Designing the microstructure and mechanical properties of bulk metallic glass matrix composites by flash-annealing

K. Kosiba[1,*,#], U. Kühn[1], A.L. Greer[2], J. Eckert[1,3,+], S. Pauly[1]

[1]IFW Dresden, Institut für Komplexe Materialien, Helmholtzstraße 20 D-01069 Dresden, Germany
[2]Department of Materials Science and Metallurgy, 27 Charles Babbage Road, University of Cambridge, Cambridge CB3 0FS, United Kingdom
[3] !TU Dresden, Institut für Werkstoffwissenschaft, Helmholtzstraße 7, D-01069 Dresden, Germany

[#]Corresponding author: k. kosiba@ifw-dresden.de

[+]present address: Erich Schmid Institute of Materials Science, Austrian Academy of Sciences, Jahnstraße 12, A-8700 Leoben, Austria and Department Materials Physics, Montanuniversität Leoben, Jahnstraße 12, A-8700 Leoben, Austria

Owing to their thermodynamical metastability, metallic glasses crystallize as they are heated. In the current work Cu-Zr-Al-based bulk metallic glasses (BMGs) were heated at different rates ranging from 0.08 – 200 K/s. The BMGs are instantaneously quenched after heating, so that controlled partial crystallization can be induced. In other words, the partially crystalline microstructure can be preserved and hence BMG composites are prepared.
Investigating their microstructure enables to study the phase formation and crystallization kinetics as a function of the heating rate. An increasing heating rate kinetically constrains the crystallization process, which changes from eutectic to polymorphic. The induced crystals are small, high in number and uniformly distributed when compared to conventional BMG composites prepared by melt-quenching. Direct observation of crystallite sizes and number allows us to investigate the crystallization kinetics in dependence of the heating rate. The nucleation rate at very fast heating significantly diverges from the steady state due to transient nucleation effects.
The heating rate and temperature to which the BMG is flash-annealed determine the nucleation rate, crystal growth rate and the time for crystal growth. Consequently, the size and number of crystals can be deliberately varied and hence the mechanical properties of BMG composites can be studied as a function of the volume fraction and particle size. The so-prepared BMG composites exhibit a strongly enhanced room-temperature deformability.
Here we show that fast heating not only permits tailoring of BMG composites in order to overcome the intrinsic brittleness of monolithic BMGs, but also permits studying the fundamental crystallization processes in highly undercooled melts.

K. Kosiba, U. Kühn, A.L. Greer, J.Eckert, S. Pauly, submitted to Scientific Reports.