UNIAXIAL MAGNETIC ANISOTROPY OF Fe-SI AND Co-Si AMORPHOUS THIN FILMS DUE TO Si NANO-SEGREGATION

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Fe-Si and Co-Si thin films were studied with different Si concentrations by x-ray absorption spectroscopy (XAFS), and the analysis was confronted to their magnetic properties of coercivity and anisotropy. The analysis of the XAFS spectra showed a higher disorder in the amorphous Fe-Si films than in the Co-Si films and a larger degree of clustering of Co atoms, consistent with the higher heat of alloying of Fe-Si with respect to Co-Si alloys. It also detected the increasing of the non-magnetic (Fe,Co)Si_2 environments with increasing Si concentration. All the amorphous samples had a well defined uniaxial anisotropy. Magnetic fields of less than 30 Oe externally applied during film deposition changed the easy axis orientation only for the most disordered Fe-Si film with Si concentrations of about 37% at.. For higher Si concentrations, the orientation of the magnetic easy axis of the Fe-Si and Co-Si films was correlated with the expected anisotropic spatial distribution of Si concentration, which was defined by the oblique angle of incidence of Si atoms during film deposition. This indicates that the spatial distribution of such a detected non-magnetic Si rich environments was anisotropic, giving rise to the observed uniaxial magnetic anisotropy of these films.

The temperature dependence of the anisotropy constant $K_u(T)$ compared with that of the magnetization $M_s(T)$ was linear near T_c and it deviated from what it might be expected from a pure shape anisotropy, indicating that magnetic coupling between the different magnetic regions in the sample was also important. The behaviour of K_u with temperature could be understood if the amorphous alloys consisted in segregated Si-rich regions in an amorphous Fe(Co)-rich amorphous matrix [1]. The magnetic coupling between the Fe-rich regions would be anisotropic due to the anisotropic distribution of Si. Figure 1 shows $K_u(T)/K_u(T=0)$ and $M_s(T)/M_s(T=0)$ for one of the Co-Si films with the highest Si concentration. The anisotropy energy increases at about 150 K, at the same temperature that the magnetization decreases. Such a sudden increase in the anisotropy could be explained if the magnetic alloy consisted of different regions with different Curie temperatures and if this regions had an anisotropic spatial distribution. This study shows that amorphous materials contain heterogeneities that can modify their magnetic properties, and that it is possible to optimize the magnetic anisotropy of this films by controlling the Si segregation either by adjusting the substrate orientation with respect to the incident beam and/or by favoring Si segregation adding other elements in the alloy.

References:

[1] W. D. Li, O. Kitakami, and Y. Shimada, J. Appl. Phys. **83** (1998) 6663.

Figures:

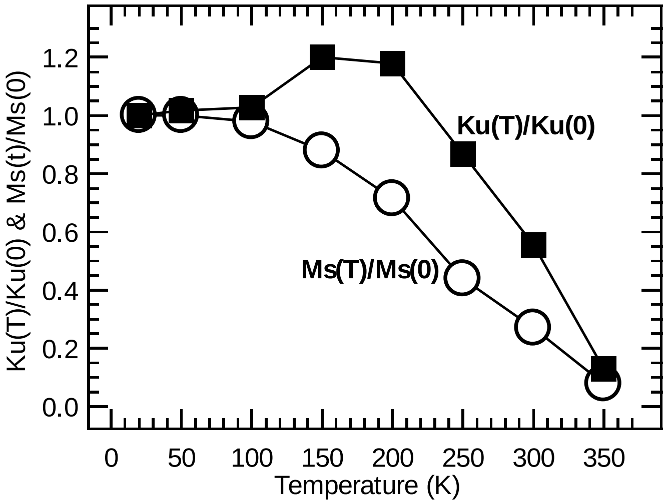

Figure 1. Temperature dependence of the anisotropy energy (solid squares) and magnetization (empty circles) of a Co-Si film with a 40% at. Si concentration.