Strong interaction between light and electrons (5)
"Frequency dependence of line width in ESR and FMR"

Product used : Electron spin resonance spectrometer (ESR)

Using the transmission ESR/FMR measurement method, spectral analysis can be done in the situation that it is not affected by the spin-cavity coupling (interaction that produce the Purcell effect and a strong coupling state) due to the high spin density samples. Obtained spectral line width of a sample is necessary to estimate an important parameter, cooperativity ($= g_m^2/k_c \cdot \gamma_m$, k_c and γ_m are HWHM (half width)) which means the degree of interaction between photon and spins. Figure 1(a) shows frequency dependence of line width obtained by paramagnetic resonance (sample is DPPH powder shown in Application Note ER200006E). Figure 1(c) shows frequency dependence of line width obtained by ferromagnetic resonance (sample is YIG thin film shown in Application Note ER200008E-9E).

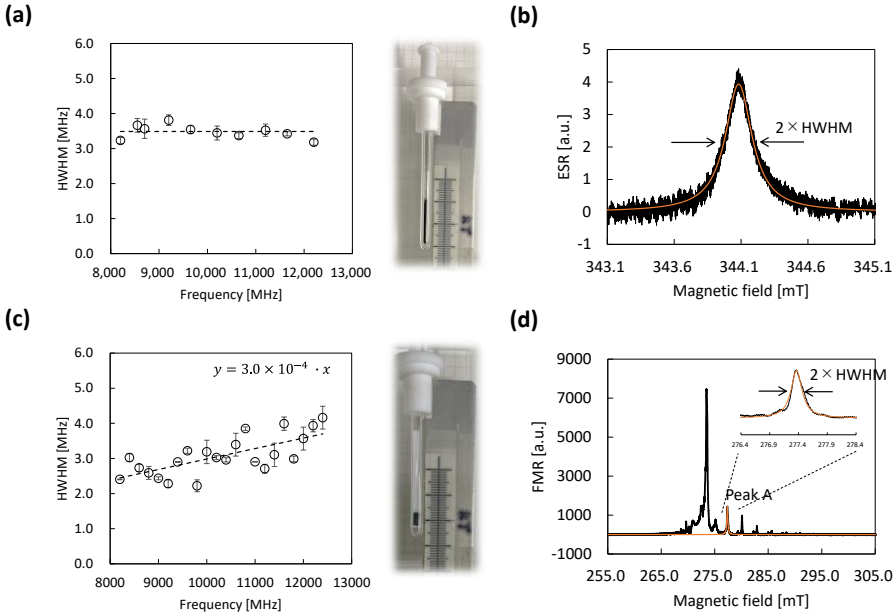

Fig.1 Frequency dependence of spectral line width by transmission ESR/FMR measurement method.
(a) DPPH sample (right photo) and frequency dependence of the line widths. (b) DPPH-ESR spectrum by transmission method. (c) YIG thin film (right photo) and frequency dependence of the line widths (Peak A). (d) YIG-thin-film- FMR spectrum by transmission method.

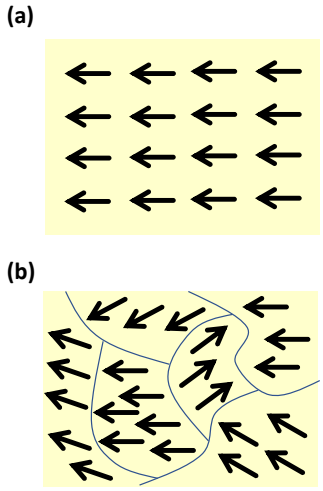

Fig.2 Homogeneity of ferromagnetic thin films.
(a) Homogeneous film. (b) Inhomogeneous film.

Damping constant and surface quality

Figure 1(a) and 1(c) show a difference on the frequency dependence of spectral line widths with respect to a paramagnet and a ferromagnet. The line width of FMR spectrum has a property that is proportional to the irradiated frequency. Its proportional coefficient is called damping constant. This damping constant α is very important on the evaluation of ferromagnetic materials. The line width (ΔH) of FMR spectrum and FMR frequency (f) have a relation as

$$\Delta H = \alpha f/|\gamma_e| + \Delta H_0.$$

ΔH_0 reflects the homogeneity of the film materials. Not zero value of ΔH_0 means the inhomogeneity of the film[1]. In recent years, spintronics devices using ferromagnetic materials are actively studied. Therefore, evaluation of the damping constant is becoming more important. In this field, a vector network analyzer is usually used for FMR measurements. Introduced waveguide method in this application note is unfortunately not sensitive. However, there are not serious constraints for sample size and shape, and it has a merit on the homogeneity of B_1 vector of microwave.

Reference: [1] J. M. Shaw, H. T. Nembach, and T. J. Silva, J. Appl. Phys. **108**, 093922 (2010).

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