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Determination of exchange length in nanocrystalline ferromagnets with XRES

Suguru Sato[1], Hideto Yanagihara[1], Eiji Kita[1], Masato Kubota[2]
[1]Institute of Applied Physics, University of Tsukuba, Tsukuba, Ibaraki 305-8573, Japan
[2]Institute of Materials Structure Science, KEK, Tsukuba, Ibaraki 305-0801, Japan

Introduction

Ferromagnetic nanocrystalline materials have been attracted much attention due to its excellent soft magnetic properties. The steep decrease in coercive force was interpreted by Herzer using the random anisotropy model (RAM) [1]. This model clearly supports the theorem that the coercive force is proportional to D^6 of the grain size D because the magnetic anisotropy of each nanocrystalline grain is averaged over the magnetically coherent area characterized by a correlation length of ferromagnetism.

This model predicts an increase of magnetic correlations with decreasing grain size D. However, the relationship between the actual magnetic coherent length and the exchange length defined by the RAM is not clear. Observation of exchange coupling length considered to be useful for development of the better soft-materials. An experimental technique to determine the exchange length of nanocrystalline materials is needed and therefore we have attempted to observe the magnetic correlation by an XRES study.

Experimental

Ni nanocrystalline films were prepared using the gas condensation and deposition method (GDM) [2]. KBr single crystal wafer was used as substrates. The samples were several micro meter thick which is much larger than the coherent length of the magnetic exchange coupling for a bulk Ni. In the GDM, a simple process prevents the surface oxidization of ultra-fine particles (UFPs) and oxygen free metallic nanocrystals can be produced. The density of the GDM nanocrystals was reported almost the same as the bulk for the Au nanocrystals and the porosity of the GDM nanocrystals is considered to be the same order or better than those from other techniques. We have demonstrated the D^6 dependence of coercive force on the grain size of single phase Ni nanocrystals (n-Ni) prepared using GDM .

X-ray resonant exchange scattering (XRES) measurement was performed at BL-16A in PF-KEK. In order to modulate the correlation length of a ferromagnetic nanocrystal, we applied magnetic field by using an electromagnet designed for this experiment. The magnetic field is parallel to the surface of the sample. All the measurements were carried out at room temperature.

Result and Discussion

Figure 1 shows the L edge energy spectrum of the Ni nanocrystals. We used 850.5 eV for the resonant state, and 840 eV for the off-resonant state. Figure 3 shows θ/2θ scan profile measured in fields from – 50 to 50 Oe (Fig.2). In the case of the off resonance (Fig 3(a)), scattering intensity did not depend on magnetic field and a nothing special structure was observed. In contrast to Fig 3 (a), the intensity depends on magnetic field and some structure associated with a magnetic domain size appears around q = 1 nm^{-1} (d = 6nm) in (b). This value is close to grain size of nanocrystals.

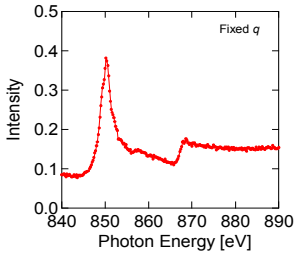

Fig.1. the L edge energy spectrum of Ni nanocrystals

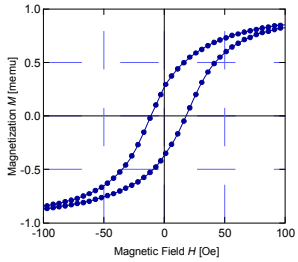

Fig 2. MH loop of the sample.

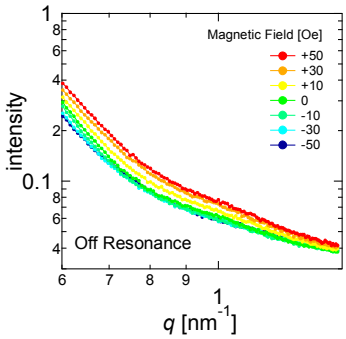

Fig 3(a). θ/2θ scan profile for off resonance.

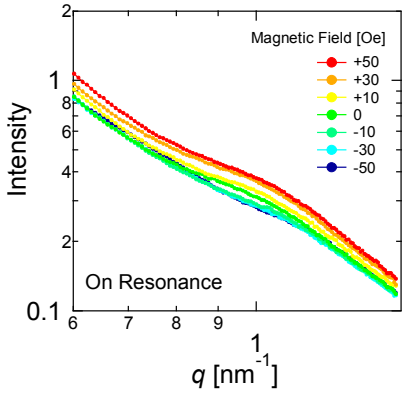

Fig 3(b). θ/2θ scan profile for on resonance.

References

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* yanagiha@bk.tsukuba.ac.jp