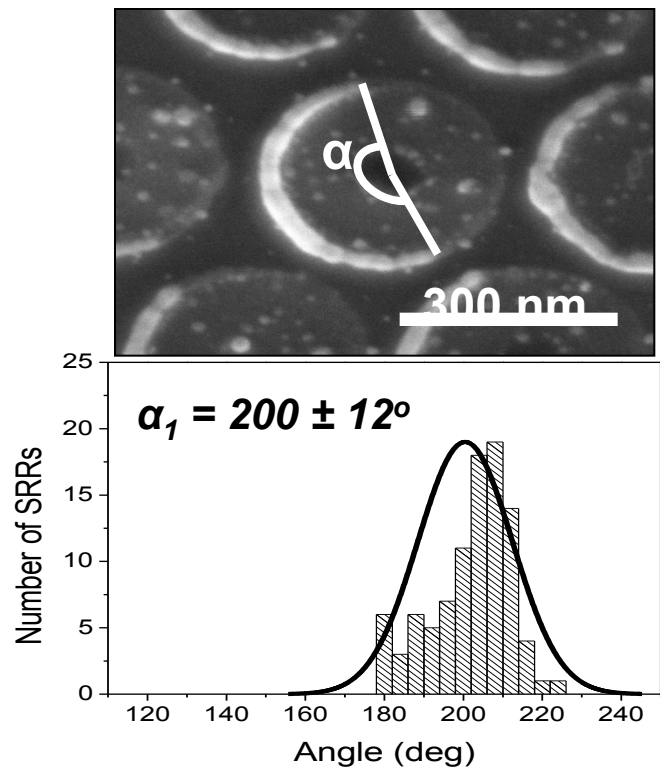
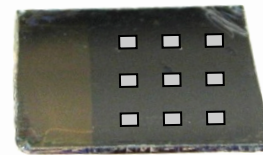


Fixed Problem with Secondary Mask



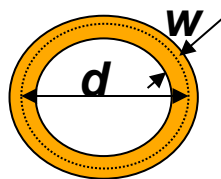
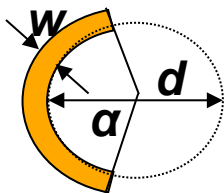
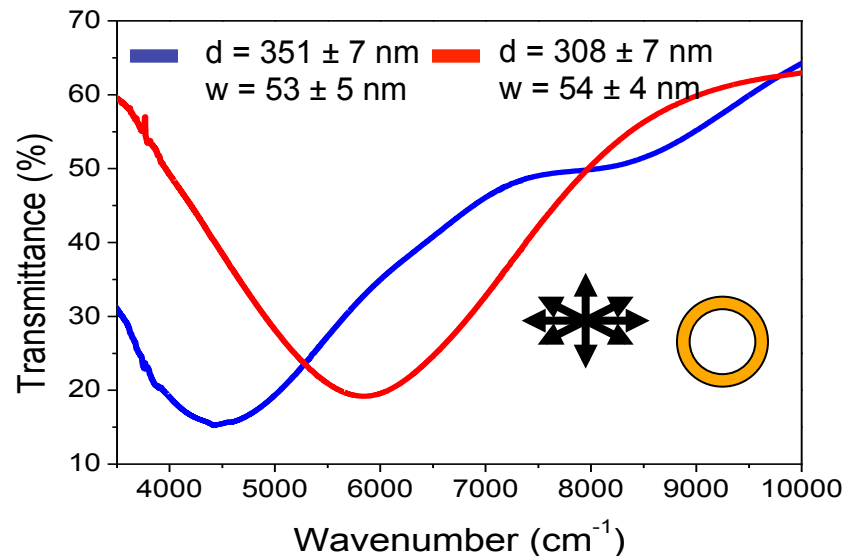
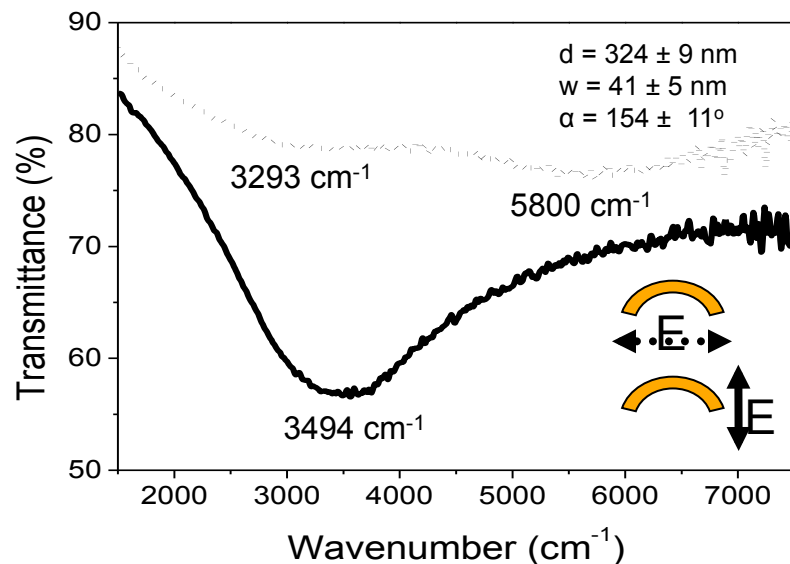
Bombarding ions are deflected by the local electric field on the edge of secondary mask and form split ring resonators

Improved Uniformity: Crescents

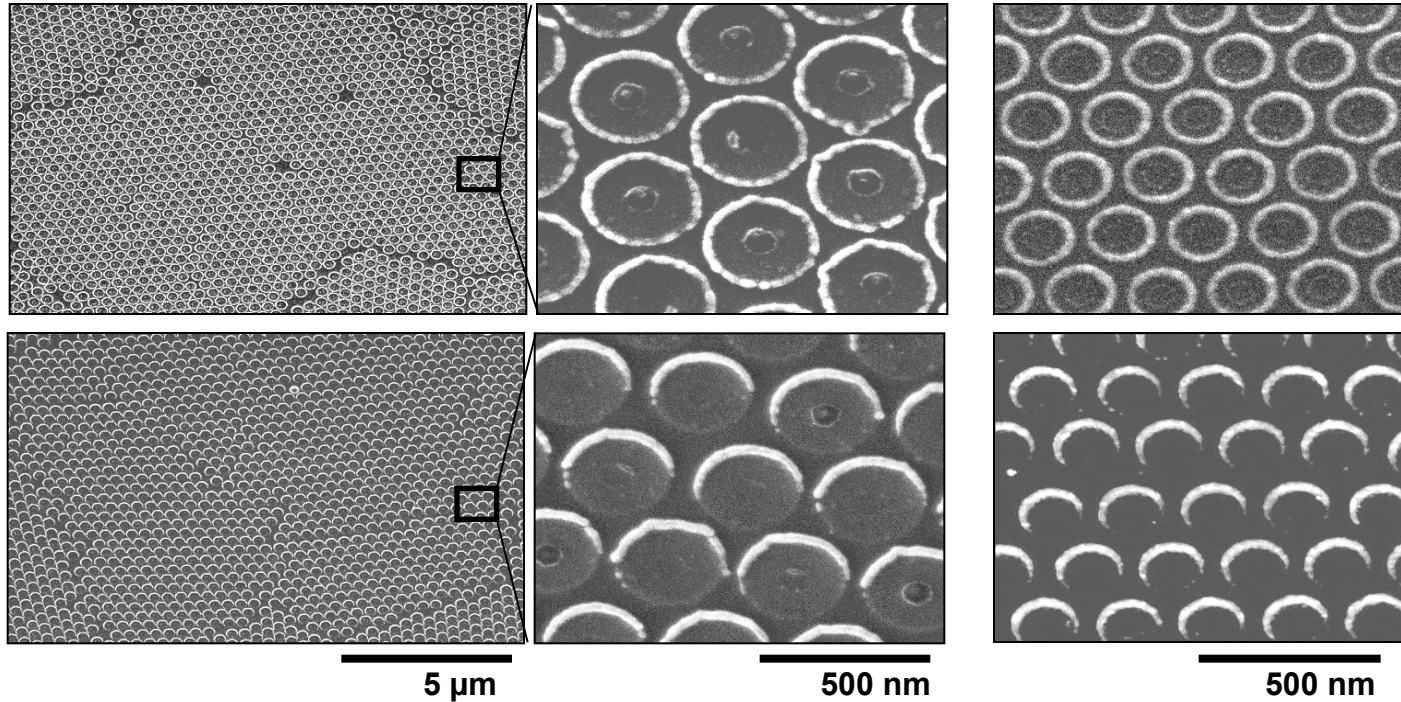


Uniform SRRs cover the sample area of about 0.6 cm²

Peaks in Transmittance: Metamaterial Resonances



Summary: Shaped Nanosphere Lithography for Infrared Metamaterials



Shaped Soft Lithography

Week 4, Lecture 8, Nanotechnology



- Ordered arrays of spheres make good mask structures
- The spheres can be shaped into mushroom type objects so as to create a protected area for metal deposition under the lip.
- Metals laid down is directed to go straight down over the mushroom structures (rings), and etching can be directional to lead to ‘c-shapes’