What are glass-forming materials? We typically associate the solid state with the crystalline materials, e.g., ice crystals or kitchen salt. However, in nature, there is quite an impressive group of materials which are characterized by a disordered structure that resemble more a liquid state rather than crystals. We termed them as glass-forming materials, or in a more general sense, amorphous materials. The glassy state can be obtained, e.g. if by cooling a liquid from the melting point it "prefers" to be supercooled instead of crystallizing. Understanding the fundamental principles underlying the glass formation, as well as an attempt to control crystallization tendency of glass-forming materials is a matter of intensive studies, not only from the point of basic research but also numerous exciting applications, e.g., in the pharmacy, food industry, electronic or material engineering. Among organic glass-formers, we can find low-molecular liquids as well as high-molecular-weight polymers.

Our motivation and research objectives - In the times of ubiquitous miniaturization, one of the fundamental problems to has to be tackled practically in all research disciplines is understanding how different is the behavior of matter at the "nano" scale in comparison to the macroscopic bulk phase, and is there any link between these two worlds? Such problem also applies to a wide range of glass forming materials.

Thus, the motivation for this proposal is to learn more about the effect of geometrical confinement in one and two dimensions on the glass transition and crystallization phenomena, as well as look for something universal that can tie up the most important dynamic features of the glass-forming liquids in macro- and nanoworlds to get a consistent picture of their glassy behavior.

Research to be carried out – To address the above questions we would like to take advantage of our experience in studying dynamics of glass-forming materials at varying thermodynamic conditions and transfer to nanoscale research, the formalism used so far to describe the behavior of bulk glass-formers under elevated pressure. In contrast to common belief, dynamics of liquids under elevated pressure and geometrical nanoconfinement does not represent two entirely different words. In both cases, we observe that density fluctuations have a significant impact on the glassy dynamics, and this might be a key to understand further nanoconfinement effects.

This project will cover the following research activities:

(T1) The impact of nanoconfinement on the dynamics of glass-forming materials.
Within the framework of this assignment, we will analyze the relationship between (i) "sensitivity" of the glassy dynamics on the density fluctuations and (ii) interactions between hard restrictive surface/soft confined sample and their impact on the phenomena observed in the presence of geometrical constraints. In addition to that, we will (iii) systematically compare the glass-transition dynamics of investigated materials in the presence of nano-confinement in 1D and 2D.

(T2) Testing density scaling idea under nanoconfinement.
The density scaling concept emerges from the high-pressure studies of dynamics in glass-forming materials, and it assumes that the dynamic properties such as relaxation time, viscosity or diffusion coefficient can be described through a single scaling relation, ρ^{γ}/T, where γ is a material constant. Here, we will perform first experimental attempts aimed to test the density scaling concept in thin films (1D-confinement) with a planar substrate interface and free surface. Its successful validation will serve as a strong argument that certain rules, which so far were considered only for bulk materials, can be adopted to describe viscous liquids and polymer's dynamics at the nanoscale, and vice versa.

(T3) Crystallization in confined geometry – 1D vs. 2D.
While keeping the same film thickness as the size of the nanopores, we will perform fist experimental studies aimed to understand the effect of the dimensionality of the spatial constraints on the crystallization tendency of glass-forming materials.