

Novel Approaches to Synthesis and Processing of Nanocomposite Magnets

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Rethink over the modeling



Old model

The soft-phase dimension for exchange coupling is not related to the soft-phase properties

$$\text{dimension of soft phase } t_s < 2(\text{domain-wall thickness in hard phase})$$

Kneller and Hawig, *IEEE Trans. On Mag.*, 27, 3588 (1991)
Skomski and Coey, *Phys. Rev. B* 48, 15812 (1993)
Schrefl, Kronmüller and Fidler, *JMMM*, 127, L273 (1993)

New model

The soft-phase dimension for exchange coupling is also related to the soft-phase properties

$$t_{S-Critical} = \frac{J/M_S}{\frac{2K_H t_H - J}{M_H} - \frac{2K_S}{M_S}}$$

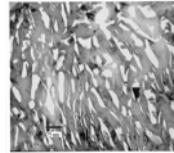
J.P. Liu et al., submitted to *IEEE Trans. On Mag.*, (2002)

Experiments to test the models have been carried out which prove the effect of soft-phase properties. For SmCo_5 and $\text{Nd}_2\text{Fe}_{14}\text{B}$ formed composites, old model gives t_s as ~ 5 nm and 9.2 nm for all soft phases respectively. Our experiments and analysis reveal big difference. t_s^* is calculated from $H_{ex} = 4(AK)/M_s t$, $t_s = 2t$ for the single-phase-like reversal between 0.3 ~ 1.0 T.

Soft phase	t_s^* (nm)	$t_s^@$ (nm)
Fe	2.7~9.0	2.5~10
Co	16.2~53.9	>20
NdCo	15.0~50.0	>7.8

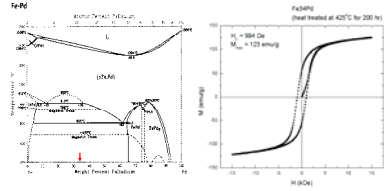
Novel approaches to synthesis of the nanocomposites

Eutectoid Decomposition

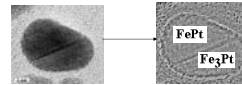


Aged Fe-34at.%Pd alloy, FePd matrix ($L1_0$) and the soft Fe (Pd) (white).

This is an excellent method for preparing nanocomposite with full density in large quantity

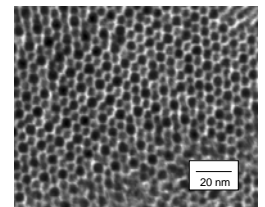


After annealing, FePt/Fe₃Pt boundaries can be observed and Energy-product enhancement of up to 30% has been achieved.

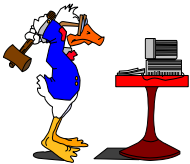


Chemical Synthesis

Mixed FePt hard phase particles (4nm) and the soft phase particles (8nm). Both phases can be precisely controlled. TEM picture of the chemically synthesized FePt particle assembly is shown below.

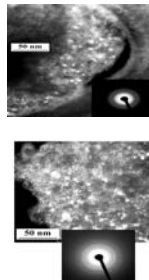
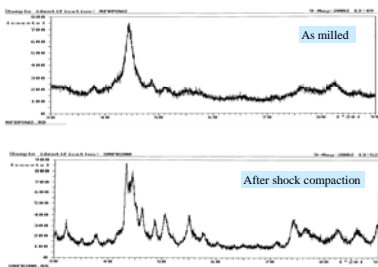
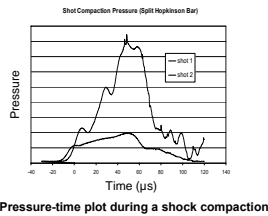


Novel approach to condensation



No time for sintering and grain growth!
One hammer does everything!

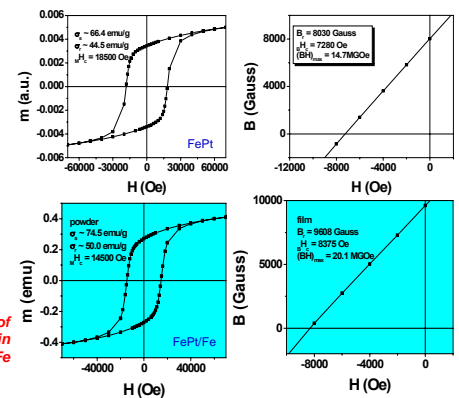
Ball milled amorphous NdFeB powder was shock-compacted to 90% density. Crystallization of the hard $\text{Nd}_2\text{Fe}_{14}\text{B}$ phase completed (see the X-ray patterns) while the soft α -Fe grains remain below 10 nm (see the dark field TEM images).



Improved energy products of isotropic magnets



Energy product enhancement of up to 30% has been achieved in chemically synthesized FePt/Fe exchange-coupled nanocomposite!



The theoretical value of energy product of isotropic FePt magnets is 13 MGOe. We have obtained energy products above 20 MGOe in the FePt/Fe nanocomposite (see above figure).

Other Approaches

- 1) Field alignment
- 2) Electrochemical deposition
- 3) Melt-spinning
- 4) Extrusion
- 5) Microwave sintering

