

Influence of hydrogenation on magnetoresonance characteristics of nanocomposite $(\text{CoFeB})_m\text{C}_{100-m}$ films

Sergei Vyzulin¹, Alexandr Kevraletin^{1,*}, and Nikolaj Syr'ev²

¹Higher Military School named after General of the Army S.M. Shtemenko, 350063 Krasnodar, Russia

²Lomonosov Moscow State University, Faculty of Physics, 119991 Moscow, Russia

Abstract. The influence of hydrogenation on the magnetoresonance characteristics of nanocomposite films during synthesis is studied by the method of ferromagnetic resonance (FMR). It is shown that introduction of hydrogen into the working chamber during the synthesis of film nanogranular structures $(\text{CoFeB})_m\text{C}_{100-m}$ leads to a change in a resonant field, to increase of the absorption line width, to reduction of anisotropy field in the film plane.

Introduction

Granular nanocomposite films, comprising magnetic and nonmagnetic phase, are promising functional materials for such varied practical applications as spintronic, single-electron electronics and so on [1].

Properties of nanocomposite films are under intensive research. The interest of researchers is associated with metal nanoparticles having the unique magnetic properties. The magnetic properties of nanoparticles are determined by many factors. One of these factors is the size and shape of nanoparticles. Changing the size and shape of nanoparticles, it is possible, within certain limits, to manage the magnetic properties of materials, based on them [2-3]. It is possible to change the size and shape of nanoparticles in the composites synthesis process. The effect of hydrogen during the synthesis to form carbon nanostructures was shown [4].

The aim of this work – to study the influence of hydrogenation on the magnetoresonance properties of nanocomposite $(\text{CoFeB})_m\text{C}_{100-m}$ film structures by the basic characteristics of the ferromagnetic resonance spectra.

Object of investigation

Nanogranule ferromagnetic – nonmagnetic matrix film structures were studied. Samples are synthesized via the ion-beam sputtering of amorphous CoFeB with samples of C on to sital substrate.

Two series of samples are investigated. The samples of 1 series were sputtered in an argon atmosphere, 2 series – in an atmosphere of argon with addition of hydrogen. Magnetic phase concentration m and thickness h were varied along the structure for both series in the same way ($35,3 \leq m \leq 65,0$ at. %, $1 \leq h \leq 2$ μm). In the transverse direction of the structure the thickness and

concentration of magnetic phase were not changed. Direction in the sample plane coinciding with the longitudinal direction of the reference nanostructure will be denoted as vector \mathbf{i} , and transverse direction as vector \mathbf{j} .

Method of analysis

The FMR spectra were measured using conventional modulation equipment with resonator at a frequency of 9,44 GHz at a room temperature.

The spectra were measured for each sample under differently oriented magnetization field \mathbf{H} relative to the film plane, from $\alpha=0$ (normal magnetization $-\mathbf{H} \parallel \mathbf{n}$) to $\alpha=90^\circ$ (tangential magnetization $-\mathbf{H} \perp \mathbf{n}$), where \mathbf{n} – is the vector normal to the film plane.

Two series of experiments were performed. In one the external magnetic field was applied as $\mathbf{H} \parallel \mathbf{i}$, in another – $\mathbf{H} \perp \mathbf{j}$. The acquired spectra enabled us to determine resonance field H_r and absorption line width ΔH .

Experimental results

The form of the observed FMR spectra, the quantitative composition of the absorption lines and value of H_r are significantly dependent on the magnetic phase concentration m and the orientation of the external magnetic field relative the normal to the film plane.

With increasing m , with $\alpha=0$, number of absorption lines for samples of 1 series are varied from 1 to 3, for 2 series samples the quantity of modes in the spectrum reached 11 (fig. 1a, b).

In case $\alpha=90^\circ$ for samples of 1 series there was mainly a single resonance mode. With increasing m the maximum number of mode reached 3. For samples 2 series, regardless of the values of m , the number of mode in the spectrum does not exceed 1 (fig. 1c, d).

* Corresponding author: kevr@list.ru

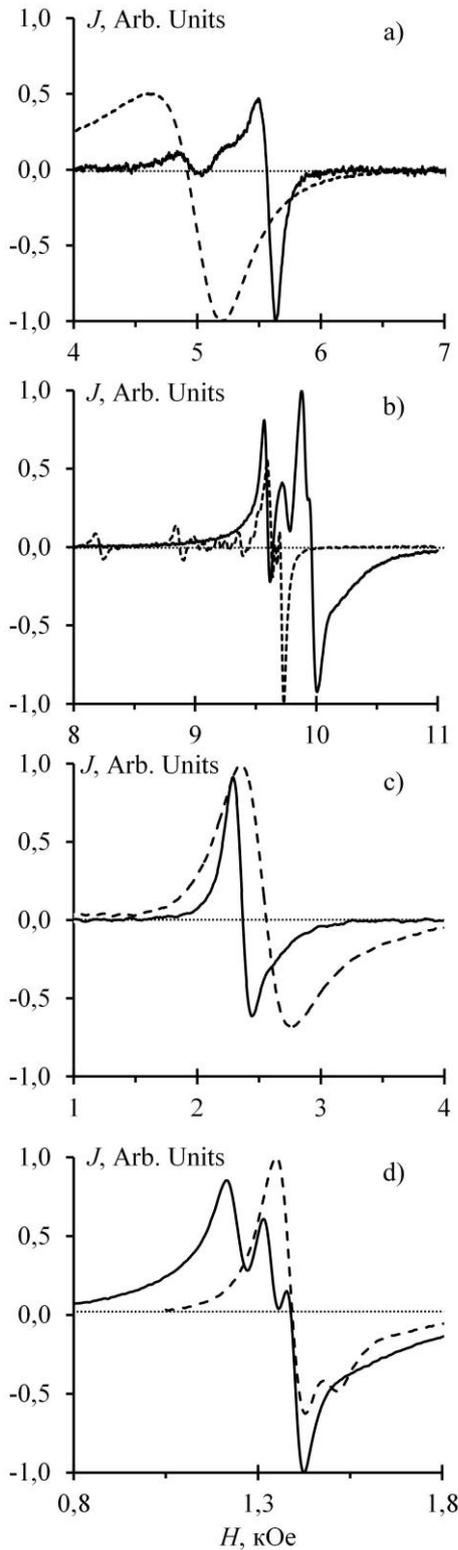


Fig. 1. FMR spectra (the solid line – for series 1, the dotted line – series 2):
 a – $m=38,1$ at. %, b – $m=65,3$ at. % ($\alpha=0$);
 c – $m=38,1$ at. %, d – $m=65,3$ at. % ($\alpha=90^\circ$).

For all films the value of H_r at $\alpha=90^\circ$ is smaller than at $\alpha=0$. For samples of series 2 H_r with tangential magnetization is more, and in normal – less than that of the film structures of series 1 (fig. 2).

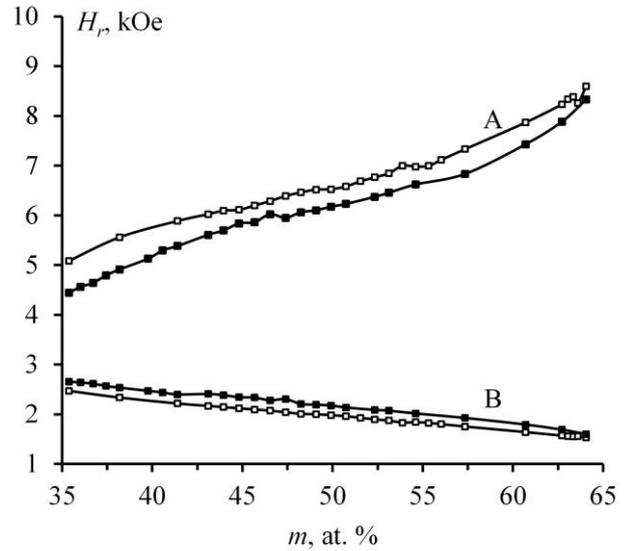


Fig. 2. Dependences H_r of m : \square – series 1, \blacksquare – series 2; A - $\alpha=0$; B - $\alpha=90^\circ$.

As m is increasing the value of H_r decreases when $\alpha=90^\circ$, and increases at $\alpha=0$.

At $\alpha=90^\circ$ the resonance field, observed in the same experimental conditions for the cases $\mathbf{H}\perp\mathbf{i}$ and $\mathbf{H}\perp\mathbf{j}$ differed for samples of both series. The differences registered in values of H_r are quantitatively characterized by the value of δH_r , that is determined by the ratio

$$\delta H_r = |H_r(\mathbf{H}\perp\mathbf{i}) - H_r(\mathbf{H}\perp\mathbf{j})|. \quad (1)$$

Values of δH_r with the tangential magnetization for the samples of series 1 were up to 215 Oe, for series 2 - 119 Oe (Fig. 3). The solid line represents the dependence δH_r of m for the samples of series 1, the dotted – for samples of series 2. Experimental points are selected with markers.

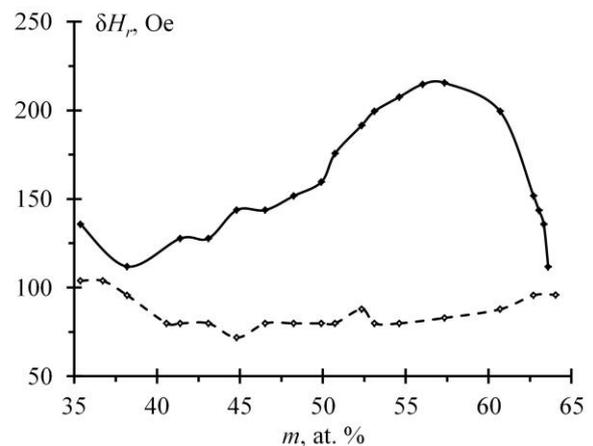


Fig. 3. Concentration dependences δH_r , $\alpha=90^\circ$: the solid line – series 1, the dotted line – series 2.

The presence of anisotropy H_r can be explained by the asymmetric shape of the magnetic granules with respect to the selected orientation axes \mathbf{i} and \mathbf{j} of the original nanostructures and \mathbf{n} .

The width of the absorption line regardless of the orientation of the magnetization field for the samples of

series 1 at a variation of m does not change significantly and has a magnitude of 100-200 Oe, for samples of series 2, with $m > 48$ at. % the values of $\Delta H \approx 150-200$ Oe.

The Dependences ΔH from m for the films of series 1 and 2, with the tangential and normal magnetization are shown in figures 4a and 4b respectively.

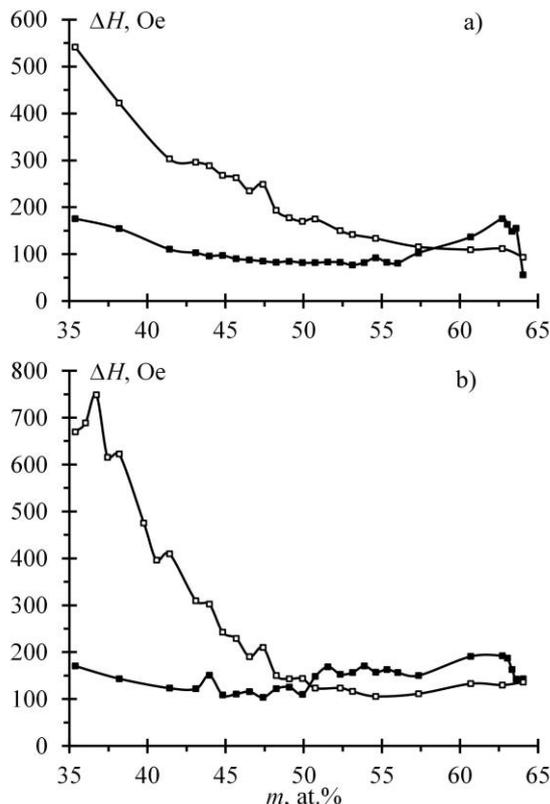


Fig. 4. Concentration dependences ΔH (\square – series 1; \blacksquare – series 2): a – $\alpha=90^\circ$; b – $\alpha=0$.

It is seen that for samples of series 2 with decreasing of m there is a sharp growth of ΔH up to the values of 550 Oe (with $\alpha=90^\circ$) and 750 Oe (with $\alpha=0$). The latter indicates the possibility of transition of the magnetic system at $35 < m < 45$ at. % from ferromagnetic to superparamagnetic state. For series 1, the percolation threshold wasn't observed. For a system similar to (composition and synthesis conditions) series 1, $48 \leq m \leq 72$ at. %, the percolation threshold was observed at $m \approx 62$ at. % [5]. A possible explanation for the observed discrepancies is the difference in performance, by which the phenomenon of percolation is recorded. In [5] it is performed by electrical resistivity along the sample, in our work – on ΔH .

Evaluation of the shape of magnetic granules is made in the framework of the theory of FMR in granular nanostructures [6] by calculating N_x , N_y and N_z demagnetizing factors of magnetic granules in longitudinal and transverse directions of the film plane, respectively. The saturation magnetization of the samples was taken equal to 1050 G. Figure 5 shows dependences of the aspect ratio $\delta = a/c$ from m , a – is the magnetic granules semiaxes length along the normal to the film plane, c – in plane of the film. The values of δ are calculated on experimental values of H_r in the approximation of spheroidal form of the granules (the

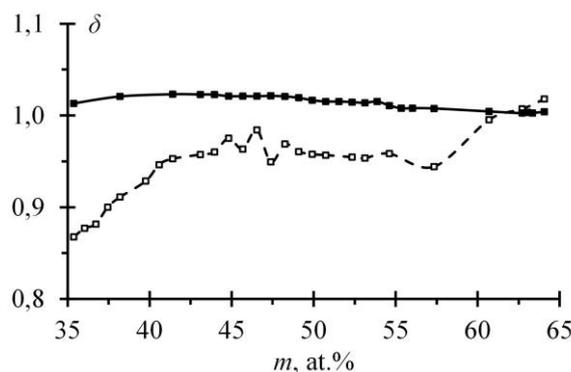


Fig. 5. Dependences δ of m : \blacksquare – series 1; \square – series 2.

calculation method described in [6]).

It is seen that the magnetic granules of the samples of series 1 are stretched, and of series of 2 – are flattened along \mathbf{n} . With the exception of nanocomposite film series 2 with $m > 60$ at. %.

The absence of percolation threshold for series 1 is explained by the distance between the magnetic granules of the samples. The distance between the granules, elongated in the plane of the film is smaller than that between the granules, extended along the normal direction. Magnetic granules of the samples of series 1 interact with each other at lower concentrations than for series 2.

The observed differences in the resonance field for systems 1 and 2 with tangential magnetization in cases $H_{\perp i}$ and $H_{\perp j}$ are explained by the different form of magnetic granules. The shape of the magnetic granules varies as a result of hydrogenation in the synthesis of composite films.

Conclusion

It was established experimentally that the introduction of hydrogen into the working chamber during the synthesis of nanostructures film $(\text{CoFeB})_m\text{C}_{100-m}$ leads to changes of values of the resonant fields: an increase in tangential and a decrease in the normal magnetization; to 1,5-2 times increase of the absorption line width. The value of anisotropy field in the plane of the samples subjected to hydrogenation during synthesis, decreases with the tangential magnetization in 1,5-2 times. The differences between magnetoresonance characteristics are explained by the shape of magnetic nanoparticles.

References

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