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Soft magnetic properties of rapidly-annealed nanocrystalline Fe-Nb-B-(Cu) alloys

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Abstract

Nanocrystalline Fe-*M*-B (*M* = Zr or Nb) alloys (Nanoperm) exhibit excellent soft magnetic properties when *M* content is 6 to 7 at%. Lowering the *M* content below 4 at% usually results in a coarsening of the nanocrystallites and so sets a lower limit on the *M* content for Nanoperm. In this report we have demonstrated that a highly refined, magnetically soft nanostructure can be achieved for Fe-Nb-B-(Cu) alloys with a Nb content well below 4 at% by employing a rapid annealing process which utilises a heating rate of 150 K s^{-1}. The low Nb-content of these nanocrystalline alloys brings about a high saturation magnetic polarization of 1.85 to 1.9 T, well above the upper limit of Nanoperm (1.7 T). These newly developed, bcc-Fe based nanocrystalline soft magnetic alloys which have an *M* content lower than 4 at% are named HiB-Nanoperm. HiB-Nanoperm exhibits excellent soft magnetic properties with a coercivity as low as 2.5 A m^{-1} and a high initial permeability of ~ 10^4 at 1 kHz. A possible explanation for the rapid annealing induced grain refinement observed for this Fe-*M*-B system is that the higher annealing temperatures used by this process bring about a lowering of the precursor amorphous phase viscosity which then triggers homogeneous nucleation, thereby considerably increasing the number density of bcc-Fe nucleation sites.

Keywords: rapid annealing, induced anisotropy, nanoperm, soft magnetic materials, nanocrystalline alloys, amorphous alloys

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