Ferromagnetic-Metal Nanocomposite Films: A Possible Candidate for Left-Handed Materials

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Outline

1. Nanocomposite films and LHMs
2. Ni-polyimide nanocomposite films
3. Ferromagnetic resonance study
4. Summary & Future works
Left-handed materials

Left-Handed Materials (LHMs):
Material with both permittivity ($\varepsilon$) and permeability ($\mu$) negative
Extraordinary electromagnetic response (Veselago, 1964)
e.g., inverse Doppler shift, negative index of refraction


Negative $\mu$?
1. Metamaterials:
   Array of split-ring resonators

2. Ferromagnetic-metal (FM-M) nanocomposite films
   Using ferromagnetic resonance (FMR)

Ferromagnetic-metal nanoparticle
Insulating matrices
Positive circularly polarised microwave ($\omega$) :

$\omega = \omega_0$ : ferromagnetic resonance (FMR)

Magnetic moment under applied field $H_0$ :
Precession with Larmor frequency ($\omega_0$)

$\frac{\mu^+}{\omega} = \frac{1}{\omega_0}$

The idea....
FM-M nanocomposite for LHMs

FM-M nanocomposite films

\[ \epsilon < 0 \]
\[ \mu^+ < 0 \]
@ vicinity of FMR frequency (\( \omega_0 \))

low eddy current loss

A possible candidate for LHMs at vicinity of a FMR frequency (microwave region)

\[ \omega_p = \sqrt{\frac{ne^2}{\epsilon_0 m}} \]
this project

Mission:
Realization of LHMs using FM-M nanocomposite

Present study:
1. Preparation of FM-M nanocomposite for LHMs
   A. Fe-SiO$_2$ nanocomposite films
      By co-sputtering method
   B. Ni-Polyimide nanocomposite films
      By chemically implantation

2. FMR studies of nanocomposite films