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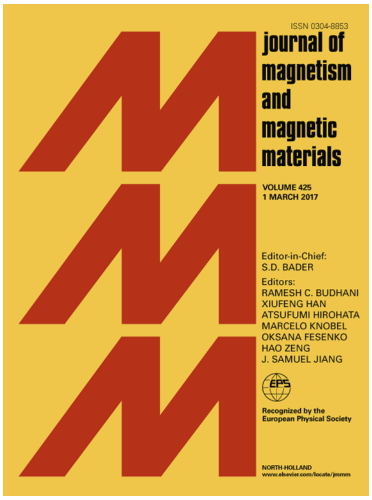

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Ferromagnetic resonance in bulk nanocrystalline Ni

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Abstract

A detailed lineshape analysis of the ferromagnetic resonance (FMR) spectra taken on pulse electrodeposited nanocrystalline (nc-) Ni sheets (with the average crystallite size, d, varying from 10 nm to 40 nm) at temperatures ranging from 113 K to 325 K yield accurate values for saturation magnetization, $M_s(T)$, Landé splitting factor, g, anisotropy field, $H_k(T)$, resonance field, H_{res}, and FMR linewidth, $\Delta H_{pp}(T)$. Thermally-excited spin-wave (SW) excitations completely account for $M_s(T)$ and the SW description of $M_s(T)$ gives the values for the saturation magnetization and spin-wave stiffness at absolute zero of temperature, i.e., $M_s(0)$ and D_0, for nc-Ni samples of different d that are in excellent agreement with the corresponding values deduced previously from an elaborate SW analysis of the bulk magnetization data. While $M_s(0)$ varies with d as $M_s(0) \sim d^{-3/2}$, D_0 follows the power law $D_0 \sim d^{4/3}$. The angular variations of H_{res} in the 'in-plane' as well as 'out-of-plane' sample configurations, demonstrate that the main contribution to $H_k(T)$ comes from the cubic magnetocrystalline anisotropy. The exchange-conductivity mechanism describes the observed thermal decline of ΔH_{pp} reasonably well but fails to explain the very large magnitude of ΔH_{pp} at any given temperature. By comparison, the Landau-Lifshitz-Gilbert (LLG) damping gives a much greater contribution to ΔH_{pp} but the LLG contribution is relatively insensitive to temperature.

Keywords: Ferromagnetic resonance, Resonance field, Linewidth, Spin waves, Magnetic anisotropy, Nanocrystalline Ni.

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1. Introduction

Ferromagnetic resonance (FMR) is an extremely sensitive experimental tool to study magnetization dynamics, magnetic excitations and relaxation phenomena. This technique has the added advantage of enabling an unambiguous distinction between different types of magnetic anisotropies (e.g., shape, magnetocrystalline, magnetoelastic and surface anisotropies) through their characteristic angular variations of the resonance field. Thus, FMR technique has been extensively used to extract information about any of these physical phenomena in thin films, ultrathin films, multilayers, superlattices [1, 2, 3, 4, 5], superparamagnetic nanoclusters/nanoparticles [4, 5, 6, 7], nanowire arrays [8], circular dot arrays [9] and ferromagnetic (FM) nanoparticles embedded in an amorphous FM matrix [10, 11]. Continued interest in studying magnetic nanomaterials stems from the complex physical phenomena that come into play when the particle size (a few nanometers) becomes comparable to the characteristic magnetic lengths such as the critical single-domain size (D_{cr}), domain wall width (δ_0) and exchange correlation length (L_{ex}). A complete knowledge of how different types of magnetic anisotropies compete to produce the resultant anisotropy is of paramount interest both from the basic and technological points of view. In the latter case, particularly in applications such as magnetic data storage devices, magnetic logic devices, spin electronic devices and magnetic field sensors.

So far as nanocrystalline (nc-) 3d transition metal ferromagnets Fe, Co, Ni and their alloys are concerned, FMR technique has hitherto been used to study the superparamagnetic behavior [4, 5, 6, 7] in an assembly of 'non-interacting' nanoparticles. In this work, we have undertaken an exhaustive study of low-lying magnetic excitations, magnetic anisotropy and FMR relaxation mechanisms in pulse electrodeposited nc-Ni sheets [12], in which nanocrystalline particles of nearly single-domain size strongly interact with one another via direct short-range exchange (across grain

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