1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: New light-controlled materials for soft robotics and nonlinear optics

1.1. Project goals

The goal of this project is to investigate new light-controlled materials for soft robotics (SR) and nonlinear optics. In this research materials that are promising candidates for such applications are based on new azo-selenoorganic compounds, modified with substituents of different nature (electron donating/accepting). Proposed materials will combine the light-responsive azo function with the organoselenium scaffold what can be used in SR. The aim of the project is to do comprehensive study of new azo-selenoorganic compounds to better understand the mechanisms of photoactivation and the possibility of exploiting their nonlinear optical properties. The goal is to use optimized materials for SR applications.

1.2. Outline

Nature has been always a source of inspiration for researchers that design new devices. This is also the case in robotics. However, switching the gear from “hard” robots that replicate solutions known from wildlife into soft robotics (SR) where the rigid parts are replaced by susceptible polymers has been possible only during recent years. The advantage of soft robotics lies in the possibility in better mimicking living organisms with their soft body leading to more efficient applications. Soft robotics solutions are possible due to rapid development of stimulus-responsive polymers that undergo macroscopic deformation in response to remote triggering. Such responsive materials can convert the energy contained in chemical or physical stimuli into macroscopic deformation. Among many actuators, light gained a lot of interest by being remote, non-destructive and precise activation stimulus. Therefore, based on the light-responsiveness of azo-dyes many photosensitive materials can be further developed for applications in soft robotics.

1.3. Work plan

Several experimental techniques will be used to study linear and nonlinear optical response of proposed photosensitive materials as well as the usefulness of such materials for soft robotics. Particularly, the dynamics of material modification under the light stimuli will be studied with two-beams technique. In this experiment, two overlapping laser beams interfere on the material forcing it to react what is observed as surface-relief grating (SRG) formation. The capabilities of SRG experiment will be expanded into all-optical poling technique that enables second-order optical effects in an initially isotropic material. This, in turn, can be used to induce holographic gratings. In addition, within the project it is also planned to perform additional experiments such as Z-scan, third-harmonic generation and photoinduced birefringence, in order to investigate the nonlinear optical response of proposed photoresponsive materials. Also, in order to demonstrate the soft robotics device, the change in the shape (such as reversible bending and/or translational movement) as response to light illumination of material (deposited on a flexible substrate) will be investigated.

1.4. **Literature** *(max. 10 listed, as a suggestion for a PhD candidate)*

[1] Y. Huang, Q. Yu , Ch. Su, J. Jiang , N. Chen, H. Shao, Light-Responsive Soft Actuators: Mechanism, Materials, Fabrication, and Applications, *Actuators* 2021, **10**, 298.
[2] H.-B. Cheng, S. Zhang, J. Qi, X.-J. Liang, J. Yoon, Advances in Application of Azobenzene as a Trigger in Biomedicine: Molecular Design and Spontaneous Assembly, *Adv. Mater.* 2021, **33**, 2007290
[3] M. Pilz da Cunha, M.G. Debije, A.P.H.J. Schenning, Bioinspired light-driven soft robots based on liquid crystal polymers, *Chem. Soc. Rev.* 2020, **49**, 6568-6578
[4] Z. Wen, K. Yang, J.-M. Raquez, A Review on Liquid Crystal Polymers in Free-Standing Reversible Shape Memory Materials, *Molecules* 2020, **25**, 1241
[5] H. Zhang, Reprocessable Photodeformable Azobenzene Polymers, *Molecules* 2021, **26**, 4455
[6] G.-Z. Yang, J. Bellingham, P.E. Dupont, P. Fischer, L. Floridi, R. Full, N. Jacobstein, V. Kumar, M. McNutt, R. Merrifield, B.J. Nelson, B. Scassellati, M. Taddeo, R. Taylor, M. Veloso, Z.L. Wang, R. Wood, The grand challenges of Science Robotics, *Sci. Robot.* 2018, **3**, eaar7650.
[7] J. Vapaavuori, C. G. Bazuin, A. Priimagi, Supramolecular design principles for efficient photoresponsive polymer-azobenzene complexes, *J. Mater. Chem. C* 2018, **6**, 2168-2188.
[8] S. L. Oscurato, M. Salvatore, P. Maddalena, A. Ambrosio, From nanoscopic to macroscopic photo-driven motion in azobenzene-containing materials, *Nanophotonics* 2018, **7**, 1387.
[9] N. Vermeulen et al., Post-2000 Nonlinear Optical Materials and Measurements: Data Tables and Best Practices, *J. Phys. Photonics* 2022 in press https://doi.org/10.1088/2515-7647/ac9e2f

1.5. Required initial knowledge and skills of the PhD candidate

Master of Physics or Master of Chemistry or related fields of Exact and Natural Sciences. Basic physics, basic organic chemistry and spectroscopy, basic experience in experimental optics, communicative English written and spoken, programming skills highly appreciated, ability of working both independently and in the team, eager to take on challenges, motivation to conduct scientific research.

1.6. Expected development of the PhD candidate's knowledge and skills

The project is aimed to optimize azo-materials responsive to light activation suitable for SR. The candidate will gain comprehensive skills in spectroscopic measurements by using several experimental techniques (what involves necessary theory, building/modifying the experimental setups and collecting data from the experiments). In addition, the crucial part of the research will be to analyze, interpret and present the obtained results what candidate will demonstrate during meetings, seminars and conferences. Therefore, the project will provide a PhD candidate an exceptional strong and complete background for the rational design of nonlinear optical materials from scratch as well as development of knowledge and skills in the field of optics, nonlinear optics and soft robotics. Additionally, PhD student will learn the basics of programming and data analysis.