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RELATION BETWEEN OBSERVED MICROMAGNETIC RIPPLE AND FMR WIDTH IN ULTRASOFT MAGNETIC FILMS

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It was demonstrated that nanocrystalline FeXN films (X is an alloying element), obtained by sputtering or electrodeposition, have excellent ultra-soft magnetic properties with a saturation magnetization up to M ≈2.0 T, a high magnetic susceptibility and a frequency range above 1 GHz. Here we report on a correlation between the microstructure, the micromagnetic ripples, and high frequency magnetism in the sputter-deposited FeZrN-films. The range of operating frequencies for the films is limited by the frequency of the ferromagnetic resonance (FMR) and by the width of FMR. Besides contributions to the FMR width due to dissipation sources, which are characteristic for crystalline and polycrystalline ferromagnetics, in nanocrystalline films there exists an additional contribution due to the local variation of the magnetic uniaxial anisotropy. Notwithstanding its importance, so far only a very few studies have been reported in literature.

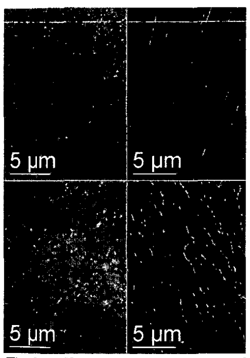

Fig.1. The microstructure and ripple for two different films.

The variation of the local anisotropy causes a magnetic ripple structure that can be observed with the Lorentz electron microscopy (LTEM) [1]. The coupling volume and the angular spread $<\phi^2>^{1/2}$ of the magnetic ripples are obtained from an analysis of the wavelength and angular distributions of the LTEM image ripples, as based on a Fourier analysis of the image. This was done for films with different thickness, grain size and microstructure, as illustrated by Fig.1. The effect of the ripples on the FMR width is analyzed using an approach based on the Landau-Lifshitz equation without the dissipative term. The local dispersion of the magnetization gives rise to a stray field [2]. In our approach we assume that this fluctuating stray field is a major cause of the broadening of the FMR-line. A strong dependence of the resonance width on the magnetic moment dispersion, $\Delta f_0/f_0 \approx 32<\phi^2>^2(dM)^2/A$, is predicted by such an approach, where d is the film thickness and A is the exchange stiffness. We show that to a large extent this particular aspect can explain the width of the resonance frequency in our films.

References:

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MOMENT REDUCTION DUE TO OXYGEN CONTAMINATION OF $Fe_{35}Co_{65}$

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Obtaining high moment sputtered thin films with soft properties requires small grains with good exchange coupling between the grains. Contamination of grain boundaries during deposition will significantly degrade magnetic softness and reduce magnetic moment. In this work, we report on such contamination induced by substrate bias during sputter deposition of $Fe_{35}Co_{65}$ films.

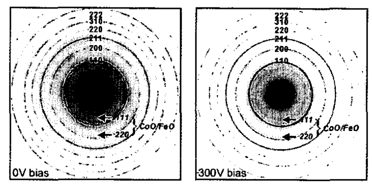

Figure 1: Diffraction images of $Fe_{35}Co_{65}$

$Fe_{35}Co_{65}$ films (thickness: 100 nm) were sputtered at 100 W target power in 3 mTorr of Ar, with varying substrate bias from 0 V to −300 V. The maximum value of moment of 2.35 T was observed at intermediate bias values, but the saturation magnetization of the films decreased nearly 10% for the samples at the highest bias. TEM analysis of the samples indicated an increase in oxide content and a decrease of grain diameter from 75 nm to 25 nm with increasing substrate bias. The increase in oxide can be seen in the TEM analysis shown in Figure 1 in which the intensity of the oxide diffraction rings is 8% stronger in the −300 V bias sample than in the 0 V bias sample. The loss of magnetization with increasing bias is quantitatively consistent with a nonmagnetic oxide shell of approximately 1 nm in thickness around each grain for all biases. This is illustrated in Figure 2, which shows the expected moment loss (calculated) as a function of grain size for such a microstructure for four different shell thicknesses. The grain and shell structure is shown in an inset in the figure. The effect is simply that of increasing surface to volume ratio as the grains get smaller. Note that the measured magnetizations and grain sizes are all consistent with a 1 nm thick shell. Importantly, we would expect a nonmagnetic shell of this thickness to be sufficient to break exchange coupling between the grains and yield very poor soft properties. This was observed in these samples, as their predicted coercivity due to magnetization ripple is much lower than what was observed.

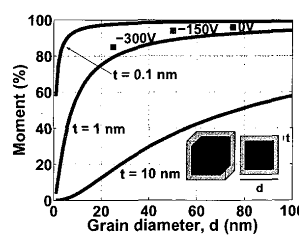

Figure 2: Moment vs. grain diameter

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