Amorphous and dual-phase nanocomposite coatings within the Zr-B-Cu system

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Abstract

In order to synthesize new materials having exceptional physical and chemical properties, amorphous–nanocrystalline alloys have attracted increasing interest in recent years. These materials are composed of both amorphous and nanocrystalline metallic phases. The synthesis of these dual-phase materials can eliminate the drawbacks of the individual phases and improve the resulting properties such as thermal stability, strength, or ductility(Borroto *et al.*, 2017). Due to associated high cooling rates, the fabrication of amorphous-nanocrystalline alloys as thin films is limited in some cases. However, the non-equilibrium process of magnetron sputtering with cooling rates of more than 10^6 K/s at atomic scale makes this possible. In the last decades, this deposition technique has been extensively used for the synthesis of amorphous alloys (thin-film metallic glasses), because even immiscible elements with a low glass-forming ability could be deposited into fully amorphous or dual-phase amorphous-nanocrystalline structures(Deng *et al.*, 2014)(Li *et al.*, 2019).

The present work aims at the preparation of dual-phase Zr-B-Cu coatings composed of a nanocrystalline ZrB_2 phase and an amorphous ZrCu phase with metallic glass behavior by non-reactive magnetron co-sputtering and investigation of their structure and properties. The elemental composition was varied so that the stoichiometry of both phases remained the same, but only the volume fraction was changed gradually. The depositions were carried out in argon (4 mTorr) using four unbalanced magnetrons equipped with two ZrB_2 targets, one Zr target, and one Cu target. The magnetrons with ZrB_2 and Zr targets were connected to dc power supplies, while the magnetron with Cu target to a high-power impulse power supply. All depositions were carried out on a rotating substrate (40 rpm) with rf biasing (50 W) at different substrate temperatures (no heating, 250°C, 350°C, 450°C).

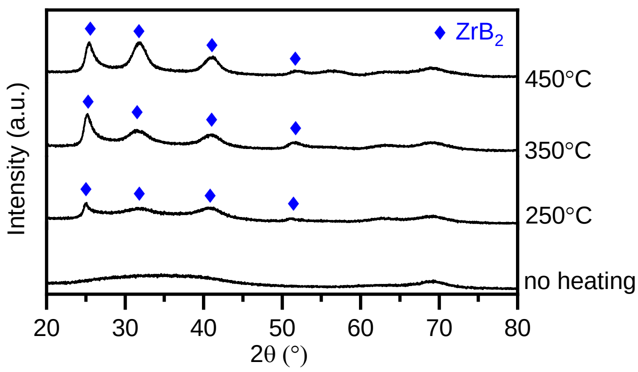

Figure 1. XRD patterns of $Zr_{35}B_{60}Cu_5$ films deposited at different substrate temperatures.

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Our first results show that the structure of Zr-B-Cu coatings deposited by magnetron sputtering without external heating is amorphous for all compositions. Increasing the substrate temperature promotes the crystallization of the coatings as depicted in Fig. 1, leading to the formation of a dual-phase nanocomposite structure based on a nanocrystalline ZrB_2 phase and an amorphous ZrCu phase. This effect becomes more pronounced as the volume fraction of the ZrCu phase decreases. Mechanical properties such as hardness and stress are affected by the volume fractions of both phases and exhibit a temperature dependence. It is anticipated that the deformation behavior, which is now being studied and will be discussed, will be closely related to the phase composition and microstructure.

References

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