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Nano-Imprinting Photonic Crystals for Optical and Near-IR Applications

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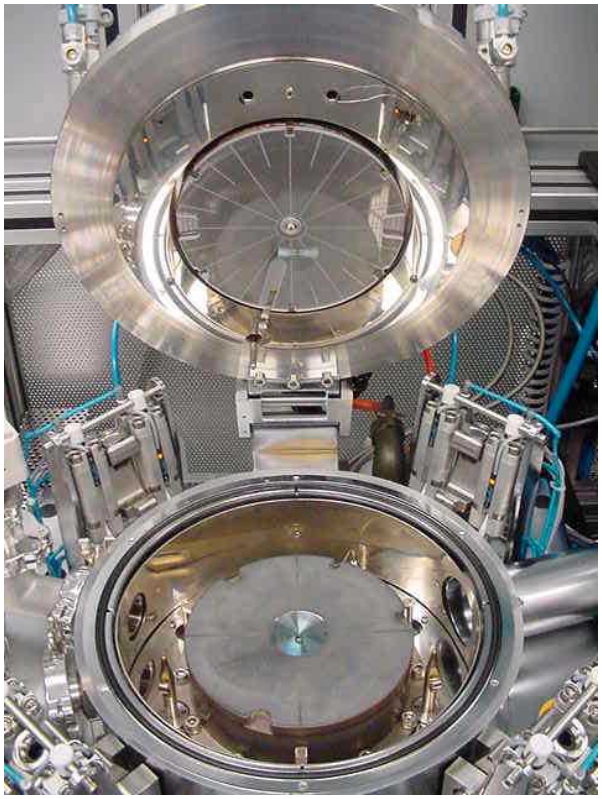
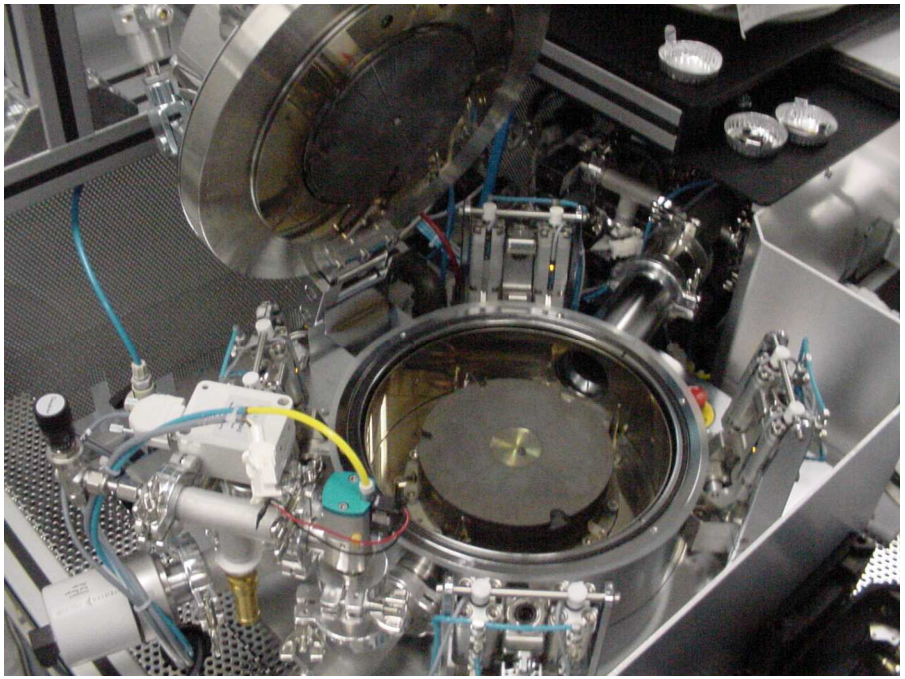
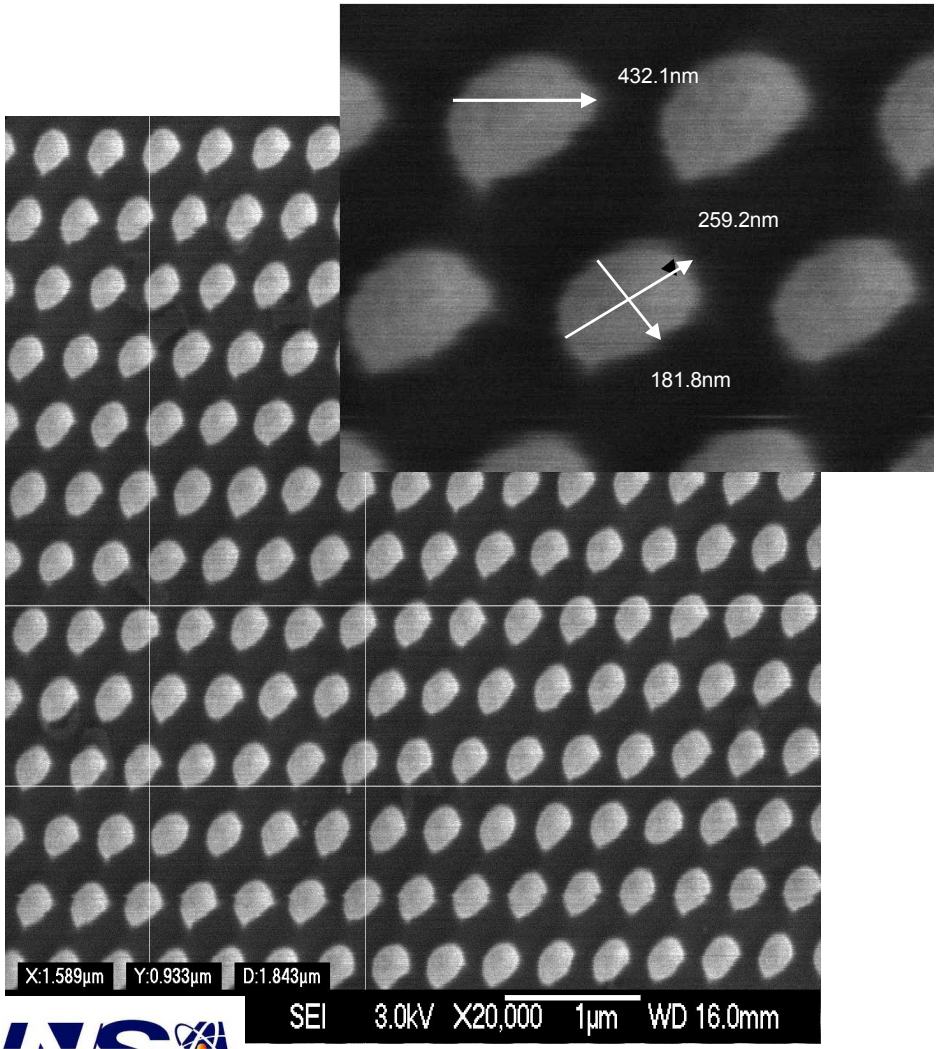
Nano-Imprint





- The Electronic Visions Tool used for Imprinting

EM's of Imprint Mold



- Interference lithography was used to create first Silicon molds.
- E-Beam lithography can be used for creating defects in the mold.
- Nano-Nex's 2010 mold release agents were applied to the mold for easy release of imprinted wafer.

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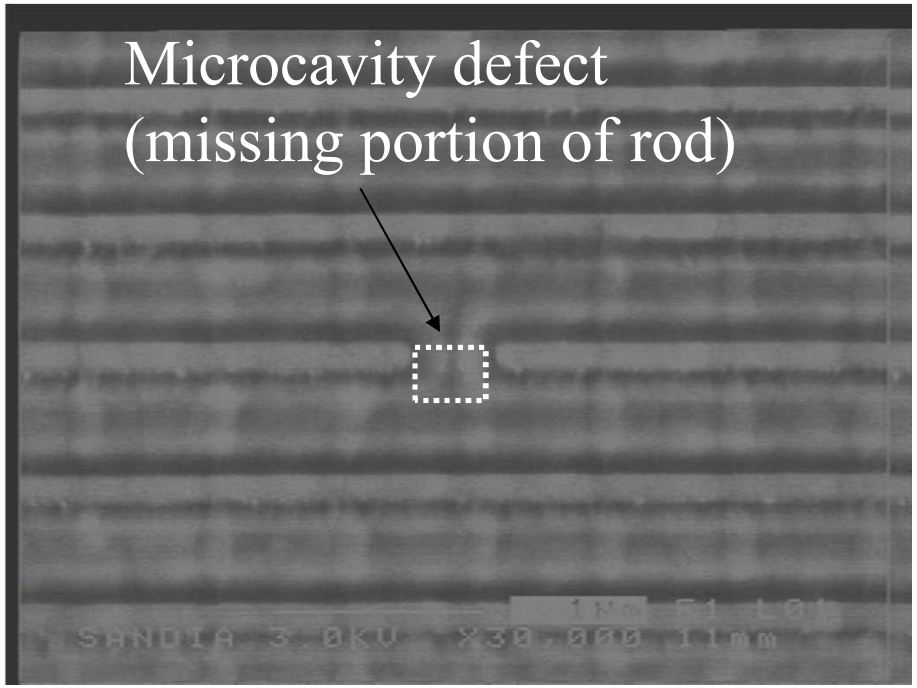
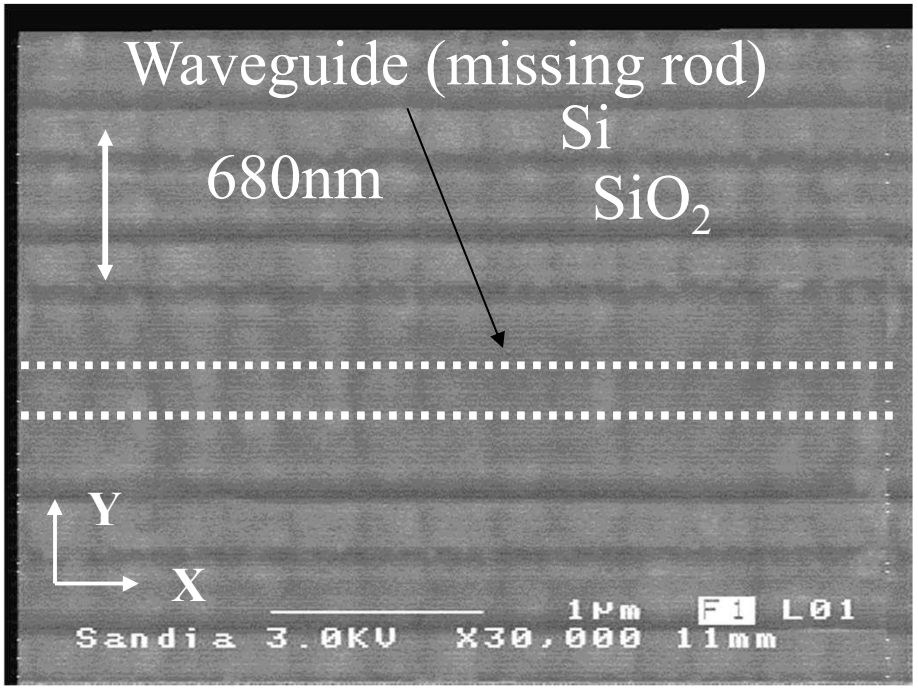
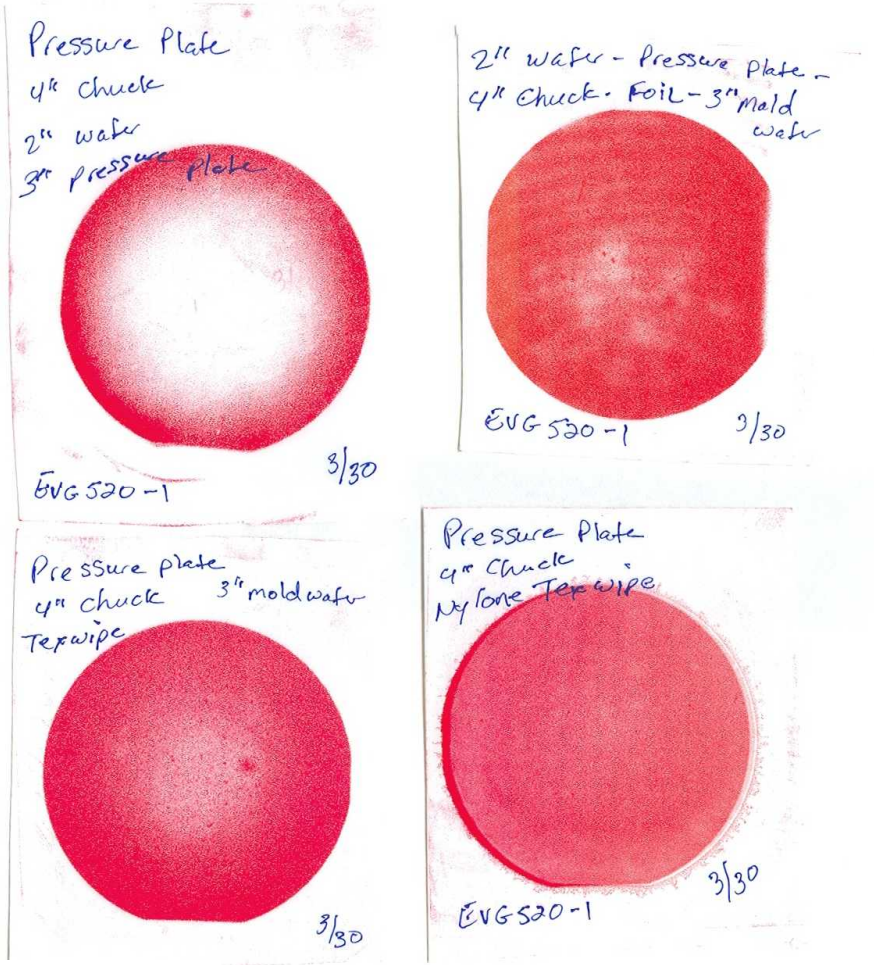
Embedding defects : Micro cavities and waveguides





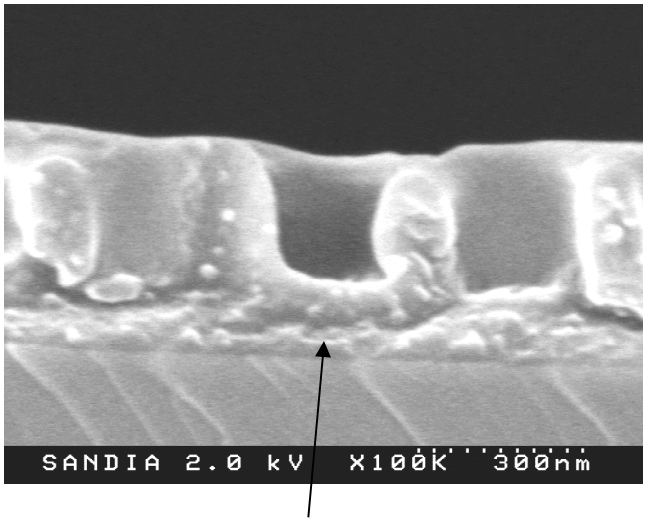
- Microcavity and waveguide structures can be created over large areas by lithographically defining defects on the master mold

Uniformity and Imprint



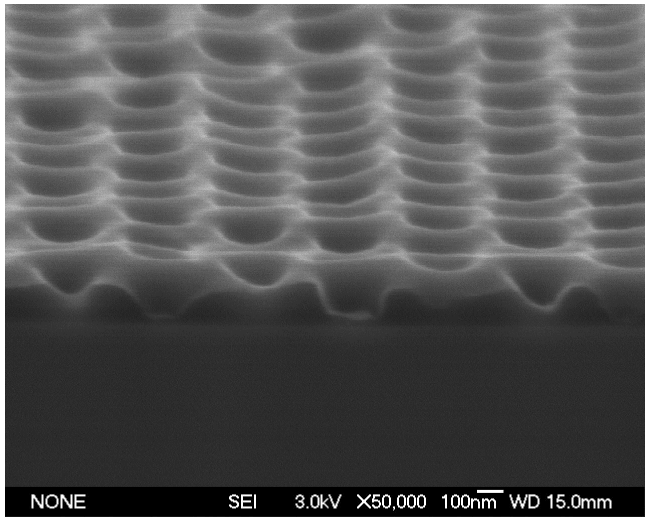
- The wafers were DSP for flatness, and the bond plates were lapped and polished for flatness.
- We found that a soft compliant surface was needed to allow the wafer and the mold to conform to each other.
- It was discovered that pattern transfer didn't only occur with the mold but the pattern of the compliant surface would also transfer through the mold and the wafer being imprinted.

Residue



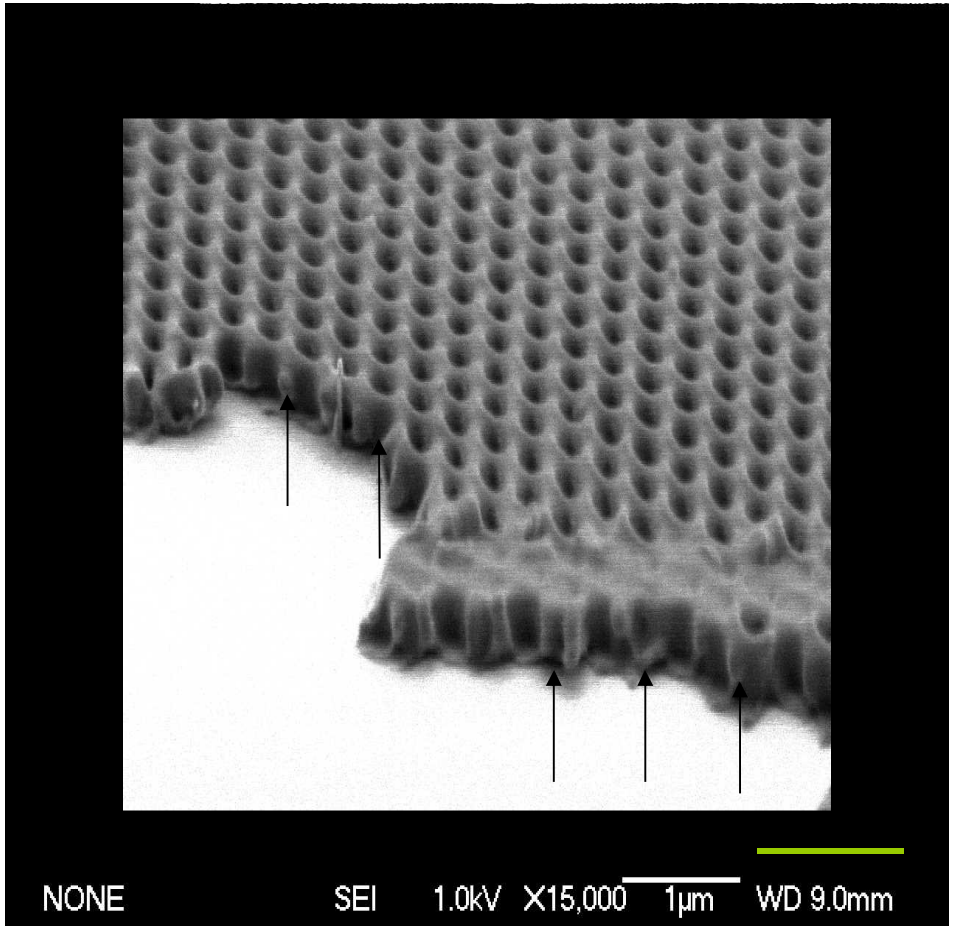
Residue

- After imprint there is always a layer of residual resist at the bottom of the imprinted areas.
- Spin speeds were optimized for the imprinting of the different depths of the different molds.
- High pressure RIE was used to clear out the bottom of the holes before any further processing of the imprinted wafer.



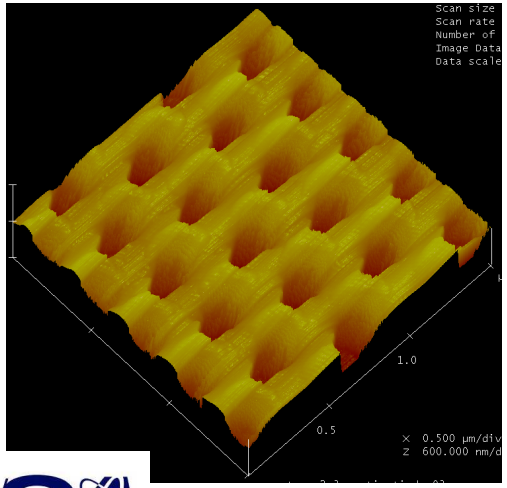
AFM of Imprinted Photonic Lattice

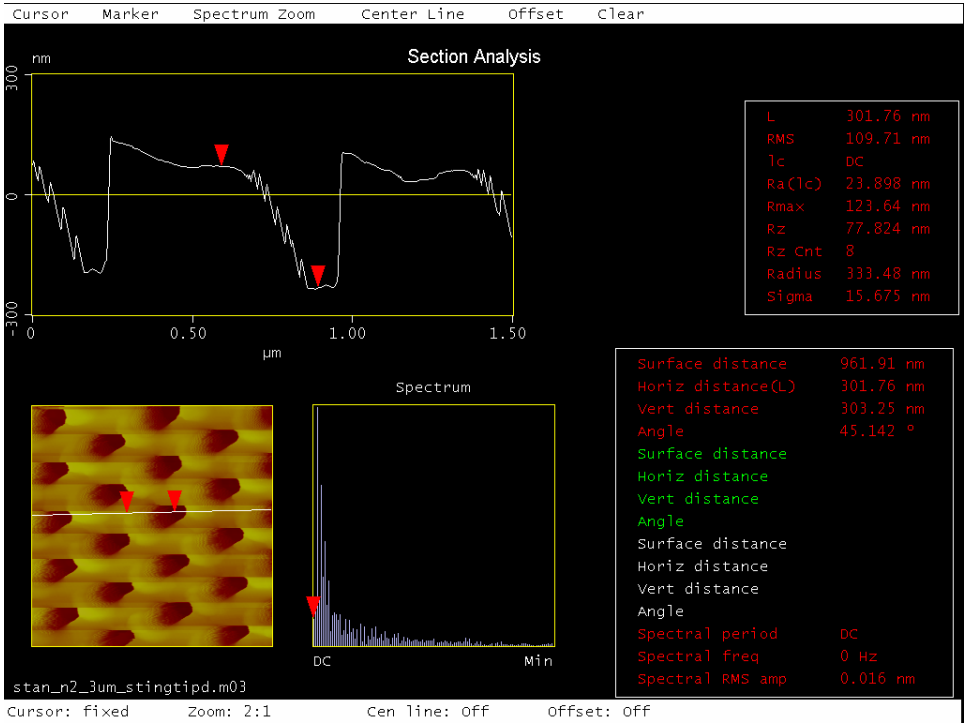
- Arrows point to residual imprint resist at the bottom of holes.
- This image was taken at 62.2 degrees → vertical distances are compressed → to get the real number divide by cos(27.8°)
- I estimate that there is 50 to 75 nm of resist at the bottom of the holes
- The resist thickness seems to be about 400 to 500 nm.



AFM Image of Imprinted Photonic Lattice

- 1.5 x 1.5 micron AFM image taken with a high aspect ratio tip
- The smear to the southwest is not real- it is an AFM artifact.
- I tip is able to find the bottom of the hole. The hole depth is on the order of 300 nm.





- There is probably some squish-out of the imprint resist that makes the imprinted resist thicker.

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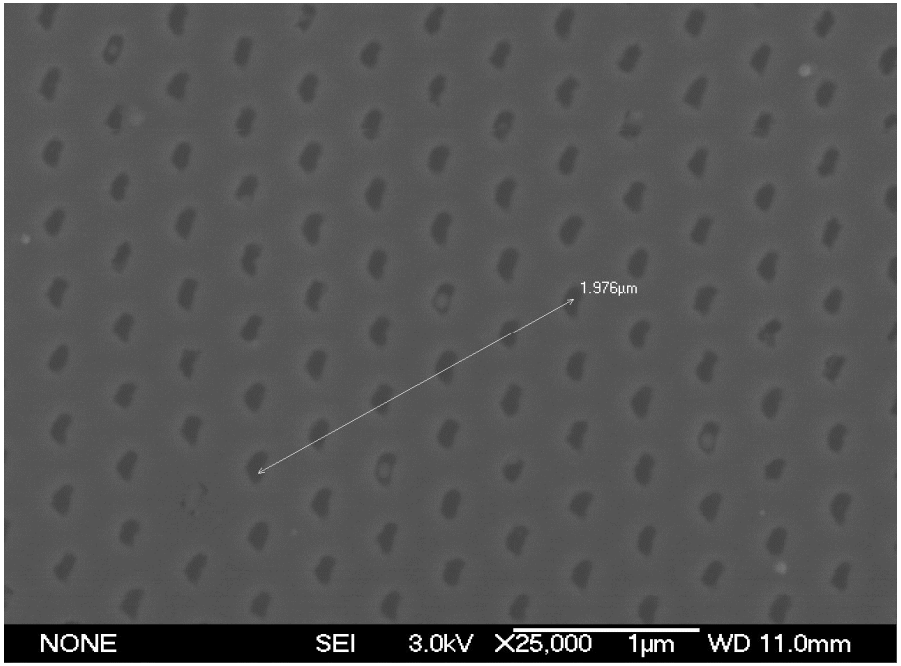
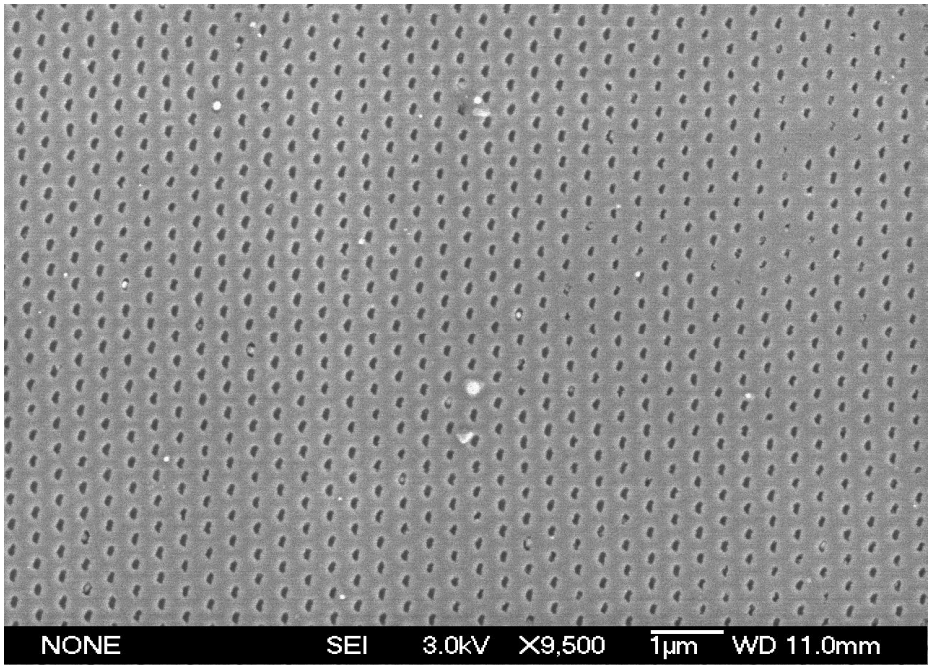
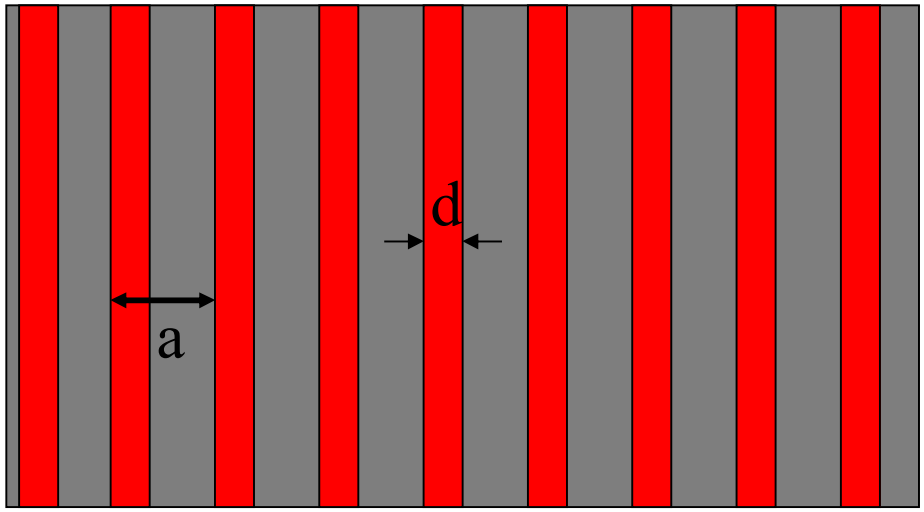
Pattern Transfer



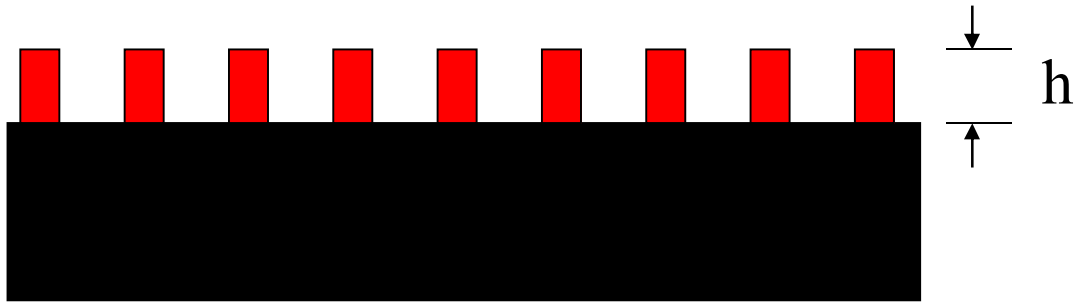


- Imprint and Etch area pretty consistent.
- RIE etch of an oxide layer on a GaN substrate.

Demonstration of Submicron Lattice Constant 3D PC



- a = 0.6 μm ; d = 0.150 μm
- h = 200-300nm



1st Level Mold from Interference Lithography

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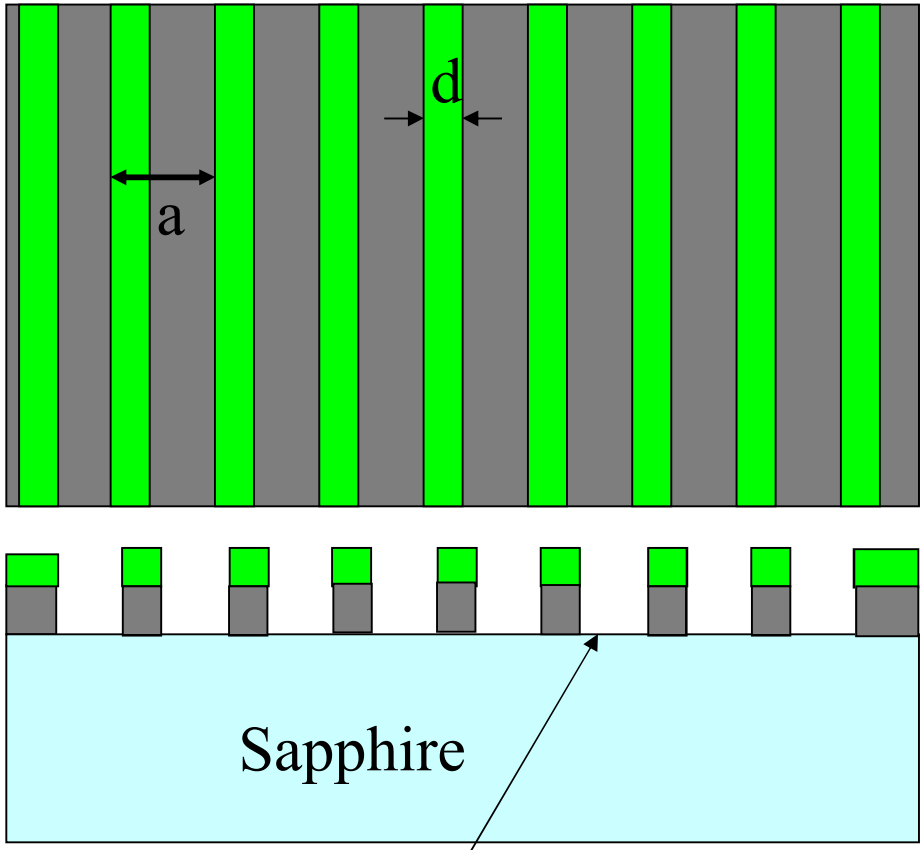
Final Structure after imprint and pattern transfer to TiO2

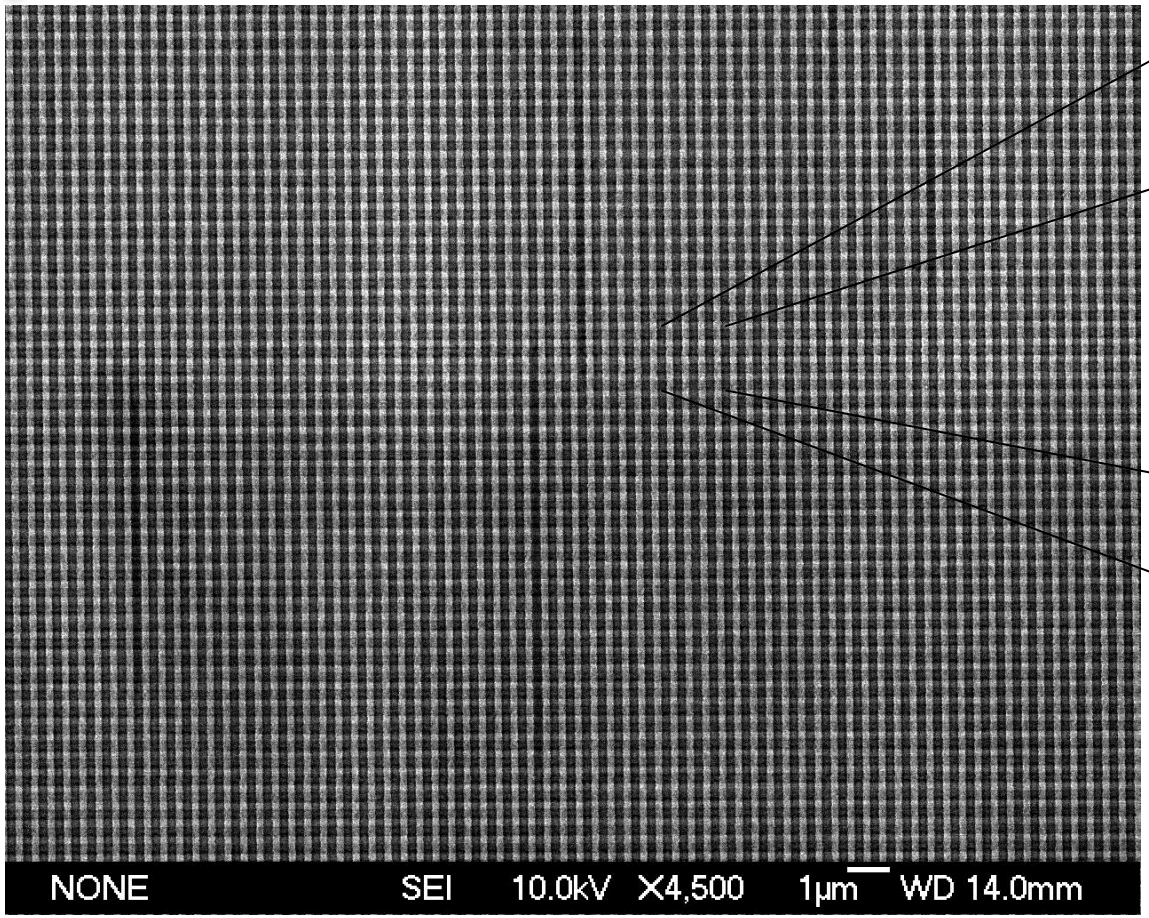


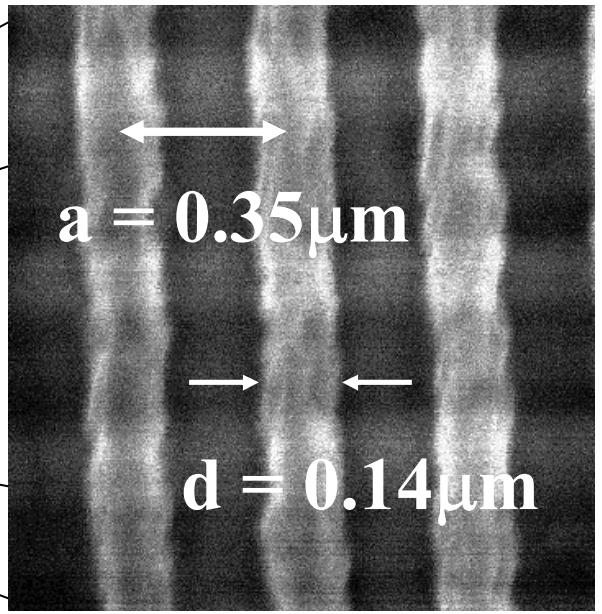
- a = 0. 6 mm ; d = 0.15mm
- h = 150-200nm required
- Thickness of TiO2 = 100-120nm

h = resist thickness left after imprint followed by descum

Patterned TiO2 after etch
Layer 1 - Area : ~ 1” X 1” square

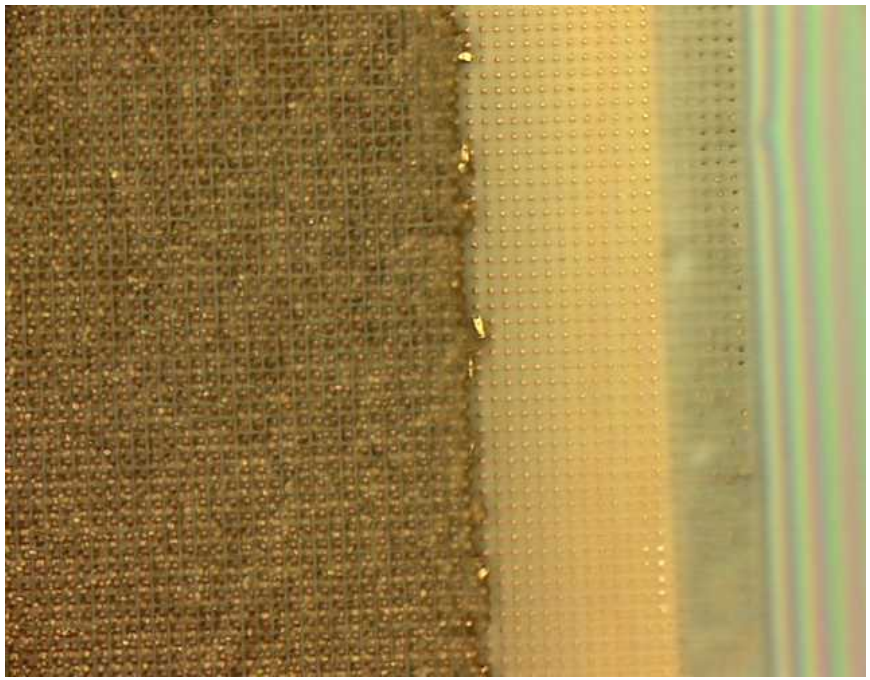
Extension to Visible Frequencies



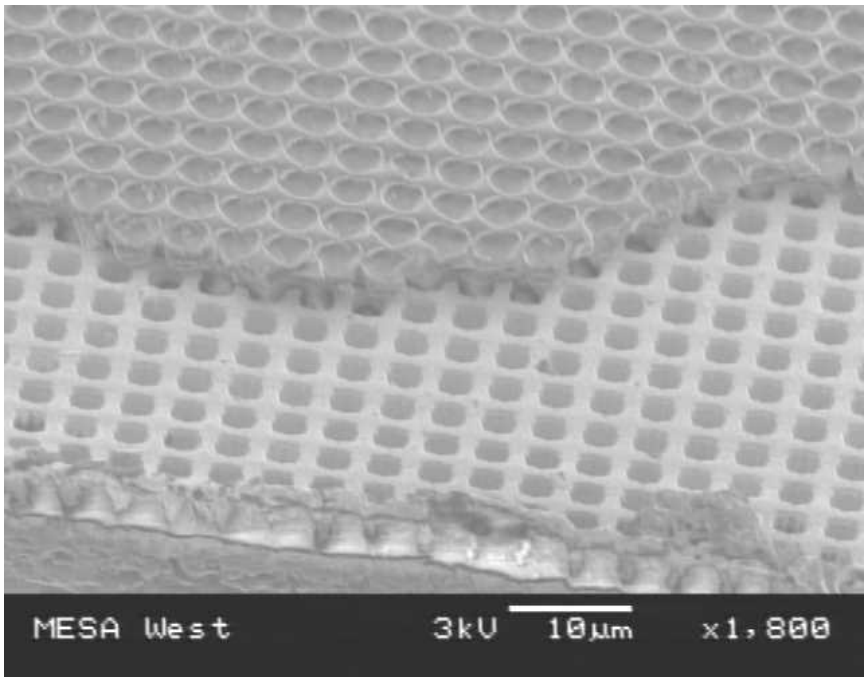


- Minimum feature sizes required < 0.2 mm: Achievable through nanoimprint
- Current challenge: Alignment between layers 0.05 mm

Multiple Layer Imprinted Thermal IR PBG



- 5X optical view of an imprinted wafer with the Cubic Array Pattern



- SEM image of the same wafer

- Feature size is 2umX2um

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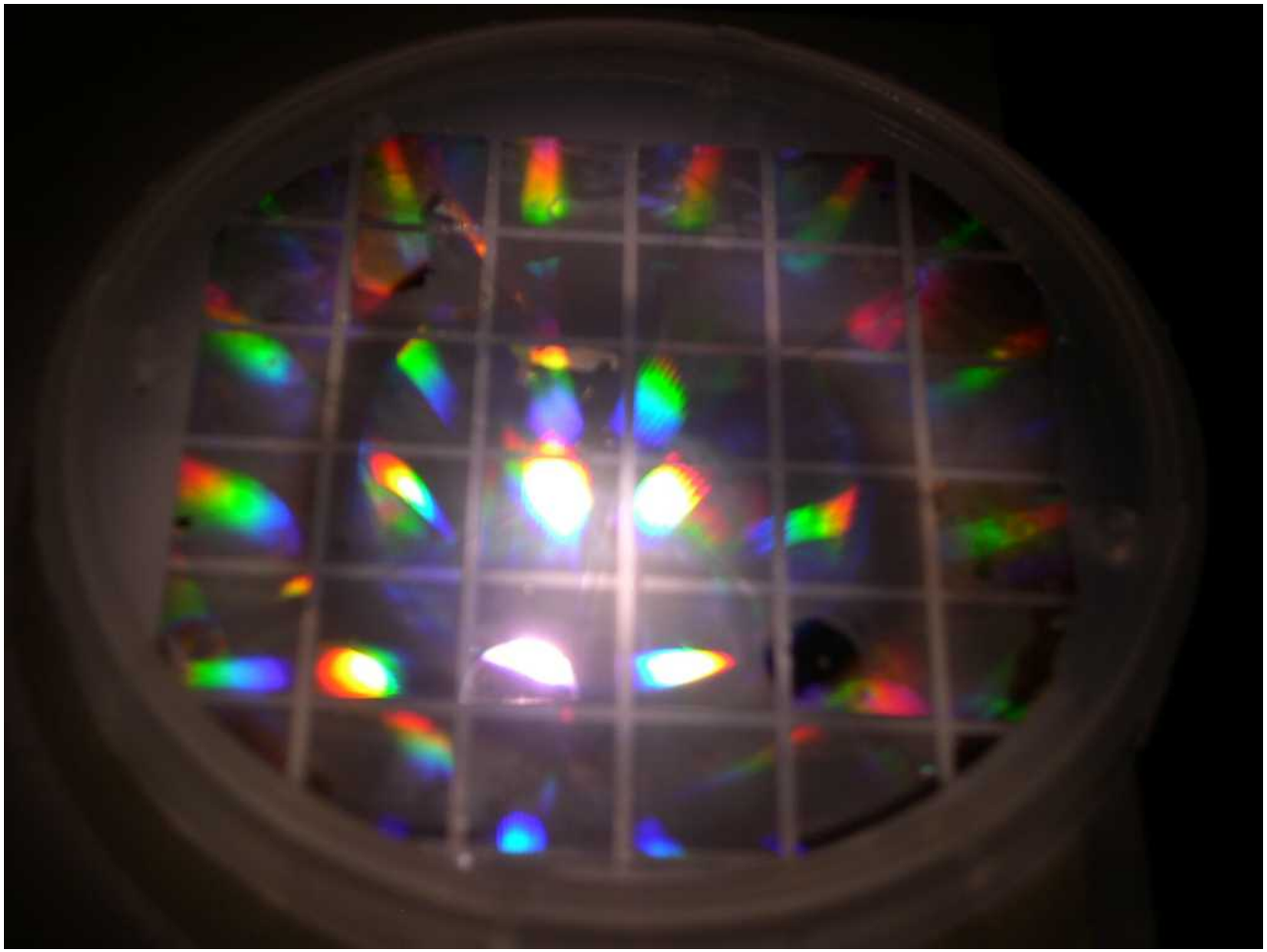
Full 3” Imprinted Wafer



Summary and Future Efforts

- Fabricated a multilayer Thermal IR PBG over a 4” wafer
- Good pattern transfer fidelity achieved for features ~200nm in size
- Determined conditions necessary to achieve uniform imprint over an entire wafer.
- Introduce structures with defects (e.g., microcavities, waveguides)
- Develop alignment techniques to achieve multilayer fabrication of IR and visible photonic crystals.
- Fabricate metamaterials