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Bulk Nanocrystalline Soft Magnetic Fe-Si-X Alloys Achieved Through Severe Plastic Deformation

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The magnetic properties of soft magnetic materials such as Fe-Si-X alloys can be strongly improved by nanocrystallization provided the grain size is smaller than the magnetic moment exchange length. Particular methods of Severe Plastic Deformation (SPD) like High Pressure Torsion (HPT) allow to achieve bulk nanocrystalline soft magnetic materials with grain and/or subgrain sizes (D) in the range D = 100-10 nm. When these values are below the size of magnetic domains, i.e., the exchange length of magnetic moments, the coercivity (H_c) markedly decreases and thus minimizes the hysteresis area i.e., losses, which is an inherent goal of soft magnetic materials research. However, HPT not only generates grain boundaries but also internal stresses including high densities of dislocations, both of which increase H_c. With the work of Khakwani [1] – on Fe-Si-X alloys by applying moderate thermal treatments till 200°C - those defects could be reduced without markedly increasing the grain and/or subgrain size. Another important result was that subgrains with low misorientation can also decrease H_c unless their size exceeds the magnetic moment exchange length. Herzer's model [2] which well describes the grain size dependent coercivity by a law $H_c \sim D^6$ for large-angle misoriented grains, turns to a law $H_c \sim D^n$ with a distinctly lower exponent $n \leq 3$ in the case of small-angle misoriented subgrains [3,4]. This change has been substantiated by the experiments carried out within work [1].

Keywords: nanocrystalline materials, subgrains, magnetic exchange length

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