# Tailored polymers for wafer-level optics manufacturing

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Wafer-level optics manufacturing has gained significant attention in recent years due to its potential to enable cost-effective production of miniaturized optical components for various applications. To meet the requirements of this manufacturing approach, tailored polymers compatible with the nanoimprint lithography (NIL) replication process have emerged as a versatile class of materials offering a range of properties necessary for the fabrication of high-quality optical devices. The presentation will provide an overview of DELO's transparent and functional materials utilized in wafer-level optics manufacturing today, targeted at applications such as imaging & sensing, automotive projection & lighting [1] or augmented reality [2].

Wafer-level optics, ranging from single optical elements such as lenses, microlens arrays or diffractive optical elements (DOEs) up to complete optical packages, can be mass-manufactured by NIL. In the most efficient variation, the polymer is used as a permanent functional material, directly forming the optical structure of choice. This does not only allow for multi-material combinations, it also removes the need for an etching step, potentially saving process time and costs. However, this approach places increased demands on the imprint material. Only a tailored polymer with optimized optical and mechanical properties enables the production of high-quality optical components with enhanced performance and reliability. This challenge has been addressed by DELO starting more than 15 years ago and results today in one of the largest material portfolios on the market specifically dedicated to wafer-level optics manufacturing.

DELO's polymer material portfolio is divided into optical solutions, functional solutions, and process solutions, according to Figure 1.

Optical solutions include transparent UV-curing polymers which can be used to directly replicate nano or micro-optical structures, or, in the simplest case, are used as an encapsulant to protect a sensor or emitter. They offer excellent optical properties such as high transparency and low light scattering, allowing for efficient light transmission. Different mechanical variations are available to address different product geometries, as well as refractive indices ranging from <1.4 to >1.9. Low shrinkage, high adhesion to the substrate and optimized demolding properties complete the outstanding properties. In contrast to typical injection molded thermoplastic materials such as PC, PMMA or COC, most UV-curable polymers can withstand a reflow process with peak temperatures up to 260 °C without deteriorating the optical properties, which also makes them suitable for optical sensor packaging and other temperature-demanding applications.

Functional solutions include light-blocking materials with high optical density to form package sidewalls or apertures within the optical system to control stray light or prevent unwanted reflections. Diffuser materials exhibit Lambertian scattering characteristics already in a 100 µm layer thickness and effectively eliminate the angular dependence of the incoming light, while filter materials can be tailored to transmit only at a specific wavelength range.

Finally, process solutions aim to unlock the full potential of wafer-level optics. E.g., multiple wafers can be bonded or stacked with tailored adhesives to form a complete optical system, and stamp materials with optimized compatibility facilitate the accurate transfer of structures from a master mold to the substrate with highest replication fidelity.

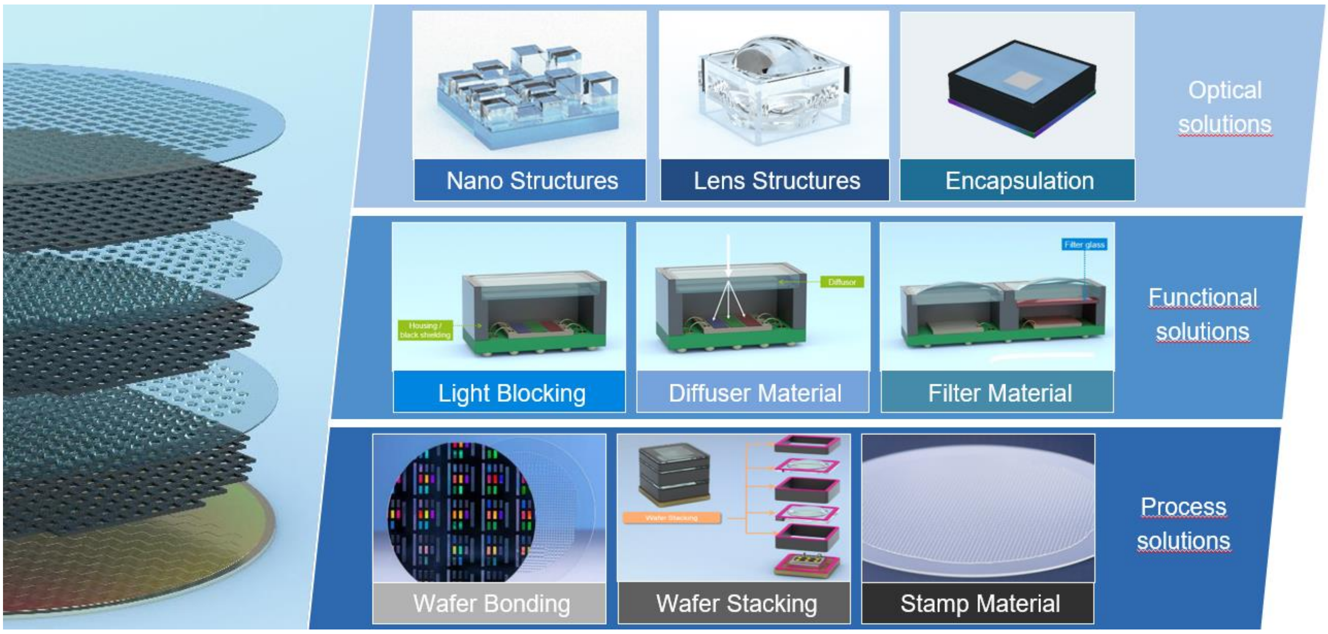

**Figure 1.** Overview of DELOs polymer material portfolio for wafer-level optics manufacturing.

Reference:

[1] Voelkel, Reinhard. "Wafer-scale micro-optics fabrication" Advanced Optical Technologies, vol. 1, no. 3, 2012, pp. 135-150.
[2] Kress, Bernard C. and Chatterjee, Ishan. "Waveguide combiners for mixed reality headsets: a nanophotonics design perspective" Nanophotonics, vol. 10, no. 1, 2021, pp. 41-74.