TECHNISCHE HOCHSCHULE LÜBECK

UNIVERSITÄT ZU LÜBECK

Department: Applied Natural Sciences
Program: Biomedical Engineering

Master Thesis

Parameter Characterization for Additive Optics Manufacturing

Micro-Optics via Two-Photon Polymerization and Material Performance Under Laser Exposure

Summary

The miniaturization of technical components has become increasingly important in various fields, particularly in biotechnology, where precise and personalized examination and treatment methods require highly accurate and specialized devices. Additive manufacturing allows the flexible design and fabrication of volume bodies using different materials and techniques. However, printing at the nano- and microscale pushes common methods to their limits. Two-photon lithography uses a tightly focused ultrashort-pulsed laser to polymerize a photosensitive resin solely in the focal volume, enabling solid three-dimensional objects with submicron details.

The present work investigates the material properties of transparent photoresists IP-Visio and OrmoComp, evaluating bulk polymerization, as well as transmission and attenuation behavior under long-term laser exposure with 407 nm and 439 nm up to 12 mW. Experiments in the field of two-photon lithography were conducted with the Photonic Professional GT2 by Nanoscribe using the 10x magnification objective. The study includes evaluations of hollow printing to reduce printing times, for which the interior of an object remains filled with liquid resin. Furthermore, shrinkage behavior during UV curing of hollow prints is analyzed. For micro-optical elements, a cylindrical lens was printed with different print configurations, optimizing towards a diffraction-limited performance. Optical evaluation of those lenses employs wavefront measurements in transmission to characterize aberrations evoked by the differently printed lenses.

The research at hand reveals that the bulk polymerization of photoresist samples is affected by shrinkage during UV curing, leading to air inclusions within the material. Careful sample filling, resting times before curing, and UV curing without heating are employed to mitigate this effect. However, IP-Visio material samples exhibit unstable transmission and attenuation over the maximum exposure time at 439 nm. OrmoComp demonstrates steady transmission under 439 nm irradiation during the 15 h exposure. For exposure with 407 nm, IP-Visio transmits only 20% but stays relatively constant throughout the measurement cycle of 15 h. OrmoComp shows degrading transmission at 407 nm during 15 h of measurement.

The results of experiments associated with hollow printing indicate that walls of only a few micrometers in thickness tend to yield, i.e., bend more easily due to tension during material shrinkage. Hollow prints provide significantly shorter printing times than solid-printed objects but show worse quality and shape accuracy. Prints with a supporting scaffold structure produce objects more closely related to the design. Although printing speed increases with this method, visible scaffold structures after UV curing suggest a refractive index mismatch between the printed and UV-cured material, rendering it unsuitable for optical applications. The optimization of printing parameters for solid-printed cylindrical lenses leads to diffraction-limited performances for IP-Visio. Lenses printed with OrmoComp could not yet reach diffraction-limited wavefronts with an RMS of $\lambda/14$, leaving room for the optimization of printing parameters in future research.

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