Optical 3D Micro- and Nano-formation of Bioplastics

SUMMARY

Technology for printing 3D micro- and nano-structures from environmentally friendly plant-derived materials – soybean or linseed oil. Non-toxicity and high biodegradability enable application in biomedicine, nanophotonics, etc.

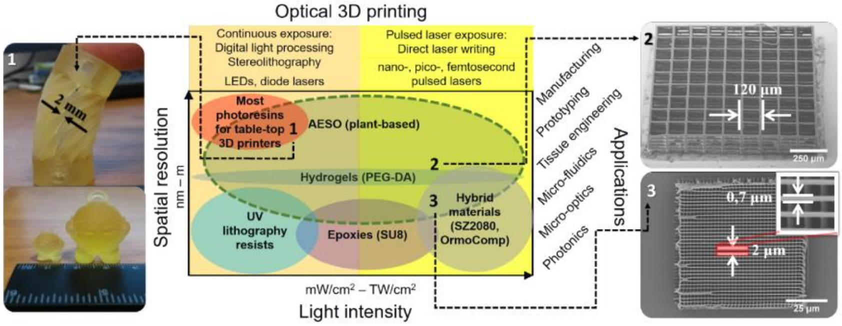
BACKGROUND

3D printing is a simple, low-cost and flexible additive manufacturing technique to create complex structures that cannot be cut, assembled or carved. It is especially useful in rapid fabrication of micro- and nano-structures to be used in health area, nanoelectronics, nanophotonics, etc. The most popular materials for optical 3D printing – epoxy and acrylic resins, have good mechanical properties, but are derived from petroleum, may have toxic ingredients and low biodegradability. Currently, soybean and linseed oil are one of the most promising materials to replace petroleum-derived resins.

TECHNOLOGY

The present technology is based on polymerization of plant-derived acrylated epoxidized soybean oil (AESO) and epoxidized linseed oil (ELO) resins using ultrashort laser pulses. AESO and ELO resins are prepared in a special way to obtain mechanical and thermal properties that are sufficient for practical application in 3D optical printing.

Using Direct Laser Writing (DLW) 3D lithography technique, photo-crosslinking can be achieved by tightly focusing ultrashort laser pulses into AESO or ELO resin, thus initiating a polymerization reaction. Selectively exposing material to laser radiation allows creating fully 3D structures with submicrometer spatial resolution. The smallest spatial features achieved are 100 nm [1], even though the formed object can be a few centimetres big while maintaining individual elements on a nm scale. Since the 3D cross-linking of the plant-derived materials is initiated using ultrafast laser induced multiphoton absorption and avalanche ionization, it does not require the usage of any photoinitiator, thus enabling green 3D micro-printing [2]. AESO resin can be used in 3D printing structures of any size with all types of optical or laser printing equipment [3].



TECHNOLOGY READINESS LEVEL

1 2 3 **4** 5 6 7 8 9 Validated in lab

INTELLECTUAL PROPERTY

Technological know-how developed in cooperation between Vilnius University and Kaunas University of Technology.

PUBLICATIONS

[1] Vegetable Oil-Based Thiol-Ene/Thiol-Epoxy Resins for Laser Direct Writing 3D Micro-/Nano-Lithography
[2] Photoinitiator Free Resins Composed of Plant-Derived Monomers for the Optical µ-3D Printing of Thermosets
[3] A Bio-Based Resin for a Multi-Scale Optical 3D Printing

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BENEFITS

- Bio-friendly: plant-derived, non-toxic and biodegradable material.
- Amount of bio-renewable carbon is up to 89 %.
- Suitable for table-top and industrial optical 3D printing.
- The smallest spatial features are 100 nm.
- Bactericidal properties and non-toxicity allows application in biomedicine.
- DLW technique does not require photoinitiators, thus reducing auto-fluorescence while performing microscopy.
- Can be used in printing structures of any size with all types of optical / laser printing equipment.

APPLICATION

The present technology can be used in various applications:

- Printing 3D cell-growth scaffolds;
- Microscopy (in vitro or in vivo);
- Biomedicine;
- Micro-optics;
- Nanophotonics;
- General optical 3D printing;
- Prototyping.

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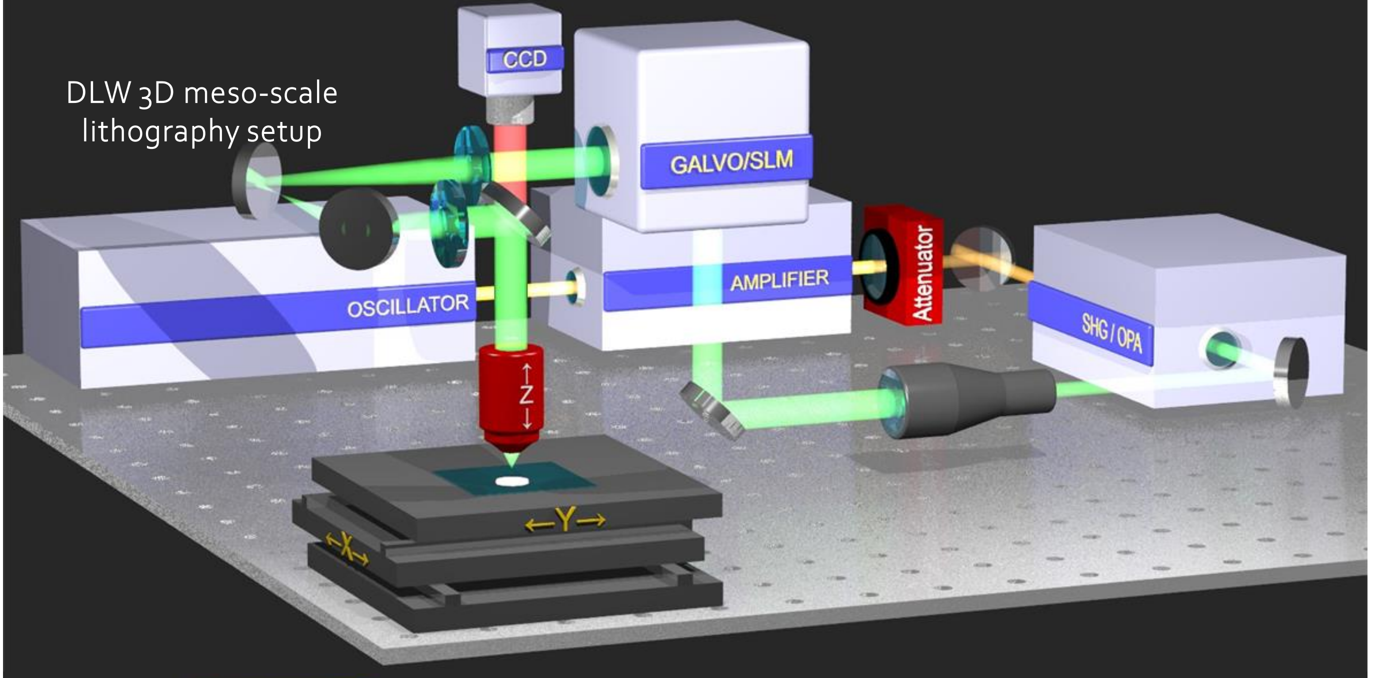
Technical Information: Direct Laser Writing 3D Meso-Scale Lithography

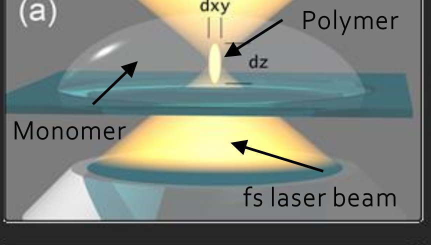
Vilnius University

Direct Laser Writing (DLW, a.k.a. Two-Photon Polymerization, Multiphoton Processing) 3D lithography is a technique of precise additive manufacturing, accomplished by illuminating positive-tone or negative-tone photoresists via femtosecond pulsed light. This technique allows producing features on a scale of nanometres in a photosensitive material, without the need to use complex electron beam or UV optical systems or photomasks (see DLW 3D fabrication setup).

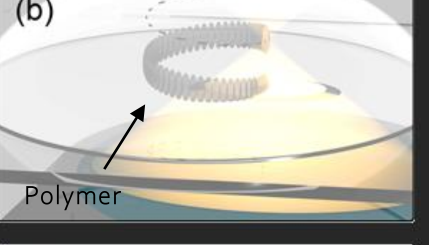
This technique relies on a multi-photon absorption process in a material. Typically its two-photon absorption when a simultaneous absorption of two-photons of the twice longer wavelength within the ultra-confined volume within a material restricted by the focus of a laser beam. It occurs once high intensities of light are reached (typically order of TW/cm^2). At the focal point of the laser beam a photochemical reaction, such as photopolymerization (photo-induced crosslinking), occurs (see a). In liquid resins, this process leads to liquid-to-solid transition (see b). By manipulating the position of the focal point in respect to volume of the modified material, e.g. by moving the stage (substrate) and/or scanning the beam, 3D structures are materialized. After the laser 3D structuring, the unexposed resin is dissolved in a developer (see c) and the fabricated structure is revealed (see d).

More details are available elsewhere: M. Malinauskas et al., Nanophotonics lithography: a versatile tool for manufacturing functional three-dimensional micro-/nano-objects, Lith. J. Phys. 52(4), 312 (2012)



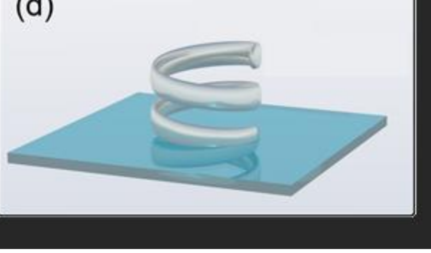


Photopoly-merization reaction is initiated in the focal point of the beam



Structure is directly written by moving sample in regard to the focal point

Organic developer washes unexposed material



3D free-standing structure is obtained on a glass substrate