Nanocrystalline Soft Magnetic Alloys

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Nanocrystalline structures offer a new opportunity for tailoring excellent soft magnetic materials. The talk surveys nanocrystalline soft magnetic alloys with particular emphasis on the features important for application.

Among the potential alloy candidates, the most prominent example which has meanwhile successfully entered into application are the alloys based on Fe-Cu-Nb-Si-B due to their ease of production and their superior properties. The material is produced by rapid quenching, giving an originally amorphous ribbon. Subsequent heat treatment above the crystallization temperature produces a homogeneous ultrafine grain structure of bcc FeSi with grain sizes of typically 10–15 nm and random orientation, embedded in a still amorphous minority matrix. This particular microstructure enables superior soft magnetic properties comparable to those of permalloys and Co-based amorphous alloys, but with a significantly higher saturation magnetization.

The magnetic softening of nanocrystalline ferromagnets basically is related to the suppression of the local magneto-crystalline anisotropy by exchange interaction. Yet, though most essential, this mechanism is only one part of the medal.

Superior soft magnetic properties also require a low or vanishing magnetostriction which reduces magneto-elastic anisotropies due to residual internal stresses. The averaging effect of exchange interaction hereby provides a new way in order to obtain an isotropically low or vanishing magnetostriction for particular compositions like $Fe_{73.5}Cu_1Nb_3Si_{15.5}B_7$.

Still, soft magnetic applications not only require highest permeability and lowest coercivity but a well defined shape of the hysteresis loop with not necessarily highest but a well defined level of permeability. This can be realized by uniaxial anisotropies induced either by magnetic field annealing or annealing under tensile stress. In particular, magnetic field induced anisotropies are of tremendous practical relevance. It is the magnitude of these induced anisotropies which mainly controls the permeability in modern nanocrystalline alloys used in application. Appropriate choice

of the alloy composition and/or the annealing conditions allow to vary the permeability by almost three orders of magnitude.