Nickel nanowires for Planer Microwave Circuits Applications and Characterization

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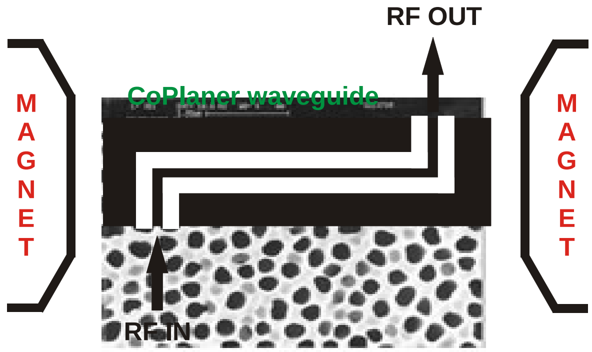
In the present investigation, we demonstrate a coplaner waveguide based tunable stop-band filter, based on a totally novel ferromagnetic nano-scale[1,2] planar technology. In the coplaner structure we used a nano-scale porous alumina matrix filled with ferromagnetic material (Ni), forming an array of nanowires (20 nm diameter 'd' and 23 and 50 μm length) perpendicular to the ground plane. The stopband effect is induced by gyromagnetic resonance phenomenon in the metallic nanowires, which occurs here even in the absence of applied dc magnetic field (at 10.5 GHz) due to the particular wire geometry. The stopband is tunable up to 14 GHz with an applied field up to 5 kOe. This is in a very good agreement with the gyromagnetic theory[1]. This novel prototype opens the road to a new generation of planar tunable devices. Further investigations were performed on the influence of wire diameter and pore density on stopband behavior.

Fig.1 shows the notch-filter in coplaner waveguide geometry made out of the alumina templates filled with Ni nano-wires by electrochemical deposition. Photolithograph and etching processes were performed to obtain coplaner waveguides of different lengths (L) and widths (W). Fig.2 shows the resonance frequencies (f_{res}) from transmission response (S_{21}) of the filter at different magnetic field applied perpendicular to the wire geometry by using a Vector Network Analyzer. The lines are the fits to FMR relation[1] taking into account the shape anisotropy in conjunction with dipolar exchange energy. The kink in the f_{res} versus magnetic field shows the effective field (H_{eff}) given by;

H_{eff}= Shape Anisotropy – Dipolar Interaction energy = $2\pi M_S - 6\pi M_S P$,
where P is the packing fraction = $3.67(d/D)^2$.

We have also performed the conventional FMR at 24 GHz to get information about fundamental magnetic parameters like spontaneous magnetization, spin-waves or gyromagnetic factor, and magnetic anisotropies of the nanowires. The in-plane angular variation of resonance field positions is shown in Fig. 3. The effective fields of the nano-wire system having 23 and 50 μm length were calculated from the resonance relation[1]. From the difference between the anisotropy field expected for a nanowire and that measured experimentally is employed to determine the filling factor (P). The study of FMR line width (ΔH) allows us to quantitatively analyze the distribution of parameters of individual wires. The width of the absorption signal can be expressed as: $\Delta H = \Delta H_{\text{int}} + \Delta H_A$,
where the two terms arise from intrinsic contributions and the fluctuations in anisotropy respectively.

[1]Armando Encinas, et al., Applied Physics Letters, Vol. 81, (2002), p. 2032.
[2]Ioan Dumitru et al., IEEE Trans. Mag., Vol. 41, (2005), p.3361.



<u>Fig. 1</u> : Coplaner wave guide on alumina template filled with Ni Nanowires.

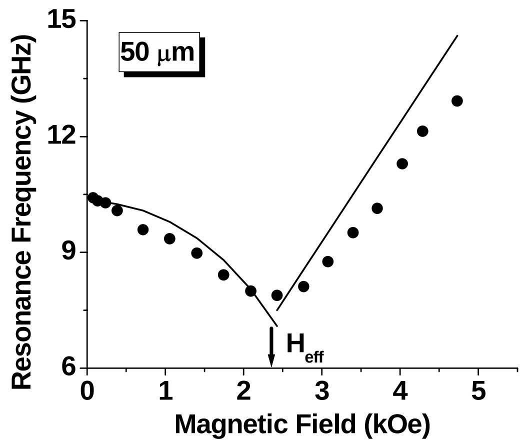


Fig. 2 : Resonance Frequencies measured by using Network Analyzer system versus DC magnetic field applied perpendicular to nanowires.

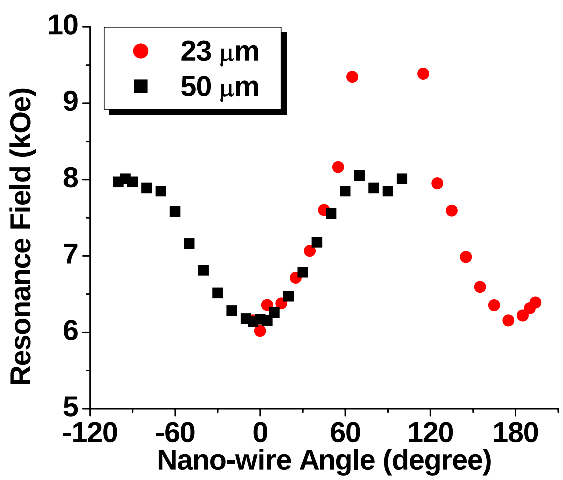


Fig. 3 : Angular variation of FMR field positions measured at 24 GHz.