Abstract

Exploration of Zr-Cu Based Thin Film Metallic Glass for Mechanical Strength, Thermal Stability, Bio-antimicrobial Ability and Diffusion Barrier

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Metallic glass has attracted lots of attention over past decades, exhibiting unique properties, such as high strength, toughness, corrosion resistance and surface roughness in atomic scale. The development of large-scale metallic glass is, however, limited by the cooling process issue. The magnetron sputtering process, with extremely high cooling rate, is therefore developed to fabricate the thin film metallic glass (TFMG). The aim of this study is to investigate the characteristics of Zr-Cu-based TFMG and to expand its application by compositional control in DC magnetron co-sputtering. With different combination of target materials during sputtering, various TFMG with specialized properties could be fabricated. Firstly, Ni-Al contents was alloyed into Zr-Cu-based matrix to form Zr-Cu-Ni-Al TFMG. The optimal composition for the better mechanical and thermal properties was revealed by adjusting target power of the co-sputtering process. Subsequently, the nitrogen was doped into the Zr-Cu-Ni-Al TFMG by controlling nitrogen gas flow rate. The relatively high mechanical performance of Zr-Cu-Ni-Al-N is attributed to the nitrogen-centered short range order clusters and the densely-packed structure.

The feasibilities of applying Zr-Cu-based TFMG on both biomedical and microelectronics field were also investigated. The microbe culture experiment and

plate counting analysis indicate that the Zr-Cu-Al-Ag-N TFMG exhibits over 99.99% antimicrobial ability. The superior antimicrobial performance could be resulted from the ultra-smooth, hydrophobic surface and the release of Ag, Cu ions from the coating. In addition, the Zr-Cu-Ni-Al-N TFME was applied as the diffusion barrier for Cu and Si. It is demonstrated that the TFMG barrier could effectively retard the Cu-Si inter-diffusion and the formation of Cu_3Si intermetallic compound when the annealing temperature is below T_x.

Furthermore, the Taguchi Design of Experiment(DOE) method was introduced to optimize the mechanical properties of Zr-Cu-Ni-Al-N TFMG. Four controlling parameters：Zr/Cu ratio, process temperature, Ni-Al target power, and nitrogen flow rate were selected. The optimal combination of controlling parameters was analyzed by analysis of mean (ANOM), and the sensitivity of each parameter was quantitatively evaluated by analysis of variance (ANOVA). The results demonstrate the feasibility and efficiency of applying Taguchi method to optimize a specific property of TFMG by physical vapor deposition.

Keywords：metallic glass；thin film metallic glass；composition control；antimicrobial；Cu-Si diffusion-barrier, Taguchi method