Design for NIL foundry using wire grid polarizer volume production release methodologies on 200mm full wafer NIL

The design and testing of nano structures such as metalenses [1], diffractive optics [2], and waveguides [3] have displayed the functionality to make the leap form stacking multiple optical elements in to a single flat optic. To bring these products to the customer, proven manufacturing needs to be demonstrated. Nanoimprint Lithography (NIL) is key in making nano structures at dimensions <50nm in the wide variety of patterns needed. Not only are very small structures needed but also repeated at a very tight tolerance i.e +/- 2nm [4].

Moxtek has built upon their expertise in volume manufacturing (≈160,000 wafers annually) of Wire Grid Polarizers (WGP) on the nano scale to also become experts in Nanoimprint Lithography processing. Expertise is routinely displayed in high volume products with nano structures down to 25nm critical dimension (CD) and aspect ratios above 7. All manufacturing is in the United States and ITAR certified for government applications.

To advance the manufacturing capabilities, NIL process was installed and released for production (SCIL). To date more than 10,000 wafers have been run through NIL. NIL support systems have been put in place and shown proven capable including master and stamp making, CD metrology and control, defect inspections, and pre/post imprint processing.

NIL performance is industry leading for full wafer imprint processing with CD control of less than 2.5% σ on structures with CD's at 45nm (Figure 1). The next important NIL parameter is residual layer thickness (RLT) which is controlled to 20nm with <2nm σ to provide extremely repeatable and reproducible printing. While achieving this exceptional NIL performance, we have stamp life up to and over 500 prints. As in all NIL processing defect reduction is critical. With ongoing improvements we have brought an originally very high defect level down to 2 defects/cm^2 (Figure 2). Defect improvement is ongoing.

For any customer interested in using Moxtek on NIL foundry projects, we can provide proven and repeatable volume print quality down to 25nm. Common substrates in use are 200mm Glass or Silicon wafers from 0.7mm thickness up to 1.8mm. Typical resist is silicon oxide based, but also work is being done with functional imprint materials, as in high index. As a benefit of making our stamps in house, we have developed an expertise in creating stamps from small and unusual masters for demonstration purposes. This is an enormous benefit before committing the expense of building a full wafer master. New device development can include design parameter skews to optimize final design which in NIL typically creates extremely long development time and high costs by needing multiple masters. We have established a method to include multiple different structures on to a single master wafer to greatly reduce development time and upfront cost.

One of the most significant barriers in ramping a new device in to high volume production using NIL is acquiring a master. Recognizing this gap in the NIL industry we have specialized in procurement of large area (300mm) Silicon masters. 300mm is important for full wafer imprint of 200mm wafers as to make quality prints out to the edge of the wafer. A high level of understanding in the stamp making process is

integral in understanding how to design a proper master (Figure 3). For high volume repeatable processing we have 30nm minimum feature size and aspect ratio around 2. For devices that don't have a defined die size, large area continuous repeating patterns are available with stitching error <10nm.

References

[1] Wei Ting Chen, Alexander Y. Zhu, Jared Sisler, Zameer Bharwani, Federico Capasso, "A broadband achromatic polarization-insensitive metalens consisting of anisotropic nanostructures," *Nature Communications,* 2019.

[2] Sourangsu Banerji, Monjurul Meen, Apratim Majumder, Fernando Guevara Vasquez, Berardi Sensale-Rodrigues, Rajesh Menon, "Imaging with flat optics: metalenses or diffractive lenses," *Optica,* vol. 6, pp. 805-810, June 2019.

[3] Han, Xiu-You; Wu, Zhen-Lin; Yang, Si-Cheng; et al., "Recent Progress of Imprinted Polymer Photonic Waveguide Devices and Applications," *Polymers,* vol. 10, no. 6, June 2018.

[4] Masafumi Asano, Ryoji Yoshikawa, Takashi Hirano, Hideaki Abe, Kazuto Matsuki, Hirotaka Tsuda, Motofumi Komori, Tomoko Ojima, Hiroki Yonemitsu, Akiko Kawamoto, "Metrology and inspection required for next generation lithography," *Japanese Journal of Applied Physics,* vol. 56, 2017.

Figure 1. CD Repeatability (6 Stamps, Same Master, 5 Sites/Wafer)

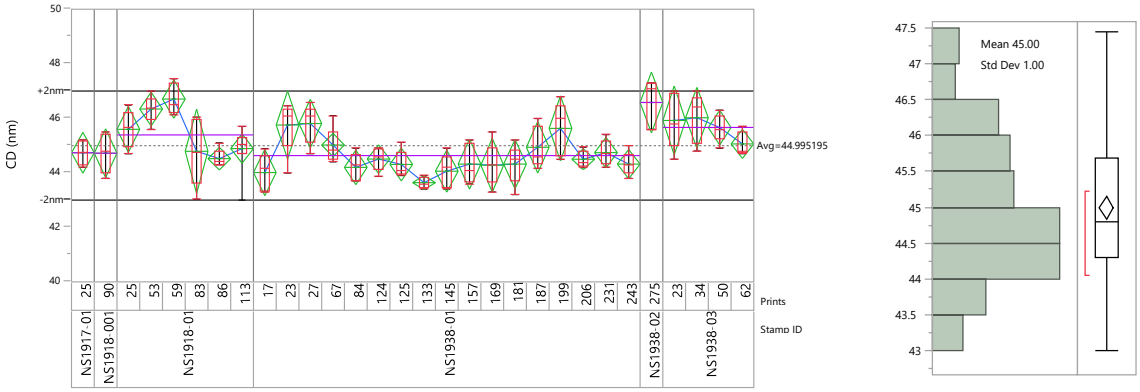


Figure 2. Active Defect Reduction

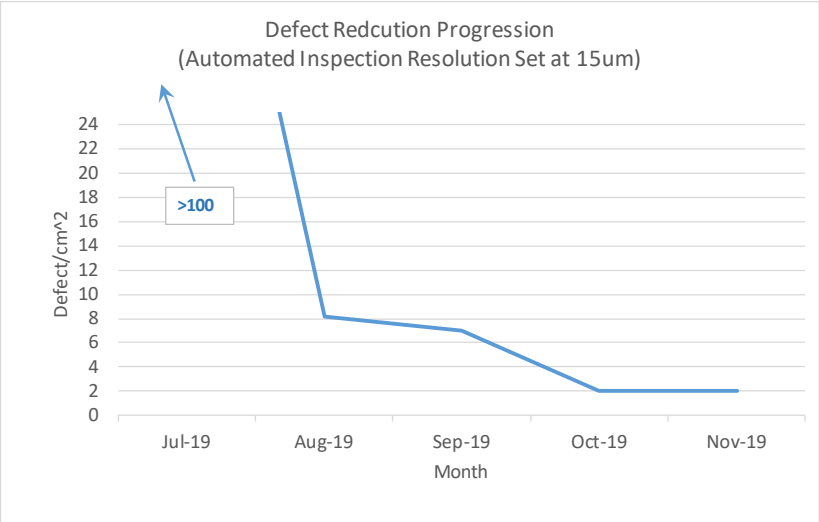
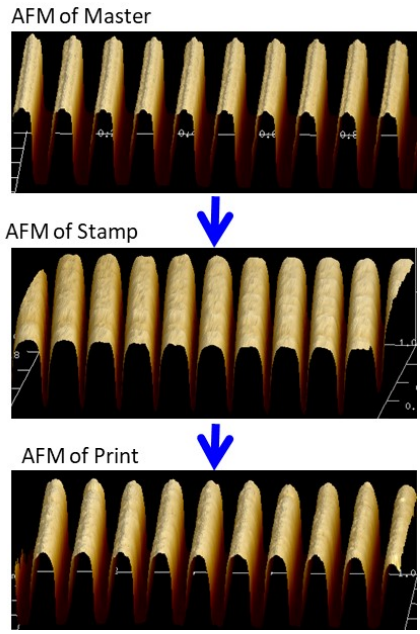
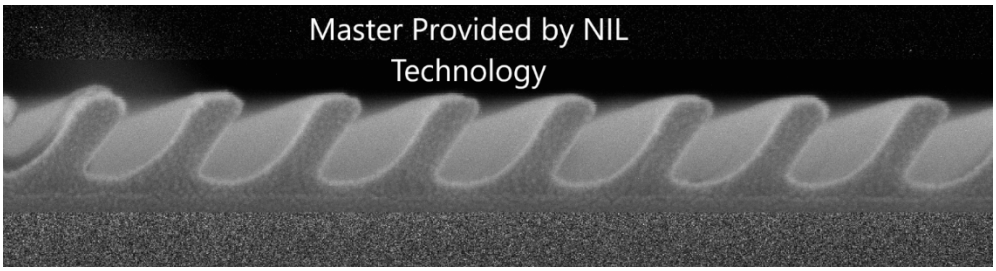
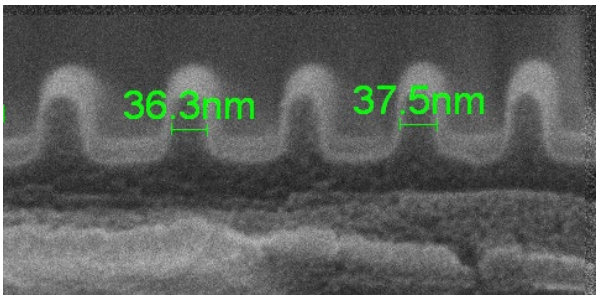
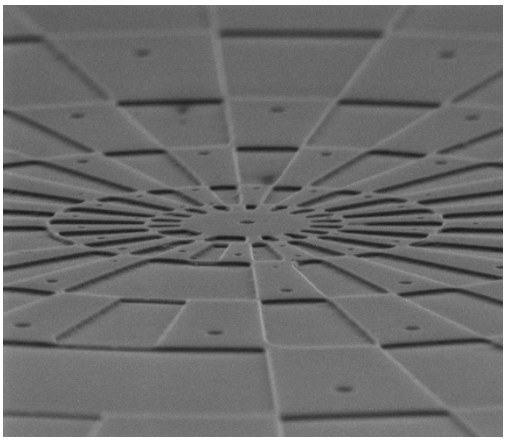


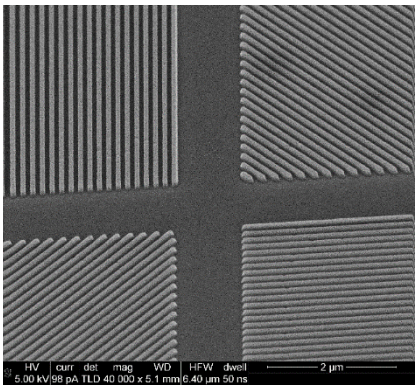
Figure 3. Structure Integrity Verification




Master Provided by NIL
Technology


36.3nm
37.5nm




HV curr det mag WD HFW dwell
5.00 kV 98 pA TLD 40 000 x 5.1 mm 6.40 µm 50 ns
2 µm