Additive Full-Wafer Fabrication of All-Inorganic Metalenses, Waveguides, and Diffractive Optics for Visible and IR Applications via Direct Nanoimprint Lithography

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Additive Manufacturing

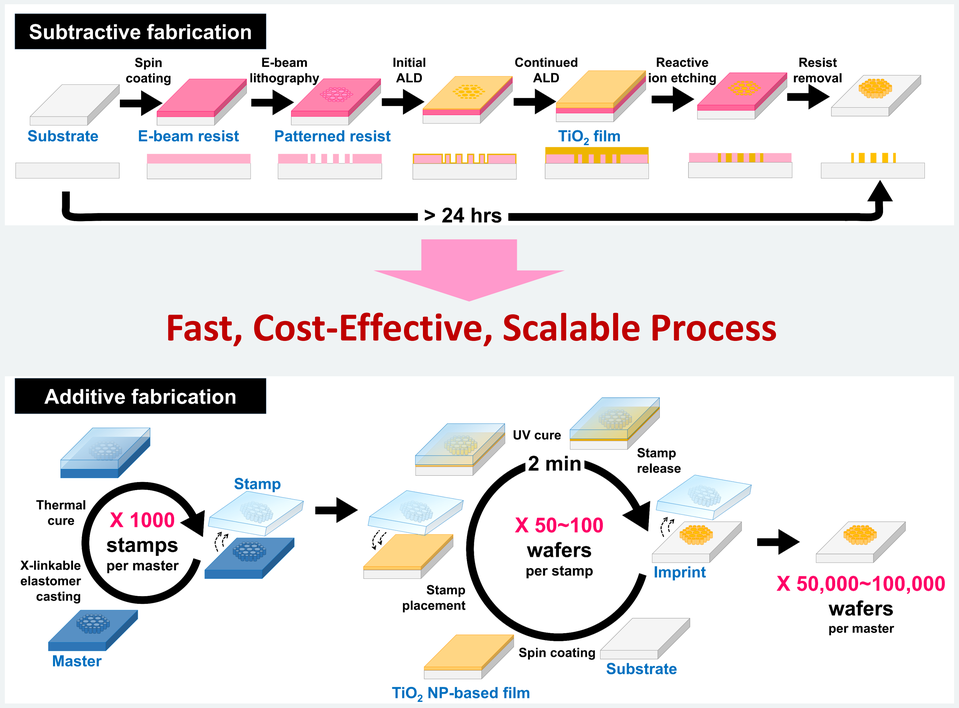
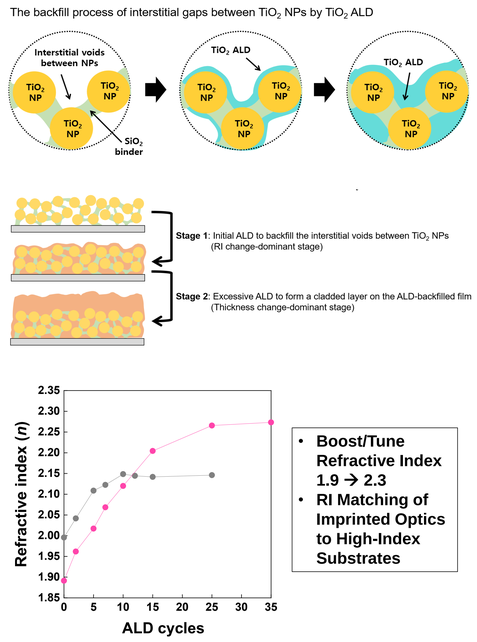


Figure 1. Comparison of subtractive and additive processes of fabricating metasurfaces and advanced optics.

[Ref] Einck *et al*. *ACS Photonics* **2021** *8* (8), 2400-2409

All-Inorganic Nanoparticle-Based Structures

Higher Refractive Index > 2.3



- Boost/Tune Refractive Index 1.9 → 2.3
- RI Matching of Imprinted Optics to High-Index Substrates

Figure 2. Effects of ALD pore-filling process throughout TiO_2 nanoparticle-based structures on refractive index.

Higher Aspect Ratio > 10

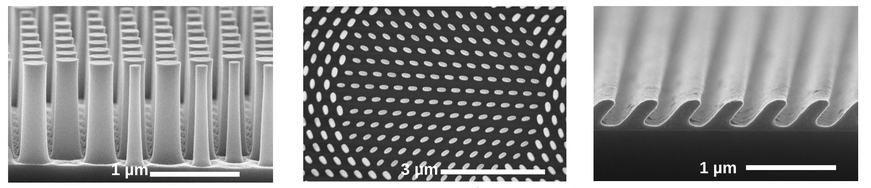
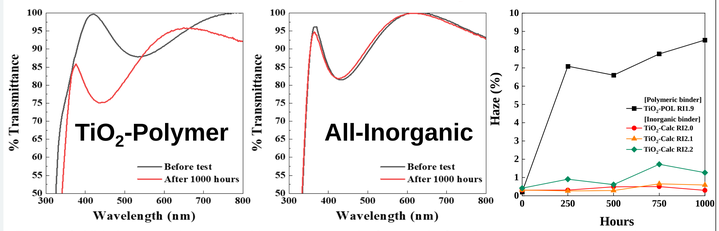


Figure 3. Various nanostructures patterned by direct NIL using TiO_2 nanoparticle-based dispersions.

- Complex Structures
- Asymmetric Structures & Polarization Control
- Slanted Grating Structures

Greater Stability > 1 Year Florida



- Weathering/UV Stability Testing (ASTM G155, Cycle 1, 1000 hrs)
- High T, High RH Testing (85°C, RH 85%, 20 days)
- All-Inorganic TiO_2 Structures >> TiO_2-Polymer Composites
- All-Inorganic: No Shrinkage, swelling, or haze
- Polymer Composites: Transmittance drop, haze develop

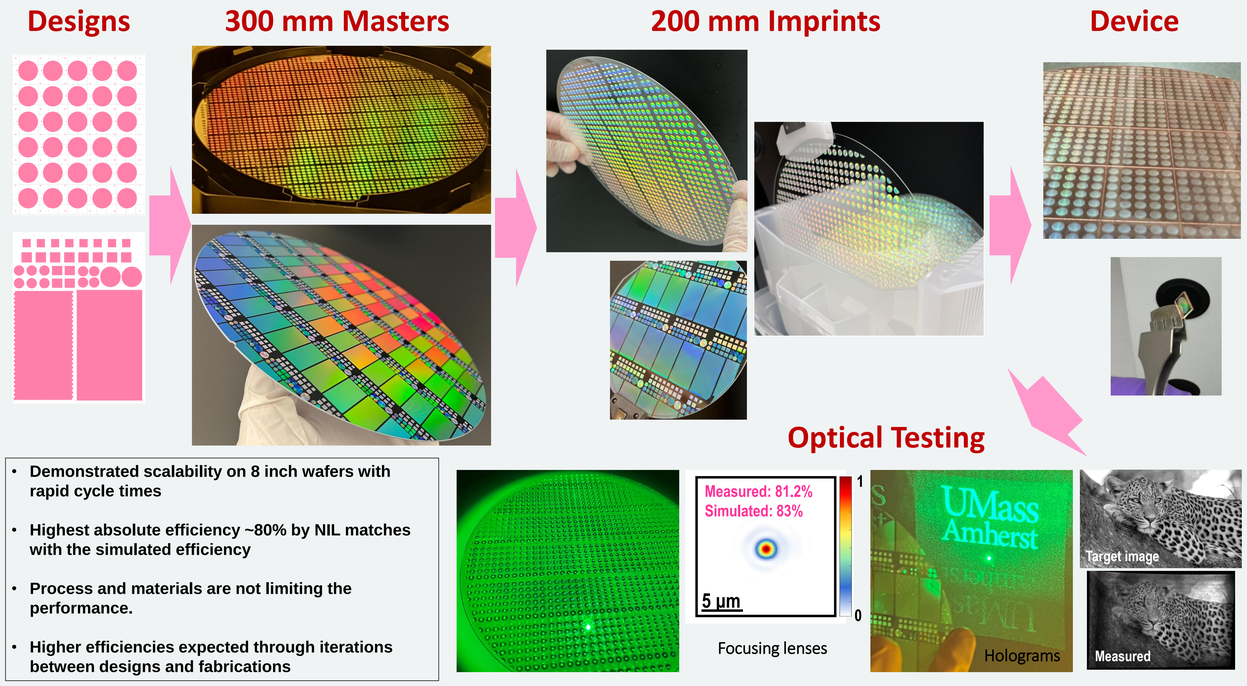
Figure 4. UV-vis transmittance and haze changes before and after the accelerated weathering test (ASTM G155) showing the difference between all-inorganic TiO_2 and TiO_2-polymer composites

Low Temp. Processing Options < 100°C

- Removal of organic residues through calcination at high temperatures for standard wafers
- Alternative approaches at low temperatures are also available for thermally sensitive substrates
- Good compatibility in process with high index substrates

[Ref] Jung *et al*. *ACS Applied Nano Materials* **2023** *6* (3), 2009-2019

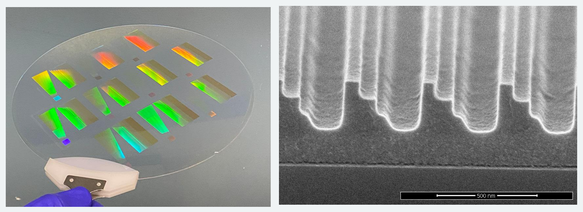
Full-Wafer Fabrication with High Efficiency



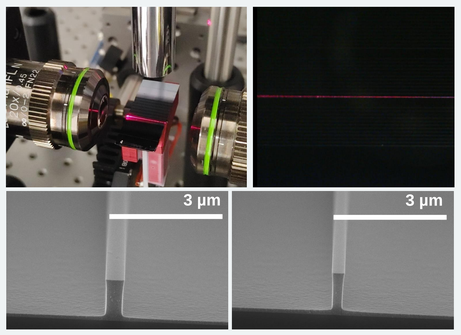
- Demonstrated scalability on 8 inch wafers with rapid cycle times
- Highest absolute efficiency ~80% by NIL matches with the simulated efficiency
- Process and materials are not limiting the performance.
- Higher efficiencies expected through iterations between designs and fabrications

Figure 6. Complete fabrication process of NIL-based direct patterning including designing metasurfaces, deep UV mastering, elastomeric stamp making, UV-assisted imprinting, mechanical dicing, and optical characterization of metalenses and holograms.

Waveguide Structures – AR/VR/MR



Full-wafer imprinting of AR/VR Waveguides in collaboration with: EVG®

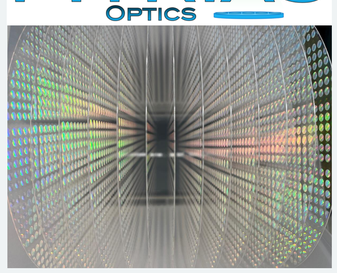


- Waveguiding structures in the visible and IR wavelengths
- Rapid imprint times / high throughput
- Product generations at 1.8-2.3 RI
- Applicable to AR/VR/MR, telecommunications, light circuits, and more

Figure 7. Setup for testing the propagation loss of waveguiding line patterns fabricated by direct patterning of TiO_2 nanoparticle-based dispersions.

Tech Transfer to Spin-Out Company Myrias Optics Inc.

MYRIAS OPTICS



www.myriasoptics.com

Myrias Optics is located in the SPIE.AR|VR|MR exhibitor hall (Moscone Center – West Level 3)

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