MICROWAVE EFFECTIVE LINEWIDTH IN AMORPHOUS Co-Ta FILMS

P. Kabos, T. Kato, T. Mizoguchi, and C. E. Patton

ABSTRACT

The effective linewidth method, originally developed to study microwave losses and microstructure in ferrites, has been applied to amorphous Co-Ta metallic films for the first time. The effective linewidth spectra reveal the presence of two magnon scattering relaxation processes in these films and are very sensitive to microsctructure changes. The effective linewidth technique can therefore be used to study structural relaxation and recrystallization processes in amorphous alloys.

INTRODUCTION

Amorphous magnetic alloys have been the subject of extensive research. One important aspect of this work concerns structural relaxation and recrystallization. Baianu and co-workers[1] used ferromagnetic resonance (FMR) experiments to investigate the effect of annealing on the resonance linewidth and lineshape of metallic glasses. More recently, Heinrich and co-workers[2] have applied FMR to study recrystallization effects in amorphous alloys. They found that the microstructure development leads to two magnon relaxation and that this relaxation may be a very sensitive indicator of structure changes from the amorphous state.

There exists a more quantitative microwave technique, the effective linewidth method, originally developed for investigation of two magnon scattering in ferrites,[3,4] which allows one to study the relaxation rate of the driven uniform mode vs. field. In this work, the first application of the effective linewidth technique to amorphous metallic ferromagnets is reported.

EFFECTIVE LINEWIDTH

The effective linewidth technique as described in ref. 5 allows one to measure the relaxation rate for the driven mode as a function of the d.c. magnetic field. In a perfectly homogeneous magnetic material, one would expect this relaxation rate (or effective linewidth, ΔH_{eff}, when expressed in linewdith units) to be constant, independent of the d.c. field, and equal to the measured FMR linewidth, the "intrinsic" linewidth of the material. The presence of microstructure would, however, lead to an additional relaxation contribution due to two magnon scattering under d.c. magnetic field conditions such that spin waves degenerate with the driving frequency are available for scattering. This generally leads to an increase in the effective linewidth over a field interval on the order of one kOe or so (depending on sample shape, magnetization, frequency, etc.) which includes the FMR field. The field limits for this interval correspond to the fields at which the spin wave frequencies at the top and bottom edges of the spin wave manifold in the limit of zero wavenumber (k = 0) pass through the excitation frequency (see. ref. 4). The coarser the microstructure, the sharper the effective linewidth increase at these limits, since the coupling is limited more and more to low-k degenerate magnons. The finer the microstructure, the more smeared out the increase in ΔH_{eff}.

In the present work, the primary objective was to perform measurements of ΔH_{eff} vs. field for amorphous alloy thin films of Co-Ta prepared by rf diode sputtering, before and after annealing treatment, and to look for evidence of two-magnon relaxation and changes in the background relaxation. The films were prepared using procedures as described in ref. 6. Microwave measurements were done following ref. 5, but adapted to the thin film geometry with in-plane and out-of-plane d.c. and microwave magnetic field, respectively. The data were obtained at 9.9 GHz and room temperature for a series of films sputtered at argon pressures of 5, 10, or 20 mTorr, and dc bias voltages of 0, 50, or 100 V. All compositions were approximately 16% Ta

RESULTS AND DISCUSSION

The Effective linwidth vs. field data for a 10 mTorr/100V film are shown in Fig. 1. The lower data set is for the as-sputtered film. The upper data set is for the same film after annealing at 570°C for one hour. The lower data set shows two distinct bumps at about 1.1 and 3.7 kOe. These are precisely the fields at which the edges of the spin wave band at the low wavenumber cross the exitation frequency. These bumps are clear evidence for some two magnon relaxation in these amorphous alloys. The data for the annealed sample show a much larger ΔH_{eff} and a somewhat broadened but still evident two magnon signature. Films prepared with zero bias voltage and 5 or 10 mTorr argon pressure had larger ΔH_{eff} values similar to the upper data set of Fig. 1. Films prepared under the remaining pressure/bias conditions had spectra similar to the lower data set in Fig. 1. While the ΔH_{eff} vs. field profiles clearly depend on the preparation conditions, systematic trends have yet to be established.

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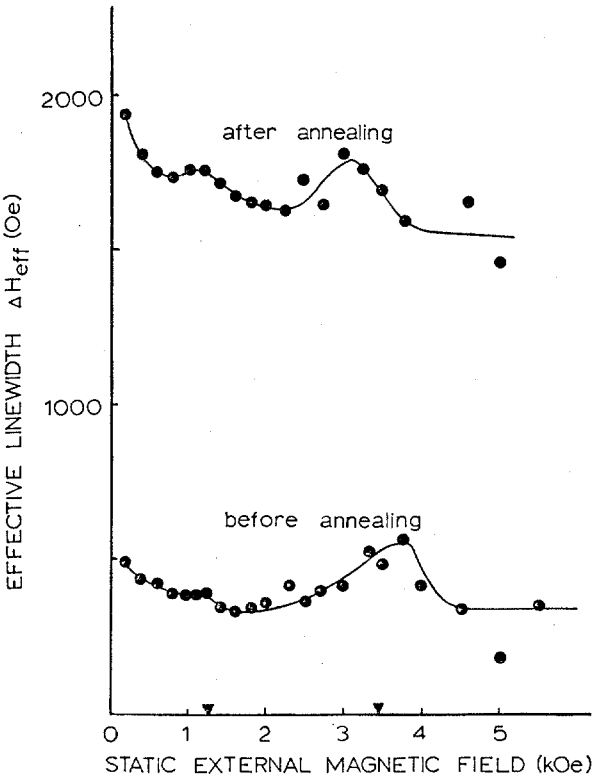

Fig. 1. Effective linewidth as a function of static external field for an amorphous Co-Ta film (∿ 16% Ta) sputtered at 10 mTorr argon pressure and 100 V, before and after annealing at 570°C for 1 hour.

The above results have interesting implications concerning microstructure and two-magnon relaxation. One is tempted to attribute the overall increase in ΔH_{eff} upon annealing to two-magnon relaxation due to the larger magnetic inhomeneity content achieved by annealing, presumably in the form of larger, randomly oriented crystallites, grain boundaries, etc. If this is indeed the case, the scale of inhomogeneities must still be rather small, below one micron or so. Otherwise, one would see a pronounced increase in ΔH_{eff} only in the degenerate spin wave region between the two bumps, as in conventional ferrites with a coarse inhomogeneity scale of tens of microns or so.

In order to get some idea of the possible roles of coarse scale vis-a-vis fine scale inhomogeneitles in the two magnon relaxation, a second series of ΔH_{eff} measurements were made in which inhomogenity was introduced by abrading the film surfaces with sandpaper of different grit sizes. This is the analogue of the early rough sphere studies of Buffler[7] which established the role of two magnon relaxation in ferromagnetic resonance. The lower data set in Fig. 2 is for no abrasion. The upper data sets are for 400 and 220 grit sandpaper abrasions, respectively. It is clear that abrasion increases the magnitude of the two magnon relaxation. The onset of the two magnon relaxation at the upper field limit also becomes broadened. Because of the qualitative nature of the abrasion, it is not possible to make any quantitative connection between grit size and the two magnon relaxation. The main point is that a

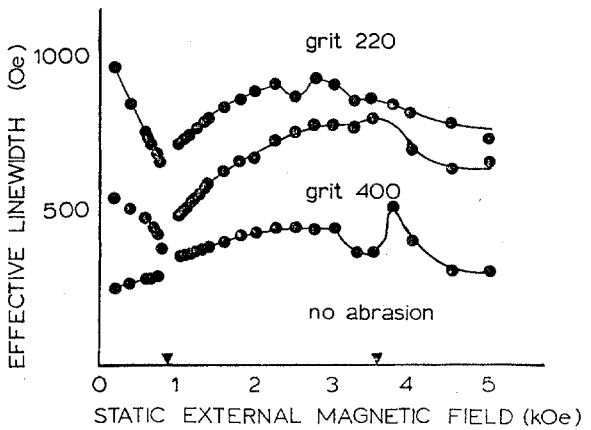

Fig. 2. Effective linewidth as a function of static external field for a Co-Ta film sputtered at 20 mTorr argon pressure and zero bias voltage, before and after abrasion as described in text.

coarse scale abrasion produces a significant increase and smearing out of the effective linewidth vs. field profile. The smearing out does not necessarily imply a fine scale inhomogeneity or microstructure development.

Further microwave experiments for films prepared under different conditions and annealed in various ways are in progress. These results, in combination with quantitative microstructure characterizations, will be used to resolve the questions indicated above. These first effective linewidth results on amorphous magnets show the potential of the technique for the investigation of microstructure changes and relaxation in these materials.

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