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Microstructure and magnetic properties of $Fe_{72.5}Cu_1M_2V_2Si_{13.5}B_9$ (M=Nb、Mo、(NbMo)、(MoW)) nanocrystalline alloys

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Abstract –The effect of partial substituting Nb by V and M (M=Nb、Mo、(NbMo)、(MoW)) elements on the structure and magnetic properties of $Fe_{72.5}Cu_1M_2V_2Si_{13.5}B_9$ alloys was studied in this presentation. Results show that the Finemet type alloy with M=Nb_1Mo_1 has the smallest grain size of about 8nm. The best combined dc soft magnetic properties have been obtained in $Fe_{72.5}Cu_1Nb_2V_2Si_{13.5}B_9$ alloy. In the case of ac soft magnetic properties, $Fe_{72.5}Cu_1Nb_2V_2Si_{13.5}B_9$ alloy also exhibits a very high complex permeability of around 90000 and very low core loss($P_{0.02/200}$=18.6KW/m^3). The V-doped Finemet-type alloys are therefore suitable for core materials in transformers.

The soft magnetic properties of Finemet ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$) alloys have been extensively studied during the last decade. Their excellent soft magnetic behavior is the result of the averaging out of the magnetocrystalline anisotropy (bcc-Fe rich nanocrystals) via magnetic interactions (exchange coupling) with the residual amorphous phase. A number of workers have investigated the effects on the soft magnetic properties of the substitution of additional alloying elements for Fe in the $Fe_{73.5}Si_{13.5}B_9Cu_1Nb_3$ alloy composition to further improve the properties as well as the substitution of Cr, U, Ta, etc., for Nb.[3~6] No significant improvements in soft magnetic properties were reported over those of the base composition. In the quest to achieve properties superior to those of the well-known Fe-Nb-Cu-Si-B system, the element Nb hasbeen substituted by V and M (M=Nb、Mo、(NbMo)、(MoW)) elements in present experiment. The aim of this work was to study the effect of partial substituting Nb by V and M (M=Nb、Mo、(NbMo)、(MoW)) elements on the structure and magnetic properties of the $Fe_{72.5}Cu_1M_2V_2Si_{13.5}B_9$ alloys. On the other hand, there is an important economical benefit in this type of alloys because the cost of V is lower than Nb .

$Fe_{72.5}Cu_1M_2V_2Si_{13.5}B_9$ (M=Nb、Mo、(NbMo)、(MoW)) amorphous ribbons were prepared by the melt spinning technique. Heat treatments were performed at temperatures 460℃~630℃ for 30mins without magnetic field and then quickly cooled in furnace in a nitrogen atmosphere in order to determine the optimum annealing temperature range，which corresponds to the maximum value of initial permeability and the minimum value of coercivity. The structure of samples was checked with X-ray diffractometry (XRD). The magnetic properties was determined from hysteresis loop traced with a fluxmeter and core losses were determined from the hysteresis loops traced at different frequency and magnetic field with a digital storage oscilloscope.

It is revealed that the microstructure and soft magnetic properties are strongly effect by the addition of M elment. The effect of different doping elments on the grain size of nanocrystalline alloys was analysized by using Scherrer equation and results show that the Finemet type alloy with M=Nb1Mo1 has the smallest grain size of about 8nm. The best combined dc soft magnetic properties have been obtained in $Fe_{72.5}Cu_1Nb_2V_2Si_{13.5}B_9$ alloy. The $Fe_{72.5}Cu_1Nb_2V_2Si_{13.5}B_9$ nanocrystalline alloy shows the highest initial permeability (109000), lower coercivity (0.56A/m) and moderate saturation field (1.04T). In the case of ac soft magnetic properties, $Fe_{72.5}Cu_1Nb_2V_2Si_{13.5}B_9$ alloy also exhibits a very high complex permeability of around 90000 and very low core loss($P_{0.02/200}$=18.6KW/m^3). The V-doped Finemet-type soft magnetic alloys are therefore suitable for core materials in power transformers. In addition, the effects of different doping elements on the microstructure and magnetic properties are discussed in detail.