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Comparative study of the thermal, elastic and mechanical properties of various families of metallic glasses

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Abstract – The correlations existing between the thermal, elastic and mechanical properties of various families of bulk metallic glasses (BMGs), based on Zr, Ti and rare earths, will be discussed. Remarkably, although all the investigated alloys share an amorphous structure, the mechanical properties strongly depend on the thermal stability and elastic constants of the different glasses. While the BMGs based on rare-earths are very brittle, other BMGs (Zr-based ones) exhibit superplastic-like behaviour during compression tests. In this presentation, particular emphasis will be given to recent results from nanoindentation experiments to shed light on several issues such as the yielding criteria, strain rate effects or mechanical softening of BMGs.

The interest for bulk metallic glasses (BMGs) has been steadily increasing during recent years, triggered in part by their unique mechanical properties, in many cases superior to their crystalline counterparts. Namely, BMGs can be twice as strong as steels, exhibit more elasticity and fracture toughness than ceramics and be less brittle than conventional oxide glasses [1,2]. Bulk metallic glass rods (Φ= 2mm), with compositions $Ti_{40}Zr_{25}Ni_8Cu_9Be_{18}$, $Zr_{62}Cu_{18}Ni_{10}Al_{10}$, $Nd_{60}Al_{10}Ni_{10}Cu_{20}$, $Pr_{60}Al_{10}Ni_{10}Cu_{20}$, $Ce_{68}Al_{10}Cu_{20}Nb_2$ and $Ce_{60}Al_{15}Ni_{15}Cu_{10}$ have been prepared by arc melting and subsequent copper mould casting. The amorphous nature of these alloys has been verified by x-ray diffraction and differential scanning calorimetry. The elastic properties have been evaluated by means of acoustic measurements (pulse-echo overlap technique). The rods have been mechanically tested under compression and are found to exhibit dissimilar properties depending on their composition (i.e, on their thermal and elastic properties). For example, while BMGs based on rare-earths fracture before yielding, the Zr-based BMGs show signatures of superplasticity. Deformation-induced structural changes can explain the latter observation. On the other hand, whereas Zr-based and Ti-based BMGs are very hard and exhibit a large Young's modulus, the rare-earth BMGs are relatively soft and show a low Young's modulus. This can be correlated with the different Poisson's ratio and glass transition temperature of the several families of BMGs. Furthermore, fracture under compression typically occurs in BMGs at an angle smaller than 45º and a vein-like pattern is observed at the fracture surface, evidencing the occurrence of local heating during the tests. However, the BMGs based on rare-earths often fracture forming an angle larger than 45º. To understand this behavior, the use of a specific yield criterion, sensitive to local normal stresses acting on the shear plane (i.e., Morh-Coulomb criterion) is required. Further insight into the mechanical behavior of the BMGs has been obtained by nanoindentation. The data reveals that deformation is inhomogeneous (it proceeds via formation and propagation of shear bands) and causes strain softening in these alloys, presumably due to the net creation of free volume. This softening manifests by the progressive decrease of hardness as the maximum load applied during nanoindentation is increased (i.e., an indentation size effect). In this presentation, a new approach to model the indentation size effect on metallic glasses using the free volume concept will be shown. This model, which has been quantitatively applied to Ti-based BMGs, takes advantage of finite-element simulations of nanoindentation curves [3].

References

[1] M. Telford. Mater. Today 7 (2004) 36-43.
[2] A. R. Yavari, J. J. Lewandowski and J. Eckert. MRS Bull., 32 (2007) 635-638.
[3] J. Fornell, A. Concustell, S. Suriñach, W. H. Li, N. Cuadrado, A. Gebert, M. D. Baró, J. Sort. Int. J. Plasticity (2009) in press.