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КЛАСТЕРИЗАЦИЯ ПОНЯТИЙ С ИСПОЛЬЗОВАНИЕМ СЕТИ ИНТЕРНЕТ

В работе рассмотрен подход к анализу текстовой информации с использованием данных из сети Интернет на примере кластеризации понятий. Задача кластеризации понятий приведена к задаче разбиения графа с изначально неизвестным количеством подграфов. Предложен алгоритм разбиение графа на подграфы путём оптимизации целевой функции. Предложен вид целевой функции для описания кластеризации понятий. Результаты проверены на экспериментальных данных.

Ключевые слова: кластеризация, анализ текста, разбиение графа на подграфы, оптимизация.

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OUT-OF-PLANE ANGULAR DEPENDENCE OF FERROMAGNETIC RESONANCE OF PERMALLOY THIN FILMS

Out-of-plane ferromagnetic resonance (FMR) spectra of Permalloy films 25, 50, 75 and 100 nm thick were measured. The angular dependence of FMR was analyzed using Landau–Lifshitz–Gilbert (LLG) equation. With increasing film thickness, the contribution to linewidth of two magnon scattering increases.

Key words: ferromagnetic resonance, Permalloy, thin film, linewidth.

Introduction. Improving the technology of thin magnetic films allows their use in spintronic devices and microwave technology. Therefore there is an interest in their studies. As a powerful technique, ferromagnetic resonance (FMR) has been employed to study magnetic anisotropy, interlayer coupling, magnetic relaxation, film quality, and so on [1, 2]. Three mechanisms have been considered to contribute to the linewidth [3–4, 7–9]. As the first contribution, intrinsic Gilbert damping, resulting from a combination of the exchange interaction and the spin–orbit coupling, exists in all magnetic materials. The second contribution to the FMR linewidth arises from the broadening induced by magnetic inhomogeneity, such as the spread of the magnitude of the magnetization or the internal static magnetic field, and the orientation of the crystallographic axes or magnetic anisotropy axes. This part strongly depends on the preparation condition and thus the film quality [5]. As the third contribution to the linewidth, the so-called extrinsic magnetic relaxation has been argued to originate from the coupling between the uniform resonance modes and degenerating spin waves through structural inhomogeneity. This phenomenon is called two-magnon scattering process [6]. Since the contributions of the intrinsic damping effect and the extrinsic magnetization relaxation, and the inhomogeneity originate from different mechanisms, they have different out-of-plane angular and microwave frequency dependence. Therefore, they should be able to be analyzed and discerned from the measured FMR linewidth.

Experimental results and discussion. The samples were prepared by Electron Beam Evaporation (EBE) and have 100, 75, 50 and 25 nm of thickness. FMR measurements were carried out at room temperature using a Bruker E580 EPR spectrometer, with a fixed microwave frequency of 9.45 GHz. The goniometer was used to vary the angle. Thus the angular dependence of the resonance field and the linewidth were obtained.

Figure 1 shows the sample oriented relative to some right-handed *X-Y-Z* frame such that the sample normal is parallel to the *Z* axis. External magnetic field H_{ext} and magnetization M_s lies in ZY plane. θ_H is the angle between H_{ext} and the sample normal Z, θ_0 is an angle between M_s and Z. The angle θ_H changes in range of 0° – 90°.

The angular dependence of FMR spectra can be obtained by using the LLG equation[1]:

$$\frac{\partial \vec{M}}{\partial t} = -\gamma \vec{M} \times \vec{H} + \frac{G}{\gamma M_S^2} \vec{M} \times \frac{\partial \vec{M}}{\partial t} \quad (1)$$

Here M_S is saturation magnetization, $\gamma = g\mu_B / h$ and G are the gyromagnetic ratio and the Gilbert damping coefficient, respectively. Using this equation, the resonance conditions can be written follow:

$$\frac{\omega}{\gamma} = \sqrt{H_1 H_2}\ , \quad (2)$$

$$H_1 = H_{res}\cos(\theta_H - \theta_0) - 4\pi M_{eff}\cos(2\theta_0)\ , \quad (3)$$

$$H_2 = H_{res}\cos(\theta_H - \theta_0) - 4\pi M_{eff}\cos^2(\theta_0)\ , \quad (4)$$

where H_{res} is the resonance magnetic field, $4\pi M_{eff} = 4\pi M_s - H_A$ and H_A are the effective demagnetizing field and anisotropy field.

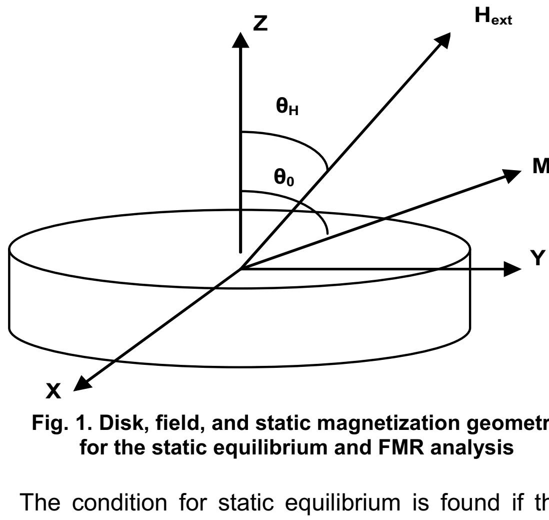

Fig. 1. Disk, field, and static magnetization geometry for the static equilibrium and FMR analysis

The condition for static equilibrium is found if the net torque on M_S is set equal to zero. The net torque is a result of the external field, the demagnetization field, and the anisotropy which acts to pull the magnetization into an easy direction. This condition yields an expression which relates the field and magnetization angles θ_H and θ_0:

$$2H_{res}\sin(\theta_0 - \theta_H) = 4\pi M_{eff}\sin(2\theta_0) \quad (5)$$

Values of the effective magnetization $4\pi M_{eff}$ can be determined from (2) attached to normal film orientation.

Figure 2 shows the out-of-plane angular dependence for the film of 50 nm thick.

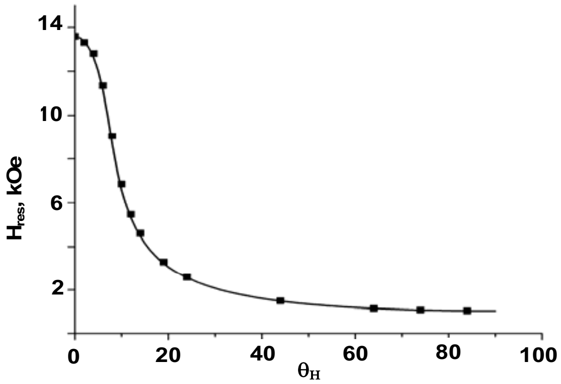

Fig. 2. Angular dependence of resonance field, d=50 nm (Points – measured, line – fitted)

This dependence has the distinct maximum for $\theta_H = 0^o$. H_{res} decreases monotonically with increasing θ_H due to the large demagnetizing. It is apparent that the fitted results, using eq. (2)–(5), are in good agreement with the experimental ones. This means that the LLG equation can be used to describe the FMR results in the present samples.

The thickness dependence of effective magnetization is shown on Figure 3. It shows that $4\pi M_{eff}$ increases with increasing film thickness. Roughly speaking, effective magnetization is an approximately linear function of $1/d$. It is also apparent that the saturation magnetization do not change with the film thickness.

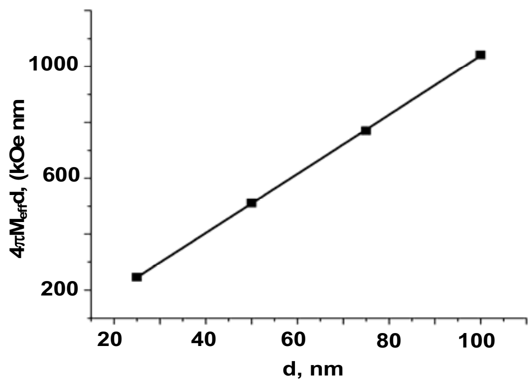

Fig. 3. Thickness dependence of effective magnetization (Points are measured, line serves as a guide to the eye)

The influence of orientation on linewidth was investigated too (Figure 4). This dependence has a strong peak $\theta_H \approx 10^o$. Theoretical description of FMR linewidth can be carried out using Gilbert damping coefficient:

$$G = \alpha\gamma M_s \tag{6}$$

where α is dimensionless damping coefficient.

In this case, FMR linewidth is described by next equation[3]:

$$\Delta H_{\text{int}\,r} = \frac{1}{\sqrt{3}}\alpha(H_1 + H_2)\left|\frac{d(\omega/\gamma)}{dH_{res}}\right|^{-1} \tag{7}$$

The coefficient $1/\sqrt{3}$ is the correction for the difference between the full width at half maximum (FWHM) and the peak-to-peak linewidth for the Lorentzian line shape. Figure 4 shows, that the angular dependence of linewidth can be fitted by Eq. (7). This equation qualitatively explains the angular dependence of linewidth.

Fitting parameters for 50 nm thick film are: $\alpha = 0.003$, $g = 2.075$. The parameter a was chosen so, $\Delta H_{pp} = \Delta H_{\text{int}\,r}$ for normal film orientation. There is a difference between ΔH_{pp} and Gilbert linewidth ($\Delta H_{\text{int}\,r}$) for films 50, 75 and 100 nm thick at normal film orientation. This effect can be explained by two magnon scattering process.

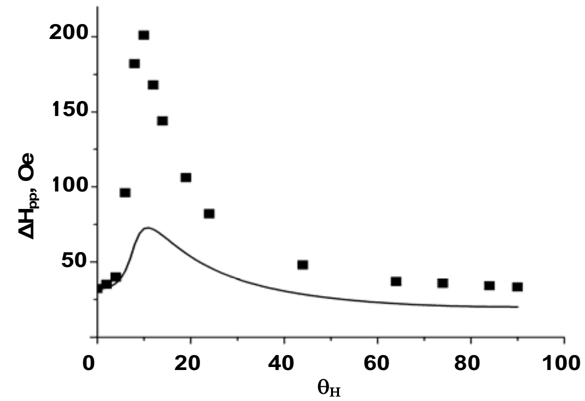

Fig.4 Angular dependence of FMR linewidth, line is calculations, points – experimental data. d= 50 nm

There is the shift of the band for two magnon scattering as the external field orientation is rotated from perpendicular to parallel. In the perpendicular configuration, the bottom of the spin wave band at $k = 0$ is coincident with the FMR frequency and there are no nonzero k spin wave states at this frequency. In the parallel configuration, the band has dropped down so that the top of the spin wave band at $k = 0$ is coincident with the FMR frequency. There is now an extended range of spin wave states degenerate with the FMR frequency. These states range from spin waves at $k = 0$ for $\theta_H = 90^o$ to rather large k values at $\theta_H = 0^o$. That's why, the two magnon scattering process makes biggest contribution to linewidth at parallel configuration and ΔH_{pp} differs from $\Delta H_{\text{int}\,r}$. However, this different depends on film thickness.

Calculations show that spin wave dispersion greatly depends on film thickness. Figure 5 shows that there is a small number of degenerate states and two magnon scattering process makes a small contribution to ΔH_{pp}. This situation arises in 25 nm thick film, where $\Delta H_{pp} \approx \Delta H_{\text{int}\,r}$ for parallel configuration. But with increasing of film thickness, the spin wave dispersion changing the way that regions of degenerate states create. So ΔH_{pp} increases.

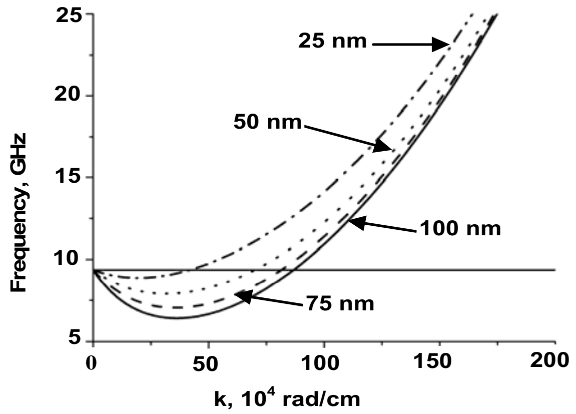

Fig. 5. Influence of film thickness on lowest spin wave dispersion branch

Conclusions. The influence of sample orientation on FMR spectra, namely value of resonance magnetic field and FMR linewidth, was investigated. It was shown that the magnitude of $4\pi M_{eff}$ depends on film thickness. Angular dependence of FMR linewidth has a strong peak and can be qualitatively explained by intrinsic Gilbert damping. The contribution of two magnon process to linewidth was shown too.

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КУТОВА ЗАЛЕЖНІСТЬ ФЕРОМАГНІТНОГО РЕЗОНАНСУ В ТОНКИХ ПЛІВКАХ ПЕРМАЛОЮ

Проведено вимірювання феромагнітного резонансу (ФМР) в широкому діапазоні кутів в тонких плівках пермалою товщиною 25, 50, 75 та 100 нм. Кутова залежність ФМР була проаналізована за допомогою рівняння Ландау-Ліфшиця-Гільберта. Із збільшенням товщини плівки, внесок двомагнонного розсіяння у напівширину лінії також збільшується.

Ключові слова: феромагнітний резонанс, пермалой, тонкі плівки, напівширина лінії.

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УГЛОВАЯ ЗАВИСИМОСТЬ ФЕРРОМАГНИТНОГО РЕЗОНАНСА В ТОНКИХ ПЛЕНКАХ ПЕРМАЛЛОЯ

Проведено измерение ферромагнитного резонанса (ФМР) в широком диапазоне углов в тонких пленках пермаллоя толщиной 25, 50, 75и 100 нм. Угловая зависимость ФМР была проанализирована при помощи уравнения Ландау-Лифшица-Гильберта. При увеличении толщины пленки, вклад двухмагнонного рассеяния в полуширину линии также возрастает.

Ключевые слова: ферромагнитный резонанс, пермаллой, тонкие пленки, полуширина линии.

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PECULIARITIES OF PLASMA SOURCES IN PLASMA MEDICINE

This paper has two goals. The first one is the characterization of the plasma source: the plasma power outflux must be known in order to control the conditions under which biology samples are treated. This is especially important in the treatment of living cells, which may not receive high energy doses. Thus, measurements of various plasma parameters relevant for cell treatment have been performed and analyzed. Special attention was given to the acoustic power transmission of the plasma source through internal media. Mechanisms of acoustic transmission in a external medium are discussed.

Key words: plasma source, biology samples, acoustic power transmission.

Introduction. Low temperature non-equilibrium atmospheric pressure plasmas for air and surface cleaning technologies have proven to be robust and safe enough for use indoors. This is partly due to high bactericidal effectiveness of plasmas and partly to their ability to penetrate into narrow and confined spaces, small cracks and microscopic openings.

Such plasmas have been used for a long time for sterilization of medical instruments, bacterial inactivation, blood coagulation, wound healing, oral hygiene, etc. [2]. Recently, with the rapid advances in the multidisciplinary research areas of cold atmospheric-pressure plasmas and plasma health care/medicine, interactions of such low-temperature, non-equilibrium plasmas with a large number of biologic objects, have attracted a major attention [1]. These objects include but are not limited to eukaryotic (mammalian) and prokaryotic (bacterial) cells, viruses, spores, fungi, DNA, lipids, proteins, cell membranes, as well as living human, animal, and plant tissues and organs.

Of particular interest are the plasma interactions with cancerous cells. It has been shown by several groups that the plasma is able to induce death (the programmed death, apoptosis or the necrotic cell rupture) in a number of cancer cell types [3]. This offers exciting prospects for clinical applications of cold atmospheric plasmas for aggressive treatment of malignant cells and ultimately as a viable alternative to the present-day interventional oncology that is capable of cancer resolution without surgery.

Application of plasma treatment in dental restoration procedures may effectively disinfect cavity-causing bacteria; reduce the use of the painful and destructive drilling currently practiced in dental clinics, and consequently save healthy dental tissues. Not only is there the vision of rapid, contact free sterilization, which can access even small pores and microscopic openings, but also one may envisage new possibilities of drug delivery at the molecular level in the dental tissues. New bio-medical effects due to ions and, in the distant future, maybe even new plasma drug developments operating at the cellular level that may act selectively might be expected [6].

Plasma sources. Atmospheric pressure plasmas are very promising tools for biomedical applications and are expected to bring new therapeutic options in surgery, dentistry and dermatology. Each scope of application requires specific, adapted plasma sources. In most cases, basic geometric criteria can be met by choosing a proper discharge type. Locally active plasmas are easily realized with single corona, jet or micro hollow cathode setups