Tape-Assisted Residual Layer-Free One-Step Nanoimprinting of High-Index Hybrid Polymer for Optical Loss-Suppressed Metasurfaces

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The commercialization of metasurfaces is crucial for real-world applications such as augmented and virtual reality devices, wearable sensors, and pigment-free color pixels. Nanoimprint lithography (NIL) has shown significant potential for the fabrication of metasurfaces due to its scalability and cost-effectiveness. However, imprinted metasurface faces two critical limitations: 1) low refractive index of commercial imprint resins, which hinders effective light modulation, and 2) residual layer that remains on the substrate, which causes optical losses in metasurfaces. In this paper, these bottlenecks in NIL for metasurface fabrication are addressed, achieving successful transfer of high-index nanostructures without residual layers[1]. To achieve high-index metasurfaces, particle-embedded resin (PER) is utilized by incorporating high-index nanoparticles into UV-curable resin. Additionally, a tape-assisted process is employed to physically peel off the high-index residual layer composed of nanoparticles. Optimized adhesion levels of the tape and PER weight ratios ensure the successful transfer of high-index, residual layer-free metasurfaces. This approach enables the replication of optical loss-suppressed metasurfaces, advancing their commercialization and expanding their application range.

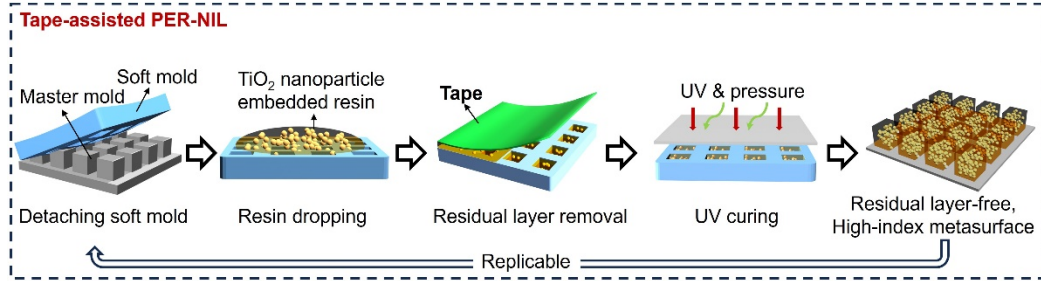[1] Y. Park, J. Kim, Y. Yang, J. Rho, *Advanced Science* 2025 *(in press)*

Figure 1: Tape-assisted particle-embedded resin (PER) based nanoimprint lithography (NIL) (PER-NIL) for one-step printable, residual layer-free metasurface. Schematic of tape-assisted PER-NIL, which enables duplication of residual layer-free meta-atoms.