Application oriented issues of amorphous and nanocrystalline alloys

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We will survey characteristic features of amorphous and nanocrystalline alloys particularly relevant for soft magnetic applications. Both materials have much in common starting from their way of production by rapid solidification as a thin ribbon and ranging over to the key factors which determine their magnetic properties. Thus, their structural correlation length is much smaller than the domain wall width. This results in a virtually negligibly magneto-crystalline anisotropy contribution − the prerequisite for good soft magnetic behaviour. Superior soft magnetic properties additionally require a low magnetostriction. This is realised for amorphous Co-based alloys and for nanocrystalline Fe-base alloys. Due to their production inherent low thickness and relatively high electrical resitivity both materials additionally reveal favourably low losses up to several 100 kHz making them even competitive with MnZn ferrites.

Soft magnetic applications typically require a well defined shape of the hysteresis loop with a specific level of permeability. This is accomplished by annealing induced uniaxial anisotropies. In particular, magnetic field induced anisotropies are of tremendous practical relevance. Their orientation relative to the magnetic path controls the shape of the hysteresis loop (Fig. 1a). The magnitude of the induced anisotropy constant, K_u, controls the level of the permeability and, particularly for square loops, is a decisive factor for excess eddy current losses (Fig. 1b). Appropriate choice of the alloy composition and the annealing conditions allows to vary K_u by about three orders of magnitude.

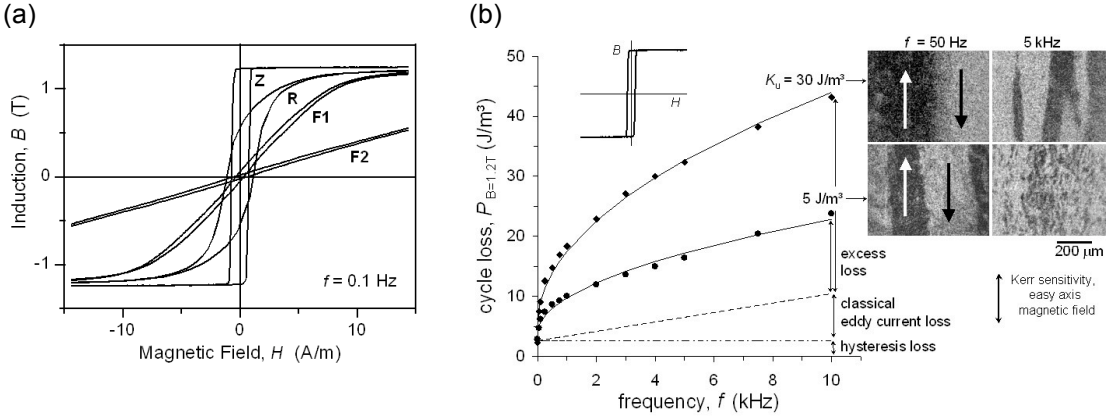

Fig. 1: Impact of field induced anisotropies on the soft magnetic properties using the example of nanocrystalline $Fe_{73.5}Cu_1Nb_3Si_{15.5}B_7$ (VITROPERM® 800).

The advantages of the nanocrystalline alloys are a higher saturation induction and a significantly better thermal stability of their soft magnetic properties than comparable amorphous or polycrystalline alloys. Additionally, they are based on the inexpensive raw materials iron and silicon. One major draw-back is the severe embrittlement upon nanocrystallization which requires final shape annealing and restricts their application mainly to toroidally wound cores. Embrittlement often is also an issue for optimally annealed amorphous alloys. However, amorphous alloys may reveal good soft magnetic properties already in the as quenched state or at least after moderate annealing. Thus, they can be delivered as a ductile ribbon useful e.g. for flexible magnetic screening or for sensor applications, most noticeably in electronic article surveillance.

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