Bulk metallic glasses are materials that have already been settled among materials engineering main development directions. They are metallic alloys that exhibit relatively large glass forming ability (GFA). From the structural applications point of view the most important are the zirconium-based alloys. They exhibit optimal set of both good GFA and high mechanical properties. This allows production of relatively large bulk samples, which are subsequently shaped in the supercooled liquid region in order to prepare products for very sophisticated applications.
Many science teams constantly seek new compositions with even higher GFA or even better mechanical performance. Currently, there are two most popular GFA determination methods:
1) critical diameter of a fully amorphous cast determination by the discrete method, i.e. by casting series of the rapidly quenched rods with a step change of the diameter,
2) calculation of one or several of many available thermal indicators, which formulae consists of characteristic temperatures determined during the glass continuous heating.
Another method of the critical diameter determination is the cone test. However, it is still not well-settled method in this research field and is significantly more difficult to handle than the discrete method. It is based on the cone-shaped ingot longitudinal section examination performed in order to find the largest fully amorphous diameter. This diameter is continuously increased along the symmetry axis of the cone, so it allows determination of the critical diameter preferably in just a single cast.
The purpose of the Project is to determine the GFA of selected Zr-based alloy groups by the three abovementioned methods: discrete, cone test and thermal indicators. This could lead to both qualitative and quantitative results comparison. Following alloy groups are proposed to be examined: alloys with slightly altered composition and alloys with constant composition but based on zirconium of various purity. This particular alloys selection may allow verification of results to be obtained in each case by the three abovementioned methods. This is yet another purpose of this Project.
Following basic researches are planned in the Project:
1) The cone test of selected Zr-based alloy groups. A cone-shaped copper mould with a diameter range from 2 to 12 mm and a similar to wedge tests opening angle of 10° will be used in this examination. After cone-shaped samples preparation and their precise cut along the symmetry axis of the cone, the standard metallographic samples should be prepared. The D_c will be determined by the microscopic observations (both light and electron microscopy). A scanning electron microscopy will provide even higher precision of sub-micron crystallites observation. The last visible crystallite will indicate the location of the critical diameter.
2) The critical diameter determination using the discrete method will be performed by several rod-shaped ingots preparation. Their diameters would be gradually increased and close to the D_c determined by the cone test. Their cross-section will be investigated by the X-ray diffraction. The critical diameters determined this way will be used as a reference to the data obtained during the cone test.
3) Characteristic temperatures, such as: T_g – glass transition temperature, T_x – onset temperature of crystallization, T_m – solidus temperature, T_l – liquidus temperature, will be determined by the differential thermal analysis. These temperatures will be used to calculate various indicators used to describe the GFA of metallic alloys, e.g. older ones: $T_{rg}=T_g/T_l$, $\gamma=T_x/(T_g+T_l)$, $\Delta T_{xg}=T_x-T_g$ or newer ones: $\alpha=T_x/T_l$, czy $\sigma=T_x/(T_l-T_g)$. Plotting the correlation functions is also planned. They would relate the critical diameters to the GFA indicators and could allow selection of the indicator that describes the GFA most accurately in case of zirconium purity variation or elemental composition modification.
The included tasks are aimed to verify the applicability of the cone test. Showing it among other commonly used methods would allow the cone test advantages promotion in the area of metallic alloys GFA determination. This would significantly facilitate the research capabilities in the field of metallic glasses.
Included research plan realization may also provide additional benefits such as:
- broadening the knowledge of the elemental composition influence on the GFA of Zr-Cu-Al-Ag alloys,
- quantitative evaluation of zirconium purity influence on its alloys GFA.