Diluted ferromagnetic-metal nanogranular films, in which a volume fraction of the granules \( x_v \) is much lower than the percolation threshold, have been of great interest because they are proposed as a possible candidate for materials with both electrical permittivity \( \varepsilon \) and magnetic permeability \( \mu \) negative, called left-handed materials (LHMs) [1]. The effective permittivity \( \varepsilon_{\text{eff}} \) of such films is negative at frequency less than the plasma frequency of ferromagnetic-metal particles. On the other hand, the effective permeability \( \mu_{\text{eff}} \) can be negative at frequency in the vicinity of the ferromagnetic resonance (FMR) frequency \( \omega_0 \). \( \omega_0 \) is usually in the region of microwaves. It may thus be possible to prepare a material with \( \varepsilon_{\text{eff}} \) and \( \mu_{\text{eff}} \) both negative for microwaves. In order to realize LHMs by using this system, detailed knowledge of FMR of the diluted ferromagnetic-metal nanogranular films is crucial.

In this contribution, we have studied FMR of diluted iron nanogranular films, in which Fe nanoparticles are embedded in amorphous SiO\(_2\) matrices. Films with different Fe volume fraction \( x_v = 0.05 \) and \( 0.15 \) were prepared by co-sputtering method. In FMR studies, we observed a clear resonance signal assigned to a uniform mode from both samples. Neither of temperature nor angular between the sample plane and applied magnetic field affects on the resonance signal of a sample with \( x_v = 0.05 \). On the contrary, the resonance signal of \( x_v = 0.15 \) strongly depends on the both parameters. The dependence can be explained by Kittel's equations for a ferromagnetic disk [2]. These results suggest that Fe nanoparticles in \( x_v = 0.15 \) are magnetically coupled. Furthermore, in FMR spectra of \( x_v = 0.15 \) at low temperature, we found that an additional resonance emerges at a magnetic field below the uniform mode. A possible origin of the additional resonance will be discussed.


**Corresponding author:**
Satoshi Tomita

*Mail: PRESTO, Japan Science and Technology Corporation (JST), Hirosawa, Wako, Saitama 351-0198, Japan*

*Email: s-tomita@riken.go.jp*