THE PHYSICS OF AMORPHOUS AND NANOCRYSTALLINE HARD MAGNETIC MATERIALS

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Hard magnetic materials are generally based on 3d-4f intermetallic compounds. For a hard magnetic behaviour an intrinsic high uniaxial magnetic anisotropy together with an adequate microstructure is necessary. Therefore in high quality magnets compounds such as $SmCo_5$ on Sm_2Co_{17} and on $Nd_2Fe_{14}B$ play an important role. The high magnetocrystalline anisotropy causes narrow domain walls which are important for a large coercivity. The coercivity mechanism depends now on the interaction between these domain walls and the micro-structure.

In amorphous materials only a local anisotropy occurs which becomes visible mostly in high magnetostriction. Because of the missing of a well defined "crystallographic axis" generally no hard magnetic behaviour is expected in a real amorphous material. However Nd-Fe-Al was proposed by Inoue et al (1) to be the first hard magnetic amorphous material. More detailed investigations showed the existence of nanosized clusters which cause pining of narrow domain walls (2) and consequently a high coercivity.

For technical applications hard magnetic nanocrystalline materials are of interest. In hard magnetic nanocrystalline materials the magnetic exchange length becomes comparable to the grain size. This leads to a remanence enhancement M_r/M_s which is higher than the expected 0.5 for noninteracting uniaxial grains. Therefore these materials show a high energy product even for the isotropic case. Exchange coupled hard magnetic materials can be divided into two main groups:

- single phased nanocrystalline materials
- nanocomposites, also known as spring magnets (contains a hard + soft magnetic phase). Here the hard magnetic phase polarises the soft magnetic phase. If now the soft magnetic phase has a saturation magnetization which is higher than that of the hard magnetic phase, this causes an additional increase in the remanence. The nanocomposites exhibit however a reduced coercivity.

In the here presented work the physical properties necessary for the formation of hard magnetic materials starting from amorphous until the nanocrystalline state will be discussed. Various types of modelling who describe the hysteresis loop, will be used in order to demonstrate and compare the different magnetization process. The effect of exchange coupling on the different other magnetic properties such as the "effective" anisotropy field, the Curie temperature, a spin reorientation temperature will be shown.

(1) A. Inoue, *Mater. Sci. Eng.*, vol. 357, pp. A226–A228, 1997.
(2) R. Sato Turtelli, D. Triyono, R. Grössinger, H. Michor, J. H. Espina, J. P. Sinnecker, H. Sassik, J. Eckert, G. Kumar, Z. G. Sun, and G. J. Fan, *Phys. Rev. B*, vol. 66, pp. 054 441–1, 2002.