SIZE EFFECT IN POLYMER-SUPPORTED ULTRATHIN METALLIC GLASS FILMS

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Although metallic glasses (MGs) exhibit a unique combination of mechanical and chemical properties, their application as structural or functional materials is hindered by the lack of ductility which leads to catastrophic brittle-like fracture. When the size of a MG sample is reduced below some critical value, typically of the order of a few hundred nanometers, then considerable ductility can be observed. However, this size effect was demonstrated so far mostly by nanomechanical testing inside a transmission electron microscope using samples prepared by focused ion beam (FIB) milling. Whether the ductile-like behavior of submicrometer-sized metallic glasses is a real "intrinsic" size effect or it is rather caused by extrinsic factors like sample shape, ion beam effect or parameters of the testing setup is currently a subject of extensive discussions in the community. In this contribution the tensile properties of thin film $Pd_{82}Si_{18}$ MGs grown by sputter deposition on a polymer substrate are considered. The integrity of the MG films during stretching was monitored by in-situ measurements of the electrical resistance. An overview of electro-mechanical behavior of considered films is demonstrated in Fig. 1.The 250, 100, and 60 nm thick films fail in a brittle manner at 2% strain through propagation of long cracks perpendicularly to the straining direction. The rapid crack propagation in these films results in rapid increase of in-situ resistance signal. The size effect on the deformation behavior appears when the film thickness drops below 15 nm. The 7 nm thick films with the same composition show a crack-free deformation up to a strain of 7%. Even at higher strains no brittle-like failure but rather short and isolated cracks are observed. Cyclic tensile loading revealed extreme fracture resistance of ultrathin amorphous films showing no cracks after 30000 stretching cycles with a strain amplitude of 3%. Since all tests are performed at ambient conditions on films deposited using an industrially scalable process, the demonstrated size effect can be directly utilized for applications, such as protective coatings, nanoelectromechanical devices or half-transparent conductive layers for flexible electronics.

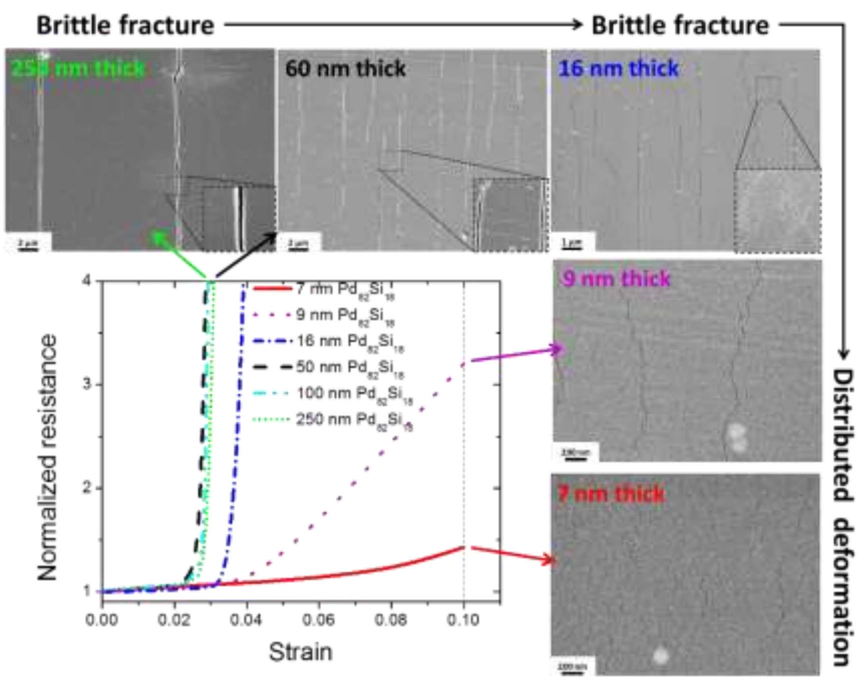

Fig. 1. Overview of electro-mechanical behavior of thin metallic glass films on polymer substrate