Transactions on Additive Manufacturing Meets Medicine
Trans. AMMM, 2023, Vol. 5, No 1, Suppl. 1, Article ID 1130, 1 Page

Infinite Science Publishing

*Abstract*

# Printing magnetically driven micro-helices using two-photon polymerization

**L. Schmidt-Russnak[1,2*], J. Ackers[2], A. Malhotra[2], A. C. Bakenecker[2], and M. Graeser[2,3]**

[1] *Department of Physics, University of Hamburg, Hamburg, Germany*
[2] *Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE, Lübeck, Germany*
[3] *Institute of Medical Engineering, University of Lübeck, Lübeck, Germany*
[*] *Corresponding author, email: {lukas.schmidt-russnak,matthias.graeser}@imte.fraunhofer.de*



Two-photon polymerization (TPP) allows additive manufacturing of objects with feature sizes down to 100 nanometers or even less [1]. This makes TPP a promising method for producing micron-sized devices for medical applications such as targeted drug delivery, hyperthermia, or interventional surgery in regions of the body that are difficult to access. In contrast to manufacturing approaches like biological templates [2], glancing angle deposition [3] or mechanical torsion [4], TPP can be employed to produce objects of almost any shape. For this reason, the micro devices can be optimized in terms of their physical properties or their specific medical application.

In our work we produce helical shaped devices of a length of about 460 µm utilizing TPP (Nanoscribe PPGT2). The geometric dimensions of the model correspond to a 30-fold magnification of a design for which data from both experimental [5] and theoretical [6] studies are available. Equipped with a magnetic moment perpendicular to their longitudinal axis, the helices can be rotated around it by means of a homogeneous rotating magnetic field. The chiral shape of the helices then leads to a forward translation that resembles a corkscrew. To achieve the desired magnetic properties, we investigated both the incorporation of magnetic nanoparticles in the photo resin and a magnetic coating.

While the embedding of particles has been limited to a weight fraction below 1 % due to bubble formation during printing, we were able to successfully apply a coating containing cobalt and nickel by a method adapted from [7]. Due to the semi-hard magnetic properties, the coated helices can be propelled by means of a rotating homogeneous magnetic field. At helix rotation frequencies of 15 Hz a speed of more than one body length per second was measured.

We developed a production process for micron-sized helices that we can actuate using magnetic fields. This enables us to make further optimizations and investigate medical applications.

### Author's statement

Conflict of interest: Authors state no conflict of interest.

Acknowledgments: Research funding: Fraunhofer IMTE is supported by the EU (EFRE) and the State Schleswig-Holstein, Germany (Project: Diagnostic and therapy methods for Individualized Medical Technology (IMTE) – Grant: 124 20 002 / LPW-E1.1.1/1536)

### References

[1] A. Ovsianikov, B. N. Chichkov, *Two-Photon Polymerization – High Resolution 3D Laser Technology and Its Applications*, in: A. Korkin, F. Rosei (eds) *Nanoelectronics and Photonics*, Nanostructure Science and Technology, Springer, New York, NY, 2008
[2] X. Yan et al., *Multifunctional biohybrid magnetite microrobots for imaging-guided therapy*, Science Robotics, 2(12), 2017
[3] Z. Wu et al., *A swarm of slippery micropropellers penetrates the vitreous body of the eye*, Science Advances, 4(11), 2018
[4] D. Li et al., *A Helical Microrobot with an Optimized Propeller-Shape for Propulsion in Viscoelastic Biological Media*, Robotics, 8(87), 2019
[5] K. E. Peyer et al., Living Machines, LeporaSpringer-Verlag, Berlin, 2013, pp. 216–227
[6] K. I. Morozov and A. M. Leshansky, *Dynamics and polarization of superparamagnetic chiral nanomotors in a rotating magnetic field*, Nanoscale, 6(20), 2014
[7] R. Bernasconi et al., *Wet metallization of 3D printed microarchitectures: Application to the manufacturing of bioinspired microswimmers*, Journal of Manufacturing Processes, 78, 2022, pp. 11-21

DOI: 10.18416/AMMM.2023.23091130