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Flash-annealed CuZr based bulk metallic glass studied by electron microscopy

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Introduction: Bulk metallic glasses (BMGs) are amorphous materials showing attractive physical and mechanical properties due to their unique atomic structures. Despite the lack of a long-range order, still topological and chemical short-range and medium-range order are expected to occur. Although being amongst the strongest engineering materials known, they exhibit a disappointingly low plastic deformability.
Objectives**:** To circumvent this limited ductility the concept of implementing a heterogeneous microstructure by the formation of composites has recently been used [1]. One way to achieve such a structure is thermal treatment of the BMG. This work deals with the structure of flash-annealed CuZr based BMGs.
Materials and Methods: During the flash-annealing process the atomic structure of the Cu44Zr44Al8Hf2Co2 BMG is modified by rapid heating to different target temperatures above glass transition temperature (712 K) and the subsequent cooling in a water bath. The samples were heated to 817 K, 898 K and 916 K with a mean rate of 67 K/s and studied using a Zeiss Supra 55VP scanning electron microscope (SEM) at 20 kV as well as a Philips CM200 transmission electron microscope (TEM) operating at 200 kV.
Results: Using back-scattered electrons the SEM observation of the sample heated to 916 K reveals both an amorphous and a crystalline part each taking up about half of the sample with spherical crystallites of different size in between. Figure 1 illustrates a TEM image of a FIB lamella taken from one of the crystallites embedded in the amorphous structure. The corresponding diffraction pattern (DP) contains superlattice reflections indicating the presence of the B2 ordered structure. This is interesting as in crystalline CuZr based materials, devitrified from the amorphous structure, Cu10Zr7 and CuZr2 structures are expected to occur.
In order to analyse and compare the structures of the fully amorphous samples flash-annealed to 817 K and 898 K as well as the amorphous part of the sample heated to 916 K, variable resolution dark field (DF) fluctuation electron microscopy (FEM) was applied. Figure 2a shows a DP with integrated intensity using the software PASAD [2] indicating the amorphous structure. Figure 2b illustrates a tilted DF image taken with a given scattering vector k showing intensity variations in the form of speckles due to local structural correlations. Fluctuations of DF image intensity reveal structural ordering at the medium range. Acquiring a series of DF images at different vectors k and azimuthal angles φ provides the mean intensity and normalized variance as a function of k. The normalized variance is defined as $V(k) = (\langle I(k,r)^2\rangle / \langle I(k,r)\rangle^2) - 1$, with I being the image intensity and <> meaning the average over sample position r.
Figure 3 illustrates the mean intensity and variance curves of the differently treated samples, calculated from 320 images each, using an aperture size of 10 µm. It is interesting to compare the profile of the normalized variance to the 4 most intense peaks in the X-ray spectrum of B2 structured CuZr, as they show remarkable similarities.
By changing the aperture size and thus varying the spatial resolution the correlation length, a length scale for medium-range order, can be derived from the pair persistence model [3]. Figure 4 compares the correlation lengths of the flash annealed amorphous samples to the as-cast state showing an increase in medium-range order with increasing target temperatures.
Conclusion: Based on our results flash-annealing of CuZr based BMGs facilitates the formation of B2 ordered crystalline structure. The profile of the normalized variance is similar to the position and intensity of the most intense peaks in the X-Ray spectrum of the B2 structure. The correlation length, as a measure for medium-range order, increases with the target temperature for flash-annealing.

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References:
[1] J. Eckert, J. Das, S. Pauly, C. Duhamel, Journal of Materials Research 22, 285 (2007).
[2] C. Gammer, C. Mangler, C. Rentenberger, H. P. Karnthaler, Scr Mater 63, 312 (2010).
[3] J.M. Gibson, M.M.J. Treacy, P.M. Voyles, Ultramicroscopy 83, 169 (2000).

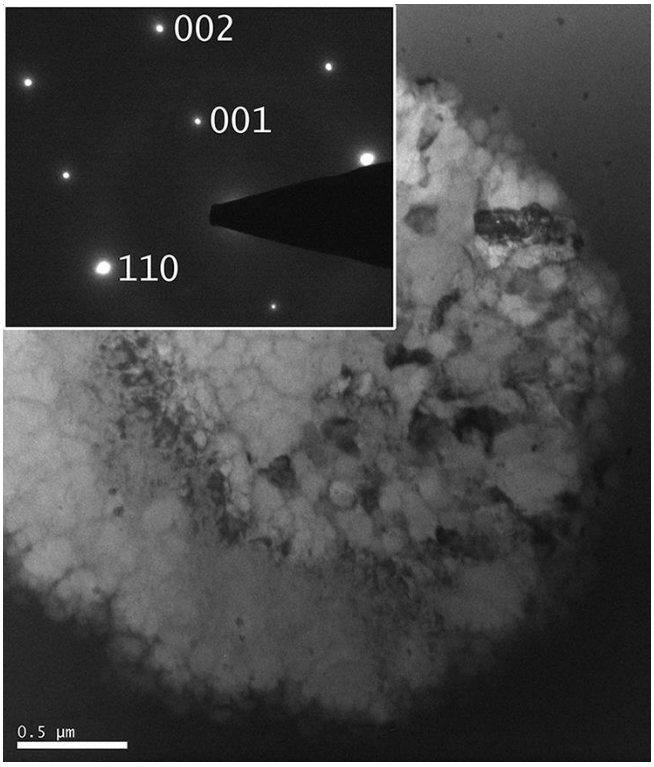

Figure 1

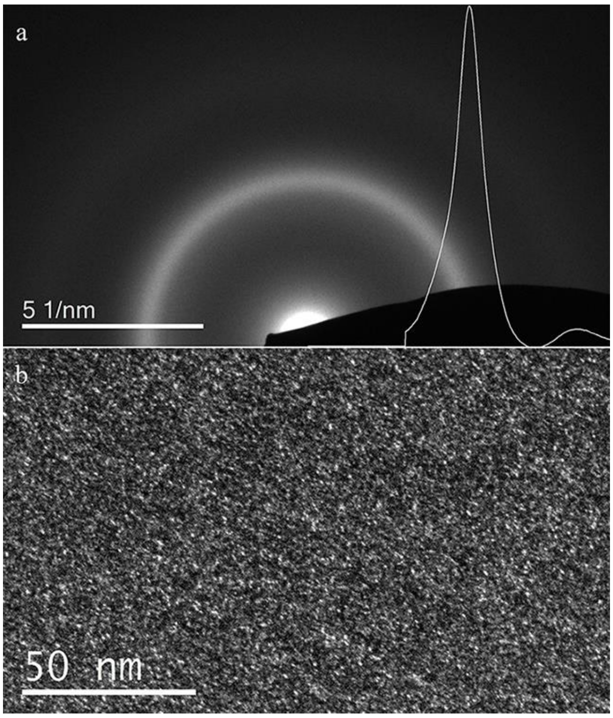

Figure 2

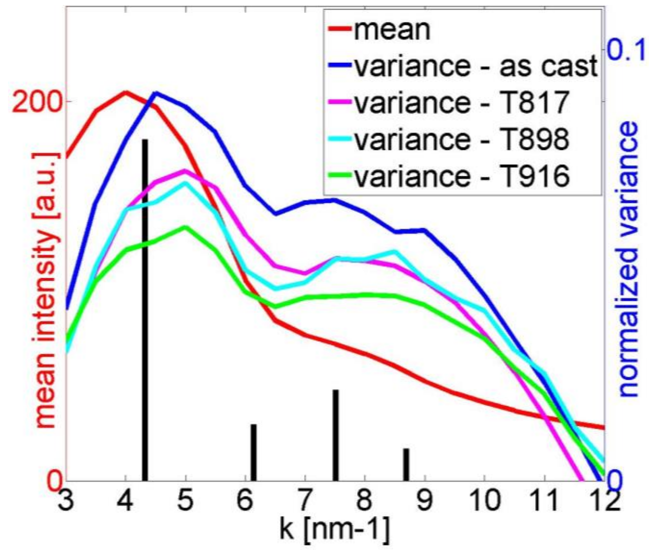

Figure 3

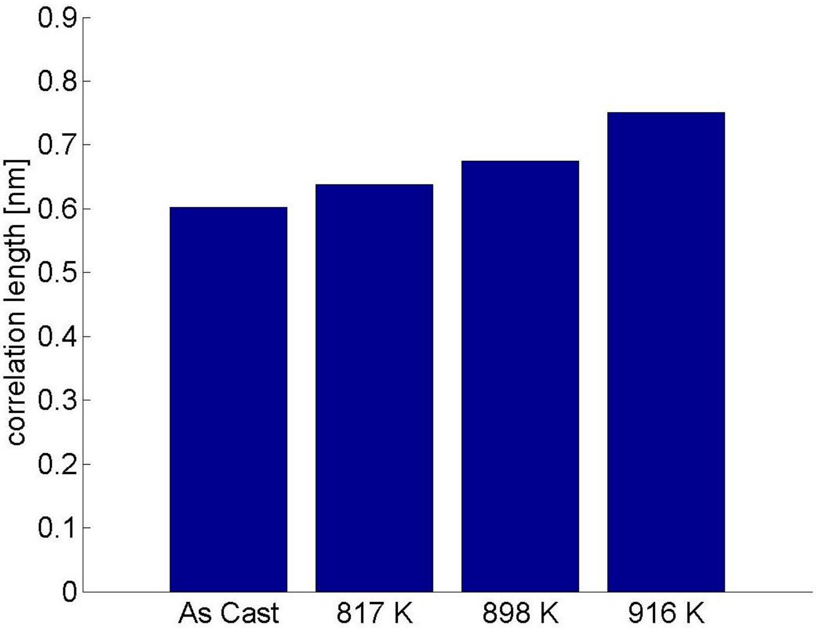

Figure 4