Investigating the effects of deposition conditions on ferromagnetic resonance of permalloy

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One of the most commonly used materials for the study of spin waves is permalloy, $Ni_{81}Fe_{19}$[1]. As a relatively low Gilbert-damping material, it allows spin waves to be transmitted coherently over distances comparable to device dimensions in the absence of Joule heating [2,3]. Owing to these qualities, a plethora of studies have investigated factors affecting its dynamic properties, including variations in annealing temperature[2] and film thickness [4]. Studies have also shown how it's static magnetic properties, such as the saturation magnetisation M_s, change depending on deposition conditions [5].

To our knowledge, no systematic study has been reported on the influence of deposition conditions on the strength of absorption of perpendicular standing wave modes (PSSW) in permalloy. In this work, we address this gap using broadband ferromagnetic resonance (bbFMR). Measurements were performed using a vector network analyser (VNA) connected to a coplanar waveguide (CPW) with a signal line width of 394 μm. Samples were placed face-down on top of the waveguide. All films were deposited with the structure Ti (5 nm) / NiFe (100 nm) / Ti (5 nm), with the permalloy layer grown under varying deposition conditions, as summarised in Table 1.

Preliminary results indicate that increasing the deposition energetics significantly influences which PSSW mode exhibits the highest absorption, as shown in Table 1. In particular, the amplitude of the zeroth-order mode (k=0) decreases with increasing deposition energy and is either strongly suppressed or overtaken by the first-order PSSW mode. Structural characterisation using X-ray diffraction (XRD) reveals no significant differences between the samples.

We will explore the deposition of magnetic multilayer structures and, potentially, transmission electron microscopy (TEM) to probe microstructural variations not detectable by XRD.

Sample & Pressure(mTorr) & Dep Rate(Å/s) & 0th Mode Amp & 1st Mode Amp
A & 0.80 & 2.82 & 0.025 & 0.010
B & 0.80 & 1.76 & 0.024 & 0.013
C & 2.90 & 1.26 & 0.009 & 0.024
D & 2.90 & 0.78 & 0.007 & 0.023

Table showing the effects of deposition conditions on 100nm permalloy samples. All the amplitude measurements (arbitrary units) were taken at 10 GHz.

References:

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