Volumetric 3D printing for the production of polymer free-form lenses

Free-form lenses are optical elements with a non-rotationally symmetrical surface. In most cases, their geometric shape is complex, allowing intricate light fields to be generated or imaging errors to be minimized. For such lenses, vat-based photopolymerization processes not only provide the highest accuracy and surface quality, but also represent a cost-effective alternative to conventional manufacturing processes. While layer-based stereolithography processes often result in optical defects at the boundary layers, volumetric 3D printing can prevent this source of error thanks to continuous process control.

Plant engineering and process control

The starting material for volumetric 3D printing are flowable photo resins in glass cuvettes. A 2-wavelength photoinitiator system can be used to spatially control the polymerization process. The polymerization takes place exclusively in the overlapping areas of a 2D laser light section of the first activating wavelength (λ = 405 nm) and the 2D image of an area illuminator of the second polymerizing wavelength spectrum (λ = 500–700 nm) arranged orthogonally to the light section. This enables quasi-continuous in-volume processing, meaning that components in the order of a few centimeters can be produced within a few minutes. This process is, therefore, 3 to 10 times faster than layer-based stereolithographic manufacturing processes. Factors that decisively influence the printing speed are the photo resin used, its viscosity and reactivity as well as the sinking speed of the components in the flask. These diverse process parameters make in-situ process development difficult.

Ex-situ characterization of the photo resins

Fraunhofer ILT has developed a characterization process to determine how suitable new material formulations for volumetric 3D printing are and to accelerate material development cycles. For this purpose, a rheometer has been equipped with a 2-wavelength exposure unit to investigate the sinking rate, reactivity and viscosity of photo resins. This makes it possible to define a process window and significantly accelerate the in-situ process development of new materials.

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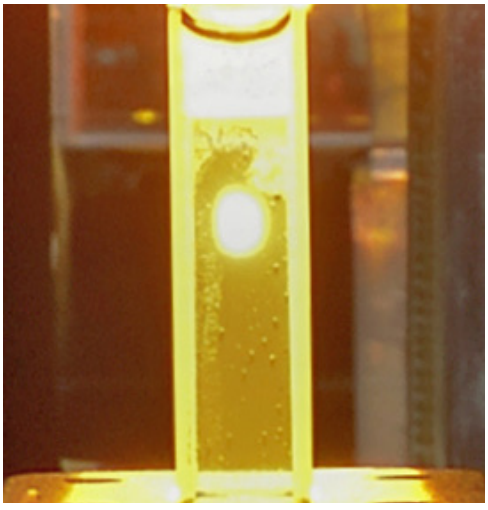

1 Exposure in volumetric 3D printing.