SmartNIL® high-pattern-fidelity replication using TOK TPIR™-2000S NL

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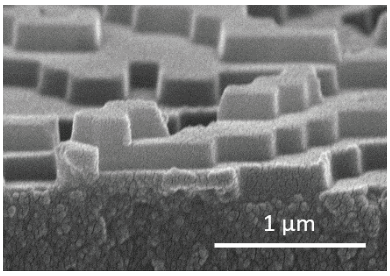
Nanostructured layers and surfaces are fundamental for development of many novel devices and applications in semiconductor, photonic and biomedical industries. Such nanostructure-based devices are already well established for silicon, compound semiconductors and glasses as well as for polymer structures. Nanoimprint lithography is now a well-established method for patterning nanostructures and also a proven fabrication method for various devices [1]. Leading manufacturers of augmented reality devices, optical sensors and biomedical chips are already utilizing NIL and realizing the benefits of this technology, including the ability to mass manufacture micro- and nano-scale structures down to less than 30 nm without restrictions to device dimensions. Additionally, complex structures, which typically need direct writing technologies, can be replicated easily and for many devices the replicated layer can be directly used as a functional layer in the product. In particular, permanent optical layers have proven to benefit a broad variety of photonic products.

Next to the nanoimprint technology and equipment, a key ingredient for successful implementation of this technique is given by the imprint resin. One example is TPIR™-2000S NL, designed by Tokyo Ohka Kogyo Co., Ltd (TOK), which is the world's top supplier of photoresists for semiconductor markets. It is a Si-containing UV imprintable material, which shows extremely high reliability (e.g., high temperature, humidity, and thermal shock), and has high transparency. The material can be applicable for various types of optical devices requiring high reliability. Further information and other material portfolios are available from https://www.tok.co.jp/eng/products/newfield/list/structure-materials/nanoimprint-materials

TOK TPIR™-2000S NL - Basic Properties	
Refractive index @ 589 - 940 nm	1.50 - 1.49
Transmittance @ 400 - 1200 nm	> 99 %
Young's modulus [GPa]	2.7
Reliability	Result (Change ratio)
- 40°C / + 125°C 1000 cycles	RI < 0.01 @ 400 - 1200 nm T% < 0.5 % @ 400 - 1200 nm



To unlock the potential of nanostructured optical resists it is important that they have good replication behavior. In particular, the complete filling of nanostructures, excellent pattern fidelity and defect-free demolding are crucial for high-quality devices. This has been investigated in more detail using a 200-mm master with 249 dies, which have a 500-nm / 300-nm line and space (L/S) pattern with 400-nm height. Images of the SmartNIL replication of these patterns are shown in Figure 1. As can be easily observed in these pictures, the TOK TPIR™-2000S NL resist shows a nice and defect free filling of all dies and the wafer scale nanoimprint could be performed in high quality.

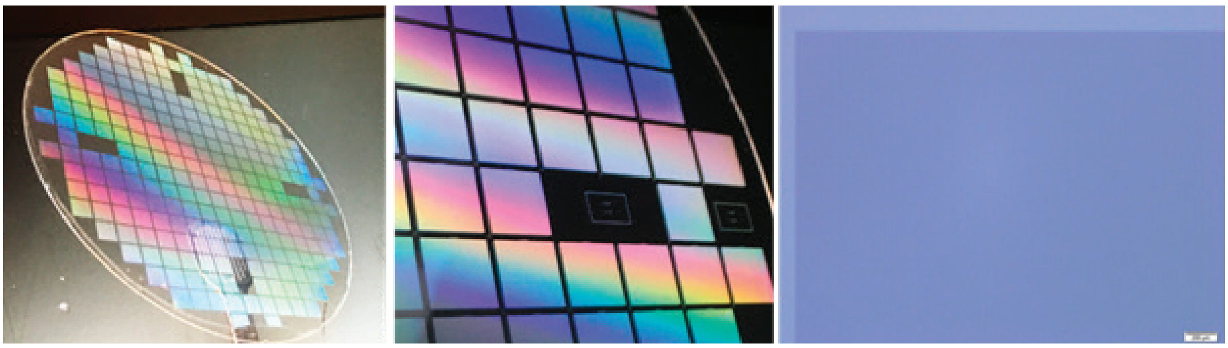
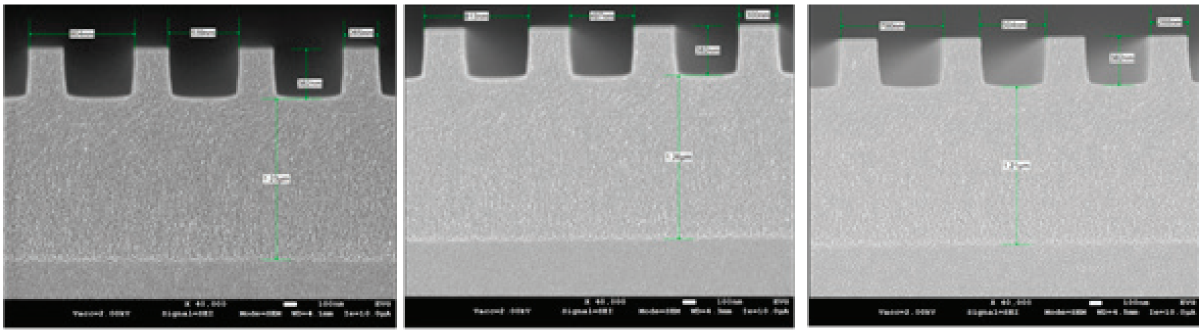


Figure 1
SmartNIL® replication of a 500-nm / 300-nm line and space structure with 249 dies using TOK TPIR™-2000S NL.

For more detailed analysis of the resist properties, a full wafer lot of 25 wafers has been imprinted and investigated. To resolve the patterns, scanning electron microscope (SEM) cross section imaging has been done. In Figure 2, such cross sections are depicted from imprint 1, 15 and 25 as representative examples. As can be seen, the whole wafer lot showed excellent pattern fidelity and uniform layer control. All structures are completely filled and nicely show the L/S pattern with high pattern fidelity. Layer thickness and uniformity are also controlled very well.



Imprint #1 Imprint #15 Imprint #25

Figure 2
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.

To prove the imprint-to-imprint quality, the height of the patterns of all 25 wafers has been measured and plotted in Figure 3. It clearly shows that only a minor variation of a few nanometers is observed. This indicated that the TOK TPIR™-2000S NL does not interact with EVG's proprietary working stamp materials and no swelling is observed.

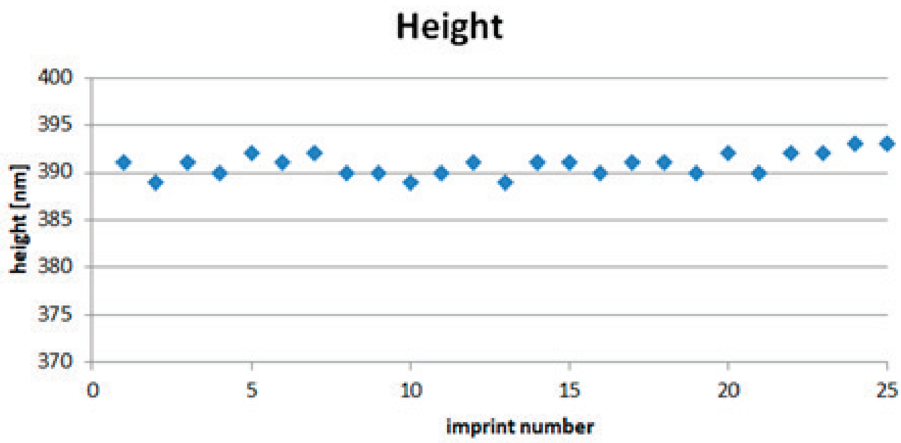


Figure 3
Height variation from imprint to imprint is within a few nm and thus proves no interaction or swelling of the working stamp is observed.

In summary this paper shows that TOK TPIR™-2000S NL in combination with the SmartNIL technology is well suited for manufacturing high-quality optical components and devices. It provides very uniform coating and good pattern filling properties. Nanostructures can be easily molded and demolded, and no defects or imprint-to-imprint variations are observed. This work has been carried out through the NILPhotonics Competence Center using an EVG101 coating system in combination with an EVG7200 SmartNIL nanoimprint system.

EVG®101 Advanced
Resist Processing System

EVG®7200 Automated
SmartNIL® UV-NIL System

NILPhotonics® Competence Center

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