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Structural and magnetic properties of highly oriented NiFe/Cu multilayer film

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1. Intorduction

NiFe/Cu multilayer films have been studied because of excellent soft magnetic properties. However, as increasing thickness of NiFe layer, inter-diffusion between NiFe and Cu layer at the interface was promoted because Ni atoms diffuse into Cu layer due to the high solubility of Ni in Cu. GMR properties becomes worse and worse with increasing NiFe layer thickness as a result.

In this work, thin films with magnetically clear interface between the NiFe and Cu layers were epitaxially grown on HF-treated Si (001) substrates. The inter-diffusion effect was studied with the variation of magnetoresistance (MR) and ferromagnetic resonance (FMR) measurement with epitaxial and non epitaxial films.

2. Experimental

[NiFe(25Å)/Cu(24Å)]$_2$/Si thin films were epitaxially grown on HF-treated Si(001) substrates by a DC magnetron sputtering method. For comparison, non-HF-treated Si(001) substrates were placed very close to the HF-treated Si (001) substrates in every sputtering. Background pressure was better than 4.5×10^{-7} torr at room temperature. The sputtering pressure was 1 mtorr and deposition rate was 1 Å/sec..

Epitaxial growth of thin film could be confirmed by X-ray diffraction (XRD) profile with Cu Kα radiation. The MR ratio was measured by the conventional four-point method at room temperature under a maximum in-plane field of 120 Oe. Magnetic properties were analyzed with a vibrating sample magnetometer (VSM) and X-band ferromagnetic resonance (FMR) at room temperature.

3. Results and discussion

XRD results of [NiFe(25Å)/Cu(24Å)]$_2$ films deposited on the HF-treated substrates as well as on the non-HF-treat substrate. Diffraction peak only from (002) planes of Cu and

NiFe in film on the HF-treated substrates can be seen. From this (002) peak epitaxial growth could be confirmed in $[NiFe/Cu]_2$ films on the HF-treated substrates. Normally (111) peak is strongest as shown in the film deposited on the non-HF-treated substrate and in Cu and NiFe powder diffraction data. From the nature of epitaxial growth, sharper and less rough interface as well as less inter-diffusion at the interface could be assumed in the films on the HF-treated substrates.

The variations of MR value of films with $[NiFe(25\text{Å})/Cu(24\text{Å})]_2$ epitaxial and non-epitaxial films were measured at room temperature under a maximum field of 120 Oe. The MR ratio of the epitaxial film is much larger than that of the non-epitaxial film even though its absolute MR value is much smaller than reported MR value of films with larger stacking layers. A low MR value may be due to a less stacking number of layers because a less stacking number gives rise to a non-uniformity of the layer properties and incomplete antiferromagnetic coupling, leading to a low MR value.

In order to understand a low MR value as well as inter-diffusion between Cu and NiFe layers of epitaxial film, FMR experiment was done. Two absorption peaks appear in both films. Microwave energy could be absorbed in the interior (bulk) and/or interface of thin films. In our case each peak was seemed to come from each NiFe layer because only one absorption peak could be clearly seen in the films with NiFe/Cu and Cu/NiFe/Cu type structure. However, which absorption derivative comes from the first NiFe layer of $[NiFe(d_{NiFe}=25\text{Å})/Cu(24\text{Å})]_2$ is not clear yet.

4. Conclusion

The $[NiFe(25\ \text{Å})/Cu(24\ \text{Å})]_2$ thin film deposited by DC sputtering method. Thin film was eptitaxially grown on the HF treated Si(001) substrates in order to get magnetically clear interface between NiFe and Cu layer. XRD profile of epitaxial film showed a good (002) epitaxial growth of Cu and NiFe layer. In MR measurement, epitaxial film showed typical GMR curve due to antiferromagnetic exchange coupling even though it was small, while non-epitaxial film shows unsaturated and broad curve with a very low MR value. It could be analyzed that the highly defined interface of the epitaxial film ensured antiferromagnetic coupling compared with the non-epitaxial film. FMR absorption peaks were consisted of two peaks in all films, which were considered to come from each NiFe layer. Very clear interface in the epitaxial films could be confirmed by a lower value of ΔH, H_r and ΔH_r of epitaxial film than those of non-epitaxial films, respectively.