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OFF RESONANCE RELAXATION IN HEXAGONAL FERRITES

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The effective linewidth technique has been applied to study field dependent microwave losses in hexagonal ferrites for the first time. Data have been obtained on single crystal Zn_2–Y and ZnTi–M as well as oriented polycrystalline NiCo–W materials. The results clearly show that the high field effective linewidth is significantly lower than the ferromagnetic resonance (FMR) linewidth. This implies that inhomogeneity or two-magnon relaxation contributes significantly to the FMR linebroadening and that the intrinsic linewidth is much lower than the FMR linewidths. The results also demonstrate the usefulness of the effective linewidth technique to study microwave losses even under conditions where the actual FMR peak is inaccessible.

1. Introduction

Microwave losses and relaxation in hexagonal ferrites have been the subject of extensive research, partly because of the potential applications of these materials at millimeter wave frequencies. In most cases, previous relaxation data were obtained by ferromagnetic resonance (FMR) experiments, and the FMR linewidth was taken as a measure of the relaxation. The FMR linewidth reported for such materials (both single crystals and polycrystals), however, are relatively large, possibly due to linebroadening due to inhomogeneities and/or two-magnon processes, and do not represent the intrinsic losses in these materials. There exists a more powerful technique than FMR, the effective linewidth method, which enables one to measure the relaxation rate for the driven uniform precession mode as a function of the applied field, both near and far from the FMR position. This technique has been shown to be quite useful for the study of two-magnon linebroadening, microstructure effects on losses, and intrinsic relaxation in polycrystalline garnets and spinels [1–4].

The purpose of this work was to use the effective linewidth technique to measure the field dependence of the microwave relaxation processes in hexagonal ferrites, and thereby determine both the two-magnon losses and the intrinsic losses in these materials. The technique makes it possible to determine the off-resonance losses at the operating frequency of 9.9 GHz, even for high anisotropy uniaxial materials for which the actual FMR peak is inaccessible by conventional resonance techniques.

2. Experiment and results

The effective linewidth (ΔH_{eff}) values were obtained as a function of applied magnetic field, using the high Q cavity feedback technique described in ref. [5]. The measurements were done at a microwave frequency of 9.9 GHz and room temperature. Data were obtained on three classes of hexagonal ferrite materials, single crystal Zn_2–Y with planar anisotropy, single crystal ZnTi–M with uniaxial anisotropy and oriented polycrystalline NiCo–W with uniaxial anisotropy.

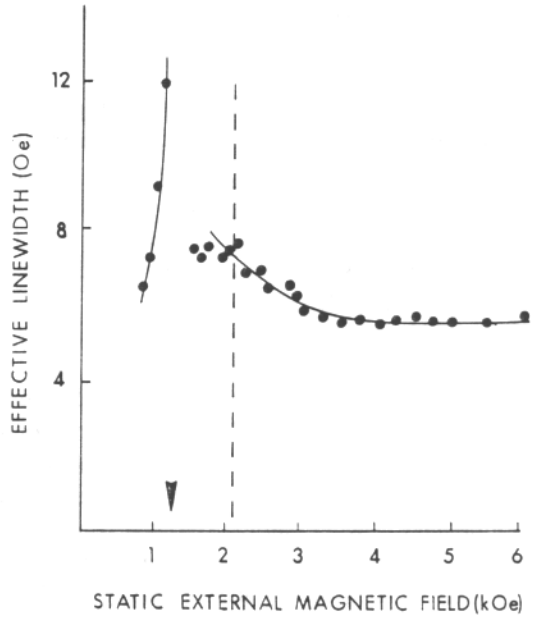

Fig. 1. Effective linewidth as a function of applied field for single crystal Zn_2–Y sphere with planar anisotropy. The pointer above the field axis represents the position of FMR field at 9.9 GHz. The broken vertical line indicates the field at which the bottom of the spin wave manifold lies at 9.9 GHz.

Fig. 1 shows the effective linewidth as a function of applied field for a Zn_2–Y sphere with planar anisotropy, magnetized in the easy plane. Planar anisotropy samples are of interest because in spite of the large anisotropy, the FMR field and the field interval over which low wave number magnons are degenerate with the uniform mode at the operating frequency are accessible at 9.9 GHz, in addition to the higher and lower field regimes for intrinsic losses. For the Zn_2–Y sphere magnetized in the easy plane, the saturation induction of 2.34 kG and the anisotropy field of 9 kOe yield an FMR field position of 1.23 kOe at 9.9 GHz, which is marked by a pointer above the field axis in fig. 1. The broken vertical line in the figure indicates the

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field at which bottom of the spin wave manifold is at 9.9 GHz. The effective linewidth increases with field as the FMR point is approached from below and drops off as one moves away from the FMR position toward higher field values. In the vicinity of the FMR field position the effective linewidth is rather high. The gap in ΔH_{eff} data around the FMR field position is due to extreme degradation in the cavity Q because of the high losses at resonance. Presumably, the effective linewidth in this region is comparable to the actual measured FMR linewidth of 60 Oe. The drop in ΔH_{eff} at fields above FMR extends somewhat beyond the point at which the spin-wave band moves above 9.9 GHz (dotted line). The effective linewidth above about 4 kOe is relatively constant at $\Delta H_{\text{eff}} \approx 5$–6 Oe, independent of field.

The above results show two significant effects. First, the large ΔH_{eff} values in the FMR-region with degenerate spin waves available as a relaxation channel and the drop off in ΔH_{eff} at higher and lower fields indicate that two-magnon losses are important for hexagonal ferrites. Second, the high field ΔH_{eff} value of 5–6 Oe indicates that the intrinsic losses are much smaller than one would infer from FMR alone.

In contrast with the planar case, for high anisotropy uniaxial hexagonal ferrites the FMR field is not accessible at 9.9 GHz by standard microwave techniques. (Negative fields or circular polarized excitation would be required.) In spite of this, it is possible to do the effective linewidth experiments on such materials at x-band frequencies. Fig. 2 shows the ΔH_{eff} vs. field results for an oriented polycrystalline NiCo–W sphere with the applied field along the average easy axis direction. This sample has a saturation induction and anisotropy field of 3.4 kG and 4.0 kOe, respectively, corresponding to an FMR-field of -0.4 kOe. The cut-off field for degenerate magnons is about 3 kOe, at the left hand field limit of the figure.

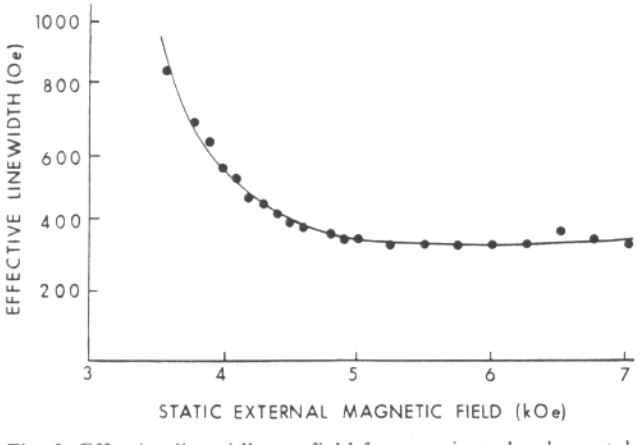

Fig. 2. Effective linewidht vs. field for an oriented polycrystalline NiCo–W sphere with uniaxial anisotropy.

The variation of ΔH_{eff} vs. field in fig. 2 is similar to that in fig. 1, with the important difference of no accessible FMR. The size of ΔH_{eff} is much larger. We see the characteristic drop in ΔH_{eff} with increasing field and a leveling off at $\Delta H_{\text{eff}} \approx 400$ Oe for fields above 5 kOe or so. The increase at low fields is probably due to a combination of demagnetizing effects (lack of saturation) and inhomogeneous and/or two-magnon linebroadening. Even though the field is above the cut-off for degenerate magnons, the linewidths are so large that the cut-off is smeared out and substantial linebroadening is still in evidence [1.6]. The fact that the intrinsic linewidth is lower than the FMR linewidth (≈ 2000 Oe) by a factor of five implies that the major sources of loss in these materials are probably two-magnon related relaxation processes and/or inhomogeneity linebroadening.

The effective linewidth vs. field was also measured for a single crystal ZnTi–M platelet with a high uniaxial anisotropy field of 11 kOe. For this value of anisotropy field, the FMR absorption curve is totally inaccessible, since the resonance would occur at negative 9 kOe. The effective linewidth, however, was readily measurable over a field interval of 2–8 kOe and found to be approximately 200–400 Oe. A characteristic increase with field, noted previously for conventional ferrites [7], was also observed. These results demonstrate the usefulness of present techniques in determining the off resonance losses far away from resonance and in the absence of any degenerate spin waves. The large ΔH_{eff}-values also show that the intrinsic losses in some single crystals can be large, even in the absence of inhomogeneity contributions.

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