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INTER-GRAIN EXCHANGE INTERACTION AND HYSTERESIS LOOPS OF MELT-SPUN $Nd_{13}Fe_{77}B_{10}$

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It is believed in general that the domain wall pinning at the grain boundaries is the origin of high coercivity of melt-spun Nd-Fe-B permanent magnet [1-2]. For near-stoichiometric alloys, J_r increases beyond $J_s/2$ and ${}_iH_c$ decreases with decrease of the scale of the nanostructure [3], which is ascribed to the inter-grain exchange interaction [4]. This work presents new evidences of the inter-grain exchange interaction, and shows that the magnetization process of the melt-spun $Nd_{13}Fe_{77}B_{10}$ is the non-coherent magnetization rotation of the grains.

A melt-spun alloy of $Nd_{13}Fe_{77}B_{10}$ was annealed at 950 K (specimen #1) or 970 K (specimen #2) for 10 minutes. The specimens are essentially single phase of $Nd_2Fe_{14}B$. The hysteresis loops were measured after cooled down at remanent state.

The model magnet is composed of n×n×n cubic $Nd_2Fe_{14}B$ grains. Both of the c- and [100]-axes of the grains are randomly oriented. Each grain is exchange coupled with the six adjacent grains. Each grain consists of m×m×m cubic elements of equal dimension L/m. The periodic boundary conditions hold for the magnet. The magnetization of the magnet was obtained from minimization of the total energy consisting of the magnetocrystalline anisotropy energy, Zeeman energy and the exchange energy $-wL^2/2\mu_0 m^2 \Sigma_{i,j} \vec{J}_s(i)\cdot \vec{J}_s(j)$. The value of w/L was obtained fitting the computation of ${}_iH_c$ at 4.2 K. m=1 and w=0, m=1 and w≠0, and m>1 and w≠0 correspond to the S-W model, the exchange coupled SD model, and micromagnetism, respectively.

Figures 4a, 5a and 6a show the experimental hysteresis loops for specimens #2 (4a) and #1 (5a and 6a). Figures nα (α=b,c,d) are the simulation of the corresponding experiments by the S-W model (α=b), exchange coupled SD model (α=c) and micromagnetism (α=d). The micromagnetism simulates the experiments fairly well quantitatily.

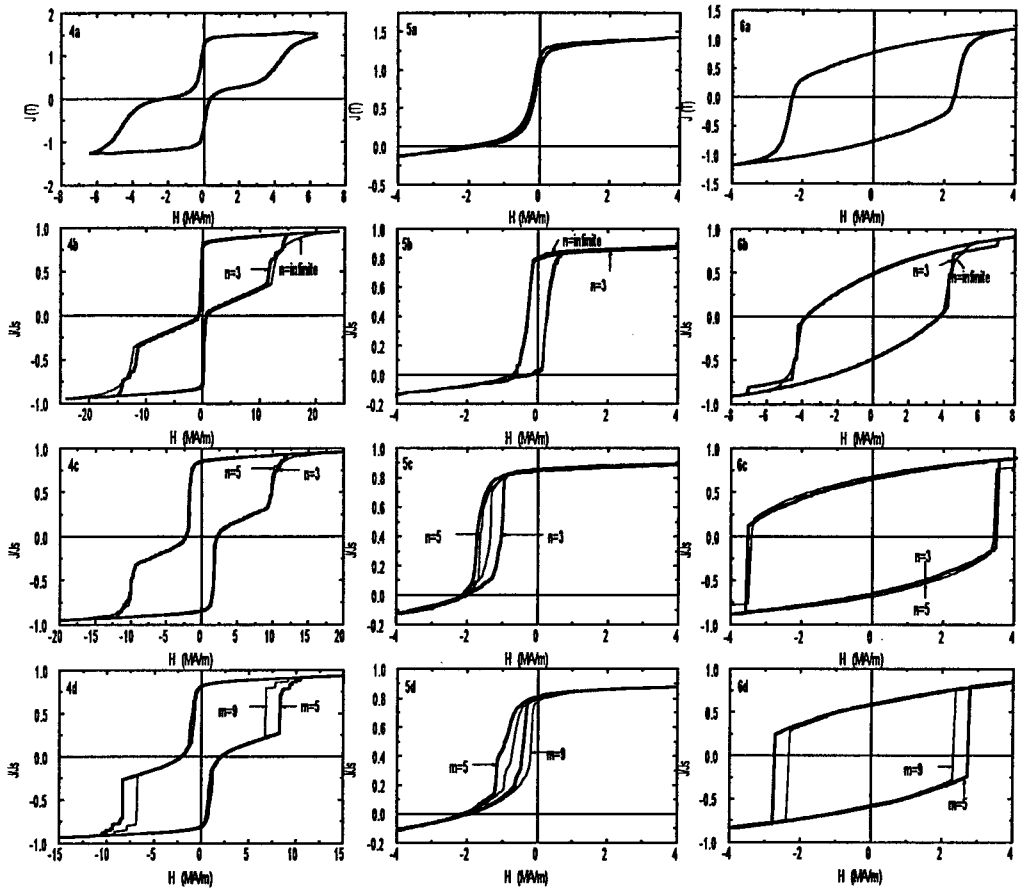

Figure 4. Hysteresis loops at 4.2 K measured in the fields of H_{max}=6.4 MA/m (a), and major loops computed by the S-W model for n=3 and ∞ (b), by the exchange coupled SD model for n=3 (w/L=0.45) and n=5 (w/L=0.48) (c), and by the micromagnetism for n=3 and m=5 (w/L= 0.32) and m=9 (w/L=0.29) (d)

Figure 5. Hysteresis loops at 4.2 K in the fields of H_{max}=4.0 MA/m measured (a), and computed by the S-W model for n=3 and ∞ (b), by the exchange coupled SD model for n=3 (w/L=0.45) and n=5 (w/L=0.48) (c), and by the micomagnetism for n=3 and m=5 (w/L=0.32) and m=9 (w/L=0.29) (d)

Figure 6. Hysteresis loops at 250 K in the fields of H_{max}=4.0 MA/m measured (a), and major loops computed by the S-W model for n=3 and ∞ (b), by the exchange coupled SD model for n=3 (w/L=0.45) and n=5 (w/L=0.48) (c), and by the micromagnetism for n=3 and m=5 (w/L=032) and m=9 (w/L=0.29) (d)

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