Westfälische
Wilhelms-Universität
Münster

Mark Stringe
Arbeitsgruppe Prof. G. Wilde
Institut für Materialphysik

Relaxation and crystallization kinetics in metallic glass-forming systems

It is well known for metallic glass-forming systems that crystallization plays a crucial role not only regarding the production of metallic glasses, but also concerning the stability of these systems. On the one hand, empirical rules dealing with the stabilization of the supercooled liquid state of metallic glasses have been developed. The obtained materials, showing enhanced stability, are called bulk metallic glasses (BMG). One possible explanation for the gain in stability is a hindered rearrangement of long range ordered regions in the system. These rearrangements can be connected with the predominant dynamics of atoms in the supercooled liquid state. On the other hand, coming from the melt, the dynamics in an undercooled liquid also influences the crystallization process upon cooling the liquid. This crystallization of the undercooled liquid has to be avoided to reach the metastable glassy state.

Thinking in terms of the main processes determining the crystallization according to classical nucleation theory, i.e. nucleation and the following growth of the stable phase, the crystallization process depends on the amount of undercooling which is the driving force for crystallization. The dynamics of atoms governs the growth of the evolving solid-liquid interface upon crystallization. With a variation of the undercooling, the crystallization behavior can be analyzed to obtain information about the mechanism of nucleation and the dynamics of the undercooled liquid at varied temperatures with respect to the melting temperature of the alloy. This helps to understand the underlying mechanisms of crystallization of BMG in more detail.

The used sample system is an AuSi based BMG with a low melting point compared to most other metallic glasses. Using a combination of both conventional Differential Scanning Calorimetry (DSC) and Fast Scanning Calorimetry (FSC), it is possible to analyze the rate dependence of phase transformations (crystallization) over a broad interval of scanning rates i.e. over a broad range of undercoolings.
In FSC experiments, the small sample masses of the order of nanograms to micrograms enable measurements with scanning rates up to 10^4 K/s. For BMG the cooling rate is high enough to freeze the glassy state in situ. Critical cooling rates can be determined and up to 1000 measurements can be performed with the same sample piece. This allows to compare measurements in a more precise way with each other, since parameters influencing the crystallization behavior like sample geometry, mass and impurities are not changed within this large number of cycles.