Friedrich-Alexander-Universität
Erlangen-Nürnberg

LEHRSTUHL
FÜR KUNSTSTOFFTECHNIK
Prof. Dr.-Ing. Dietmar Drummer

Fluid-based Additive Manufacturing

Motivation

Additive Manufacturing (AM) techniques allow for the generation of highly complex and functional polymer parts from CAD data. The use of resins enables the production of parts with enhanced chemical, thermal and mechanical resistance compared to thermoplastics processing. Furthermore, filigrane and transparent parts with high surface quality can be generated using stereolithography (SLA) or digital light synthesis (DLP) (Fig. 1). UV-assisted direct ink writing (UV-DIW) uses the advantages of extrusion based additive manufacturing and of thermoset materials (Fig. 2). Due to the spatial very precise photo-curing reaction, high process stability and dimensional accuracy can be achieved. The understanding of the material behavior and tailoring part properties by adapting the chemical composition are important research topics at the Institute of Polymer Technology (LKT).

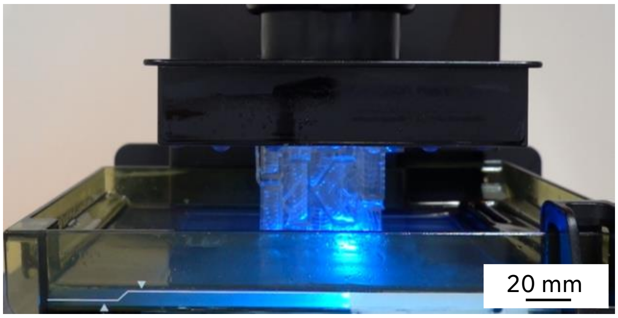

Fig. 1: Production of a filigrane structure via stereolithography

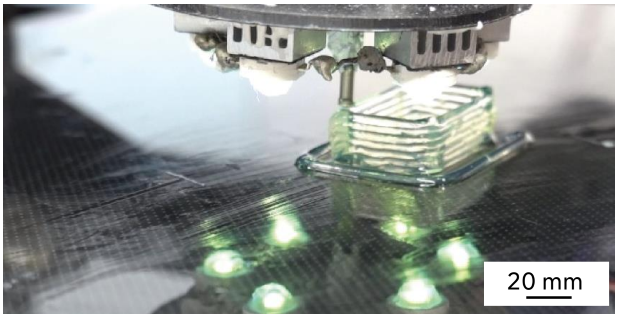

Fig. 2: UV-assisted direct ink writing

Application

Due to the high surface and detail quality of UV-acrylates in combination with high mechanical properties of epoxies, so called dual-cure materials offer the possibility to advance from rapid prototyping to end user parts. Also, the excellent chemical compatibility of epoxy has a huge potential for adding different kinds of fillers and functional materials, e.g. fibers (Fig. 3) or heat conductive powder. Therefore, liquid based AM can find application in almost every field of engineering.

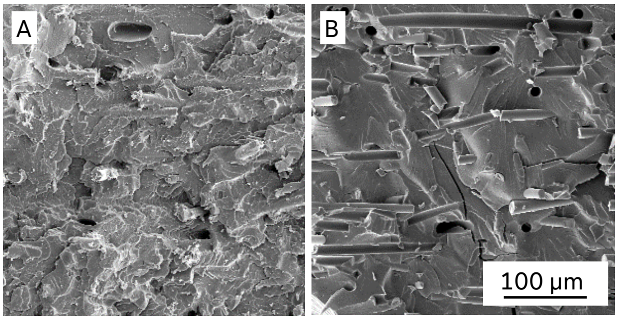

Fig. 3: SEM images of glass fiber filled material system:
A) dual-cure system
B) pure acrylate

| Institute of Polymer Technology
| Am Weichselgarten 10 | 91058 Erlangen-Tennenlohe, Germany
| Phone: +49 9131 85 710 00 | Fax: +49 9131 85 710 07
| Mail: lkt-info@fau.de | https://www.lkt.tf.fau.eu/

Research Focus

The research focus of the LKT in fluid-based additive manufacturing lies on the development of materials for SLA, DLP and UV-DIW as well as on the understanding of process interactions for tailoring part properties. Therefore, the characterization of the rheological properties of the resins and the UV-curing kinetics is of fundamental importance for understanding the process behavior (Fig. 4). The rheological behavior determines the flowability and the polymers capacity for filler integration. In addition, curing dynamics and therefore layer adhesion in SLA or DLP as well as the effect of the nozzle system in UV-DIW on filler orientation and part anisotropy is important for the layer-wise production of high quality parts.

Main research results

Within the last years many insights have been gained at the LKT. In studies on UV-DIW, it was found that the orientation of the fibers can be controlled by the printing direction of the nozzle (Fig. 5). This is similar to fiber orientation in the composite injection molding process. Furthermore, the effect of UV-light intensity on new resin systems has been analyzed systematically.

Besides material characterization, new processing and curing strategies were tested systematically. Dual-cure material systems, that are UV-cured to achieve sufficient stability during processing and thermally cured after the process to realize the desired part properties, have been developed. An increasing epoxy content leads to an increasing value of tensile strength. Compared to pure acrylate, the mechanical properties can be improved significantly (Fig. 6). In addition, using these dual-cure systems with fillers, better fiber bonding can be achieved, leading to mechanically reinforced SLA parts.

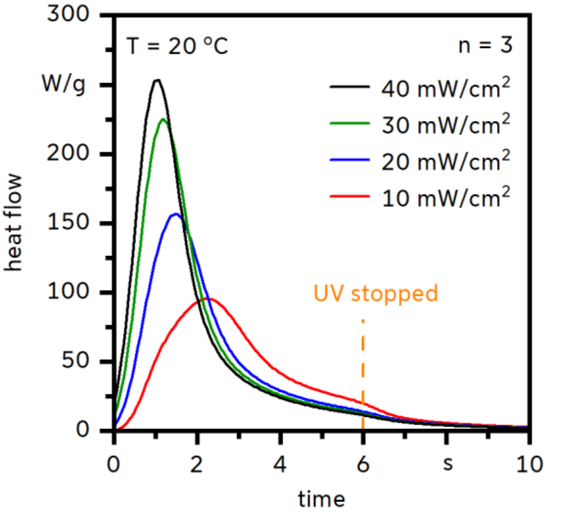

Fig. 4: UV-curing kinetics depending on light intensity

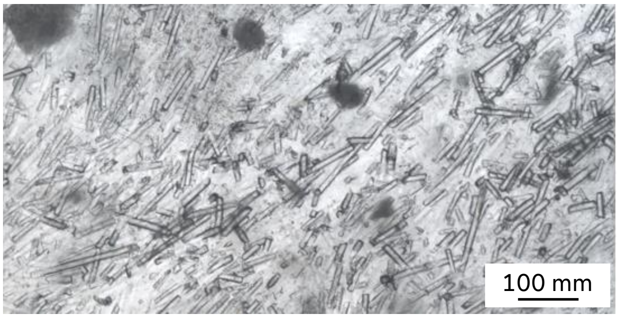

Fig. 5: Orientation control of short glass fibers in UV-DIW resin

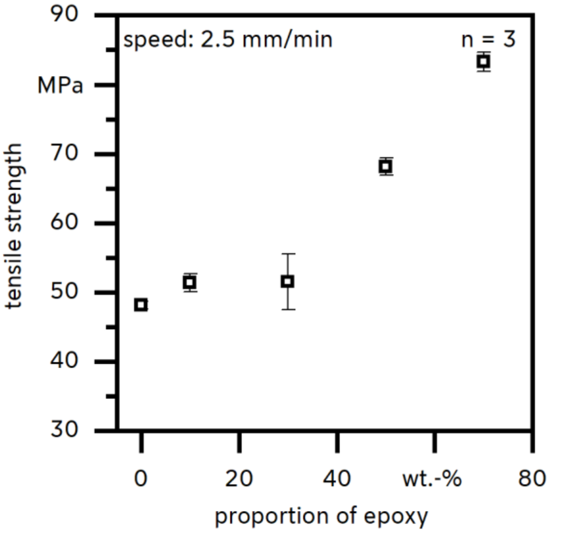

Fig. 6: Tensile strength of a dual-cure system in relation to epoxy content

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