Applications of soft magnetic properties of hexagonal ferrites in high frequency device design

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Hexagonal ferrites are widely recognized for their hard magnetic properties attributed to large magnetocrystalline anisotropy fields. Soft magnetic properties of hexagonal ferrites, however, have not received adequate attention in the past. In this work we're utilizing the soft magnetic properties of hexagonal Y-type ferrite (Zn_2Y) to drastically reduce bias field requirements in high frequency phase shifter devices.

The Zn_2Y crystal utilized in this study was grown by the flux-melt method [1]. The strong magnetocrystalline anisotropy field (H_θ = 9 kOe) aligns the magnetization in the basal plane of the hexagonal unit cell as shown in Figure 1. Low microwave losses of the Zn_2Y crystal are evident from the ferromagnetic resonance (FMR) measurements at X-band with a peak-to-peak linewidth of 23 Oe as shown in Figure 1. FMR condition for Y-type ferrites with the bias field applied in the basal plane is given by [2]

$$f_{FMR} = \gamma' \sqrt{H\left(H + 4\pi M_{eff}\right)}. \tag{1}$$

where γ' is the gyromagnetic ratio divided by 2π, H is the external magnetic field, and $4\pi M_{eff} = (H_\theta + 4\pi M_S)$ is the effective saturation magnetization. The antiresonance frequency (AFMR) is proportional to the FMR frequency through $f_{AFMR} \approx f_{FMR}\sqrt{4\pi M_S/H}$. The rapid variation in magnetic permeability near AFMR frequency was utilized to develop a microstrip phase shifter device on a single crystal c-axis oriented Zn_2Y substrate. Differential

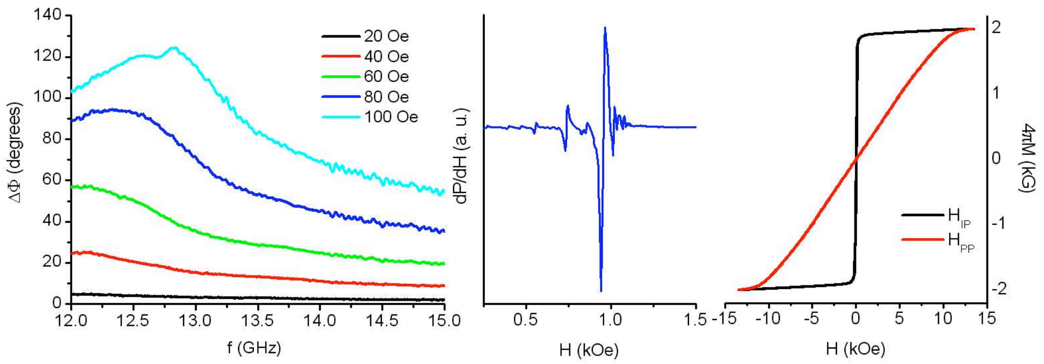

Figure 1: Differential phase shift as a function of bias field (left). FMR spectrum at X-band (center). Hysteresis loops with the field applied parallel (H_{IP}) and perpendicular (H_{PP}) to the basal plane (right).

phase shifts obtained by subtracting insertion phase at zero bias field from that at various values of bias field are shown in Figure 1. Practical phase shifts of more than 100 degrees/cm are obtained with bias fields as low as 100 Oe near the AFMR frequency of 13.5 GHz. Low bias field requirements in this case are a direct consequence of the soft magnetic properties of Zn_2Y crystal while the high frequency of operation is made possible by the high magnetocrystalline anisotropy field. We conclude that Y-type ferrites hold great potential in reducing bias field requirements in high frequency device design resulting in smaller, lighter, cheaper, more power efficient components.

[1] M.A. Wittenauer, J.A. Nyenhuis, and A.I. Schindler, J. Cryst. Growth 130, 533 (1993).

[2] X. Zuo, H. How, P. Shi, S. A. Oliver, and C. Vittoria, IEEE Trans. Magn. 38, 3493 (2002).

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