Giant ductility of ZrNi thin freestanding metallic glass films

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Abstract

Thin film metallic glasses (TFMGs) have recently attracted attention with a potential to mitigate the brittle-like mechanical behavior of their bulk counterparts, leading to superior mechanical properties among which a fracture strength close to the theoretical limit and large elastic deformation [1]. Moreover, TFMGs have been shown very recently to sustain outstanding plastic deformation above 10% involving homogeneous deformation, instead of shear bands-induced severe localization [2]. Most studies deal with FIB-milled micro-scale specimens involving the potential risk of defect generation. The on-going debate on length-scale effects on shear bands formation is not fully settled.

Here, we investigate the mechanical properties of submicron Zr_xNi_{1-x} TFMGs deposited by DC-magnetron sputtering with different thicknesses smaller than 900 nm. The mechanical test methods involve nanoindentation, nanostratch, fracture tests and an innovative method based on an on-chip internal stress actuated microtensile testing set-up for freestanding films [3]. With the last method, tests are simultaneously performed on thousands of specimens, deformed up to different strain levels to obtain the stress-strain curve up to fracture, while avoiding FIB-milling. The amorphous structure of the different films has been confirmed by X-ray diffraction and transmission electron microscopy. The tensile tests show unexpectedly large ductility up to 15% involving elastic deformation up to 5% and up to 10% of homogenous plastic deformation before failure, with the fracture strain increasing with decreasing specimen dimensions (length, width and thickness). It is worth noting that this large ductility is obtained for specimens up to 6 micrometers wide and up to 100 micrometers long which is significantly more than earlier results reported in the literature [2]. The elastic, plastic and viscous properties are independent or almost independent of thickness when measured by nanoindentation while the yield strength measured by tensile testing depends on the specimen cross-section area. The key characteristic of the films is a large rate sensitivity compared to other literature data, which can explain the large ductility, but also leads to significant creep at room temperature. Furthermore, the Young's modulus, strength, fracture toughness, Poisson ratio and activation volume increase when decreasing the Zr content. Nanoscratch tests are finally analyzed to determine the impact of these results on an important end-use coating property.

References

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