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Intrinsic and domain magnetism of nanocrystalline Fe, Fe(Si) and Ni(Fe) alloys produced by ball-milling

Experimental results in ball-milled nanocrystalline Fe, Fe(Si) and Ni(Fe) alloys, based on measurements of the temperature dependence of magnetization, Barkhausen noise, hysteresis loops and Mössbauer-effect at our Department [1-5], are reviewed and compared with results of measurements obtained on nanocrystalline samples produced by other techniques.

It is shown that the intrinsic magnetic properties (the saturation magnetization (M_s), the hyperfine magnetic field (HMF) in the Mössbauer-spectrum, and the Curie-temperature (T_C)) are almost independent of the grain size down to about 6 nm (figure 1, 2): the decrease in M_s is less than 10%. Similar conclusion can be drawn for the Curie temperature. These conclusions are in accordance with the newest experimental results obtained on nanocrystalline Fe produced by inert gas evaporation [6] and on Ni produced by severe plastic deformation consolidation of ball-milled powders [7] and by elektrodeposition [8].

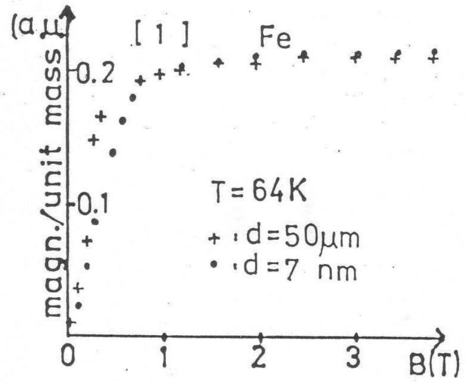

Figure 1: Magnetization curve of microcrystallinne and nanocrystalline Fe.

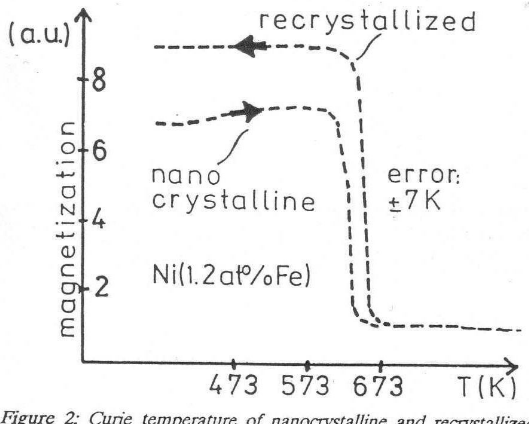

Figure 2: Curie temperature of nanocrystalline and recrystallized Ni(1.2at%Fe) alloy.

The coercitive force, (H_c), -as a function of grain size- qualitatively shows a similar dependence which is expected from the classical and random anisotropy model (Figure 3). The main reason for the differences between the curves shown in Figure 3 can be attributed to different sample preparation methods and to the different materials. The results are in accordance with the recent results obtained on Fe samples produced by inert-gas condensation [9], although the shape of the curves are not absolutely the same here and there.

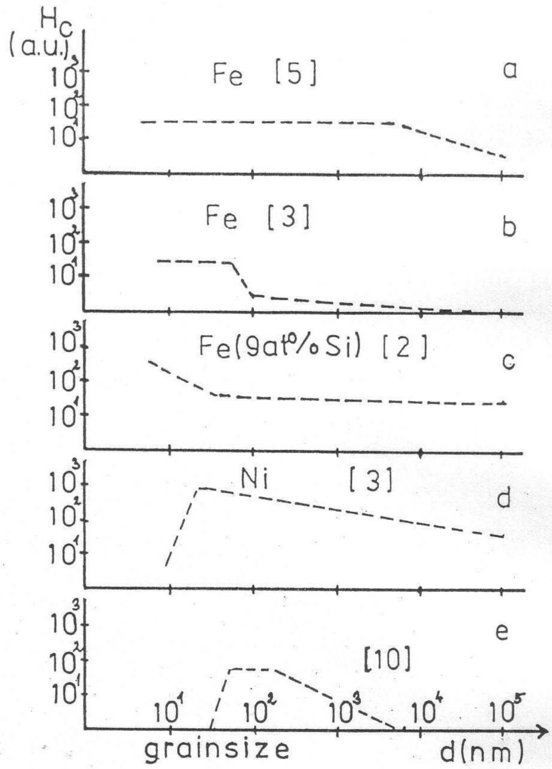

Figure 3: H_c-d functions for ball-milled Fe (a, b), Fe(9at%Si) (c) and Ni (d). Schematic H_c-d function on the basis of the classical random anisotropy model (e).

A definite correlation between the magnetic Barkhausen-noise (MBN) and the grain shape has been found in Fe, which has been attributed to the formation of lamellar and textured grain structure (Figure 4). In Ni - where no texture formation was observed - there was a maximum on the MBN curve versus grain size at the same d where the sharp drop in H_c at small d values was observed.

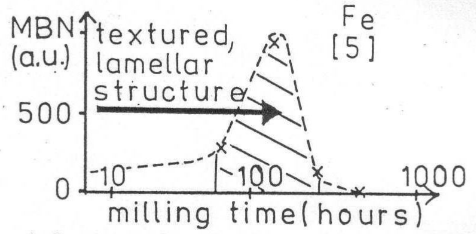

Figure 4: Correlation between MBN and structure of ball-milled Fe.

Furthermore it was also shown - by the separation of the effect of grain size and the residual strain (by relaxing it in an appropriate heat treatment) - that in nanocrystalline Ni H_c is practically independent of the residual strain.

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