Investigation of hydrogel-based glass powder suspensions for 3D printing of transparent glassy materials.

In recent years, additive manufacturing methods, commonly known as 3D printing, have been developed rapidly. In simple terms, these methods involve the production of objects in a layer-by-layer manner. Their rapid development has led to many techniques: from typical fused deposition modelling (commercial 3D printer for plastics), through UV curing of photosensitive resins, to fusing materials with a high-power laser. However, despite the development of 3D printing methods in producing objects from plastics, metals, or even ceramics, there are still no commercial methods of additive manufacturing of transparent glasses of optical quality.

One of the main applications of glasses in modern technologies is fiber optics. Depending on the type of glasses and the structure of optical fibers (all-glass, glass-air), they can be used in telecommunications, gas detectors (methane, nitrogen oxides), or in medical diagnostic methods such as optical coherence tomography or multi-photon tomography. Currently, the construction of novel optical fibers is expensive and time-consuming. The structure based on numerical modeling results is stacked from specially prepared capillaries and rods made of glasses with the desired properties. As a result, a preform that in larger sizes reflects the final structure of the optical fiber is obtained. The process of assembling and joining the preform elements is performed manually, and in the case of complex structures, such as nanostructured optical fibers, it can take many weeks. Assembling also requires very clean (dust-free) conditions. The prepared preform is then thinned to a thickness of about 120 μm using a fiber drawing tower. 3D printing methods can significantly simplify the entire fiber manufacturing process. 3D printing of optical-quality transparent glasses would make it possible to produce fiber-optic preforms in a repeatable and automated process. This means that the production stage of the constituent components and preform stacking can be omitted. Thus, the time of fiber production could be reduced from several weeks to several days. Consequently, the production of optical fibers and the development of this field of science would significantly accelerate.

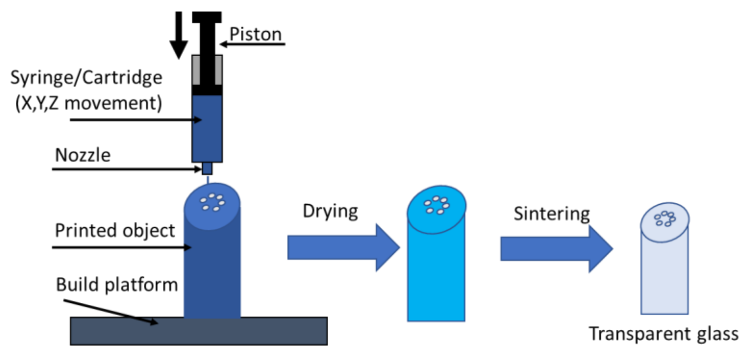

Figure 1*. Schematic illustration of optical fiber preform printing using Direct Ink Writing method*

In this project, the research will focus on the production of transparent glasses using the Direct ink Writing method. In simple terms, it consists of the extrusion of a suspension (ink) containing the printed material in the form of a powder. First, ink is extruded to form elements layer by layer (Figure 1). In the following steps, the obtained product is dried and fired (sintered) in a high-temperature furnace to obtain a high-density transparent product.

This project covers the preparation of glass powders suspensions (silica glass and multi-component glasses) in hydrogels and the study of their viscoelastic properties. These tests will determine the compositions that will ensure the proper behaviour of the inks. During extrusion (high values of stress), the suspensions should flow out of the nozzle like a viscous liquid. After deposition on the substrate, inks, like a solid material, should retain their shape (low values of stress) even under a load of subsequent deposited material layers. In the next stage, the thermal properties of the obtained suspensions and printed objects will be examined. The results will allow us to determine the temperature range and atmosphere (air or vacuum) for the sintering process in order to produce highly transparent glass objects. As a proof-of-concept of the proposed research, optical fiber preforms will be printed. In the next step, printed preforms will be thinned using a fiber tower in order to obtain optical fibers with a diameter of 120-200 μm. Finally, the obtained fibers will be characterized in terms of their optical properties.

The project's main goal is to establish the relation between viscoelastic properties and the composition of the inks. Specific viscoelastic properties and optimized heat treatment will allow obtaining transparent glass elements and preforms for the preparation of optical fibers. The obtained results may contribute to the improvement of additive manufacturing methods and may accelerate the development of research in optical fiber optics.