PO4055

Differences in properties and oxidation behavior of amorphous and crystalline magnetron sputtered Zr–Cu alloys

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Metallic alloys are fabricated either as crystalline solids by a relatively slow cooling process or as metallic glasses by a rapid cooling. These different structures lead to different properties and behavior of metallic alloys.
Therefore the present work is focused on a comparison of the properties and oxidation behavior of amorphous and crystalline Zr–Cu thin-film metallic alloys with an identical composition. The amorphous $Zr_{54}Cu_{46}$ films were deposited onto unheated rotating substrates by non-reactive magnetron co-sputtering of the Zr and Cu targets. The magnetron with the Zr target was operated in dc regime while the magnetron with the Cu target in high-power impulse regime. In order to obtain smooth and dense crystalline films of the identical composition, some of the as-deposited films were annealed slightly above the crystallization temperature for a few minutes in high vacuum.
The amorphous $Zr_{54}Cu_{46}$ film was found to be a metallic glass exhibiting the glass transition at 408°C while the annealed $Zr_{54}Cu_{46}$ film possessed a crystalline structure consisting of a mixture of the $CuZr_2$ and $Cu_{10}Zr_7$ phases. The crystalline film exhibited a higher hardness (7.7 GPa vs. 5.4 GPa) and elastic recovery (41 % vs. 35 %) and a lower electrical resistivity (0.7 μΩm vs. 1.7 μΩm) than the amorphous film. In addition, the amorphous film showed shear banding plastic deformation and partial shape recovery behavior. Dynamical thermogravimetric curves revealed that the onset of the oxidation of the amorphous film (≈ 475°C) was shifted by about 120°C to a higher temperature than for the crystalline film. Moreover, lower mass gains were observed for the amorphous film up to 800°C. As for oxidation kinetics, all isothermal thermogravimetric curves (400 - 575°C) showed parabolic dependencies, i.e. diffusion controlled oxidation. Lower oxidation rate constants and a higher activation energy of the oxidation (142.5 kJ/mol vs. 111.5 kJ/mol) were evaluated for the amorphous film.

Keywords
Zr–Cu metallic glass
Zr–Cu crystalline alloy
Oxidation behavior
Mechanical properties