Nanoimprint Lithography Using Novel Optical Materials For AR|MR Devices

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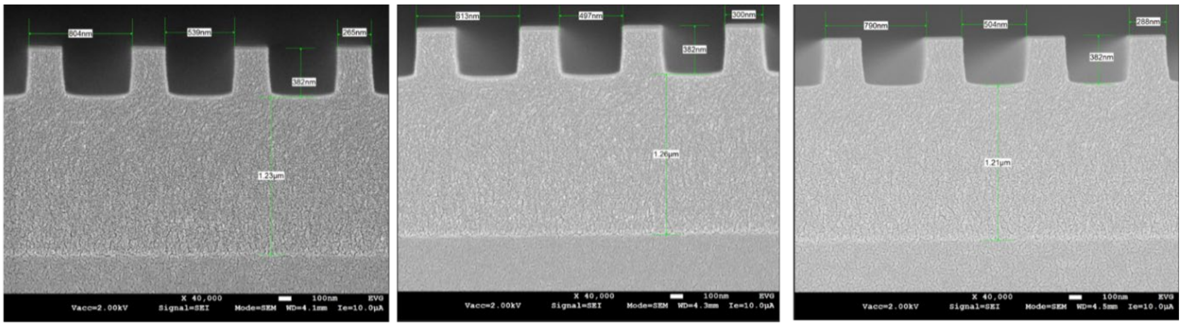
Nanoimprint Lithography (NIL) development started in mid-1990's[1] and since then has made significant progress in improving throughput, resolution, and cost reduction[2]. Recently NIL has been used in manufacturing many novel opto-electronic, photonic, and biomedical devices consisting of nanostructured surfaces. NIL, because of its significantly lower costs compared to traditional optical lithography renders itself as a manufacturing technology of choice for these devices[3].

With the advent of novel optical and photonic devices such as Augmented Reality (AR), and Mixed Reality (MR) and meta lenses, there is renewed interest in NIL technology to manufacture key performance enhancing components for these devices, such as surface relief gratings (SRGs) for waveguides[4.] Functional organic NIL resists for SRGs must balance many challenging and stringent optical & physical property requirements. For example, functional resists for SRGs need to have a very high % transmittance (%T > 95%), usually a high refractive index (R.I.~ 1.50 to 2.0) to match with the R.I. of the substrate to increase the field of view (FoV) and at the same time deliver optimal visco-elastic, mechanical, as well as surface adhesion and de-bonding properties with working stamp materials to enable highly repeatable and effective NIL process with low and uniform Residual Layer Thickness (RLT) across the substrate to ensure high efficiency of SRGs.

Typically, organic resists by themselves cannot provide very high R.I. while maintaining the balance of optical properties as well as physical properties desired for NIL process. To achieve high R.I. in organic resists, the use of high R.I. nanoparticles has become a well-known approach to yield high R.I. hybrid resists[5]. However, use of nanoparticles makes it very challenging to get desired viscoelastic, mechanical, and reliable optical properties in these hybrid resists. This paper will discuss how TOK has developed spin coated and ink-jetted NIL resists achieving effective NIL while maintaining reliable optical properties.

[1] Helmut Schift; “Nanoimprint Lithography: An old story in modern times” Journal of Vacuum Science and Technology B Microelectronics and Nanometer Structures, 2008 March
[2] Dongxu Wu, Nitul Rajput, Xichun Luo; “Nanoimprint Lithography – The Past The Present and The Future” Current Nanoscience, 2016 Oct.
[3] Weimin Zhou; “Nanoimprint Lithography: An Enabling Process for Nanofabrication” Springer ISBN 978-3-642-34428-2 (eBook)
[4] Bernard Kress, Ishan Chatterjee; “Waveguide Combiners for Mixed Reality Headsets: A Nanophotonics Design Perspective” Nanophotonics 2020, Oct.
[5] Irene Howell, Vincent Einck, Dieter Nees, Barbara Stadlober, James Watkins; “Solvent free, Transparent, High Refractive Index ZrO$_2$ Nanoparticle Composite Resin for Roll to Roll UV-Nanoimprint Lithography” Optics and Laser Technology Vol. 141, Sept. 2021, 107101
[6] Martin Eibulhuber (EVG), Thanner Christine (EV Group), Yohei Aoyama (TOK), Katsuhito Iijima (TOK); “SmartNIL High pattern – fidelity-transfer replication using TOK TPIR-2000S NL EV Group White Paper Jan. 2021.

Following images are an example demonstrating capability and repeatability of consistent NIL performance on 25 wafers of TOK TPIR$^{\mathrm{TM}}$-2000S NL Resist (R.I. 1.50)[6]



Imprint #1　Imprint #15　Imprint #25

Figure 1: SEM cross section images of imprint number 1, 15 and 25 of 25 consecutive nanoimprinted wafers. The patterns show complete filling and high pattern fidelity with a very uniform layer beneath[6]

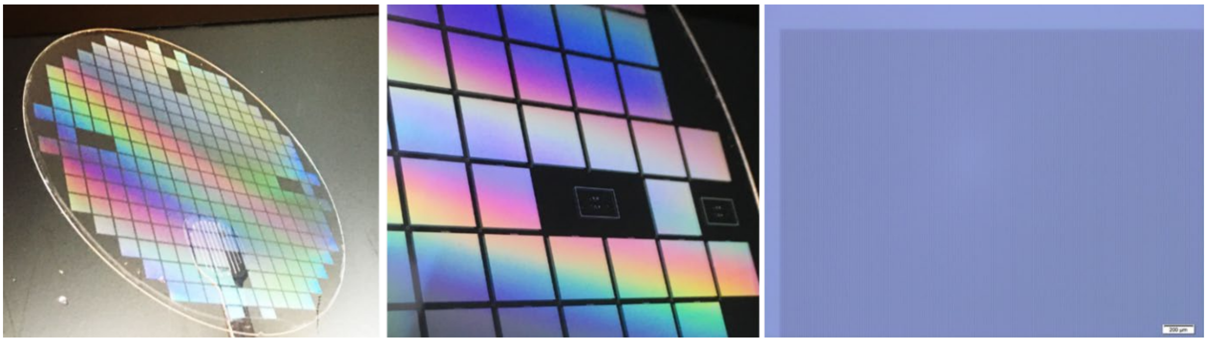


Figure 2: Replication of a 500nm/300nm line and space structures with 249 dies using TOK

TPIR^{TM}-2000S NL resist and EVG 7200 SmartNIL Technology[6]