Composition engineering of ultra-soft-magnetic Co-based alloys

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Abstract

In the present study, the liquidus temperature, mixing enthalpy, and atomic mismatch factor are used to predict and empirically evaluate the amorphisation capability of Co-Fe-B alloys fabricated by melt spinning. Based on this approach, five out of seven alloys have an amorphous structure, confirming the capability of the proposed model in predicting the alloy compositions with higher amorphisation ability in a ternary alloy system in the absence of any costly elements, such as Nb, Mo and Zr. X-ray diffraction, TEM and Mössbauer results show that the other two alloys exhibit different in-situ crystallisation behaviour. In one case, only the free side crystallises, whereas the crystallisation occurs through the entire thickness of the ribbon in the other alloy. The lower amorphisation ability exhibited by these alloys in relation to the predictive parameters has been evaluated. Additionally, there is a strong correlation between amorphisation ability and crystallisation behaviour of alloys. Alloys which crystallise through eutectic mode are more likely to exhibit high amorphisation, whereas crystallisation via primary mechanism can be the sign of lower amorphisation ability. The output of the alloy design process was five amorphous alloys compositions, among which, one is magnetically ultra-soft, H_c= 2.9 A/m; a surface crystalline alloy, with low H_c and 50% lower power loss at high frequencies compared to the best amorphous ribbons, due to the in-situ induced out of plane anisotropy of the crystalline phase on the surface; and a nanocrystalline sample with very high saturation magnetisation, M_s= 1.57 T. The surface crystallisation can eliminate the need for inducing transverse anisotropy by magnetic annealing. Therefore, optimising the alloy composition through this strategy can be a universal strategy on composition design for the fabrication of alloys with excellent properties to be utilised in different applications.

Keywords: Alloy design, CALPHAD, Amorphisation capability, Nanostructured alloys, soft magnetic properties, Rapid quenching, Mössbauer studies