Project 4.21. Ultrafast structural transitions in condensed matter (experimental)

Supervisor: dr hab. inż. Ryszard Sobierajski

Institute: Institute of Physics PAS

Unit: SL1.1

www: http://www.ifpan.edu.pl/SL-1/index.html

Background:

Recently, the advancement in modern measurement techniques of ultrafast processes and molecular dynamics modeling has enabled rapid development of materials research in which there is no long-range order (e.g. glasses, liquids). It is a the fundamental question how metallic and semiconducting glasses can be made from a supercooled liquid [1]. The main obstacle is the nucleation and growth of crystalline phases, which can be avoided by rapid cooling of the liquid [2]. In particular in the case of metals, the critical cooling rate is usually much higher than for other materials and may reach 10^13 K/s. The most important from the glass-forming ability point of view is the temperature range corresponding to the maximum crystallization rate. This range, located above the glass transition temperature, and just below the equilibrium melting point, remains as yet relatively poorly understood. The reason for this is the short duration of changes occurring at high temperatures, which does not allow the use of conventional experimental techniques. This limitation can be overcome by using the impulse annealing method (using femtosecond optical lasers) [3], combined with structural characterization of the frozen-in, intermediate stages of devitrification as well as time-resolved studies (pump-probe experiments).

1. A. L. Greer, New horizons for glass formation and stability, Nature Materials 14, 542 (2015)
2. R. Zallen 'Fizyka ciał amorficznych" (Wyd. Naukowe PWN 1994)
3. P. Zalden, A. Hoegen, P. Landreman, M. Wuttig, A. Lindenberg, How supercooled liquid phase-change materials crystallize: Snapshots after femtosecond optical excitation, Chemistry of Materials 27, 5641 (2015)

Aim:

The aim of the proposed project is to understand the process of melting followed by glass formation and/or crystallization in metals and semiconductors. Pure elements and alloys in form of nanostructures (mostly thin layers) will be studied. The planned research involves the use of ultrafast annealing methods with laser and electrical current pulses. It will be combined with structural characterization by a variety of experimental techniques involving optical, X-ray and electron scattering, both with use of laboratory equipment available at IP PAS (optical and electron microscopy, SEM, TEM) and large scale facilities (x-ray diffraction on synchrotron sources and free electron lasers). The work will provide experimental data and analysis significant for understanding of the fundamental mechanisms responsible for melting and glass formation.

Requirements:

- Highly motivated student, preferably with physics educational background and interest are desired
- He/She should hold a M.Sc. degree in Physics or Materials Sciences or in a related research field
- She/He should have strong interest in experimental science

- Any experience with fs lasers and/or X-ray-based techniques, in particular X-ray diffraction will be an asset
- Experimental data analysis and theoretical modelling require basic programming skills, preferable in Matlab or Python environments
- Good communication skills in written and spoken English are necessary given the international environment, in which the project will be carried out, in particular in collaboration with Stanford University, European XFEL and Universitaet Duisburg-Essen.

Funding:

Standard Polish PhD scholarship.