Influence of Ta buffer layer thickness on magnetic properties and microstructure parameters of CoFeB and MgO layers

J. Kanak[1], J. Wrona[1,3], M. Banasik[1], A. Żywczak[2], W. Powroźnik[1], M. Czapkiewicz[1] and T. Stobiecki[1]

[1] AGH University of Science and Technology, Department of Electronics, Al. Mickiewicza 30, 30-059 Kraków, Poland
[2] AGH University of Science and Technology, Academic Centre of Materials and Nanotechnology, Al. Mickiewicza 30, 30-059 Kraków, Poland
[3] Singulus Technologies AG, Hanauer Landstrasse 103, 63796 Kahl am Main, Germany

Aim

Structural and magnetic properties of CoFeB/MgO/CoFeB magnetic tunnel junctions strongly depends on buffer layers structures.

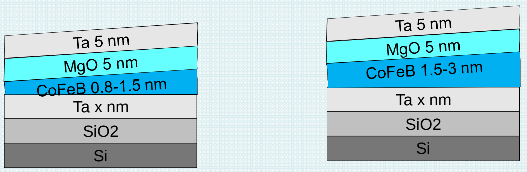
In this work we report samples with different thickness of Ta seed-buffer layer and its influence on microstructure and CoFeB dead layer thickness. The obtained results allow to optimize the Spin-Hall angle of Ta underlayer in the system Ta/CoFeB/MgO.

Experiment

The samples with three buffers of different Ta thickness: 5 nm, 10 nm and 15 nm were prepared. Layers system of the samples was as follows: buffer / wedge Co40Fe40B20 / MgO 5 nm / Ta 3 nm. The multilayers were deposited on thermally oxidized Si(001) substrates and then annealed at 330°C for 20 min using Singulus Timaris PVD Cluster Tool system. The CoFeB layers were deposited in two wedges with thickness of the CoFeB varied from 0.8 nm to 1.5 nm and 1.5 nm to 3 nm. Additionally samples with single buffer layers only (without CoFeB/MgO) were deposited.

The crystallographic microstructure of the layers were investigated by means of X-ray diffraction (XRD) θ-2θ and rocking curve measurements. Thickness of the layers and interface roughness were examined by X-ray reflectivity (XRR) measurements. Topography and surface roughness were measured using an atomic force microscopy (AFM). The magnetic moment was determined from vibrating sample magnetometer (VSM) measurements.

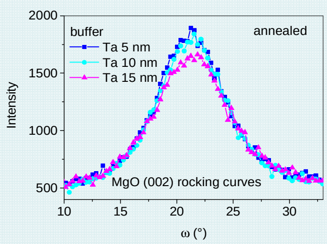
Samples Structure



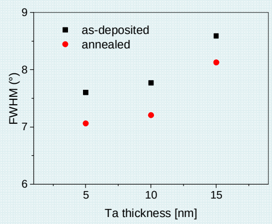
Ta seed layer thickness: x = 5 nm, 10 nm, 15 nm

Rocking curve measurements

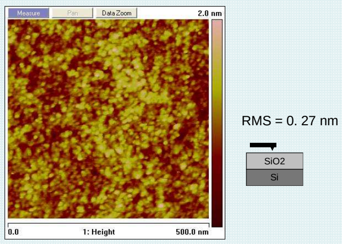
Rocking curve profiles measured on MgO (200) reflection.

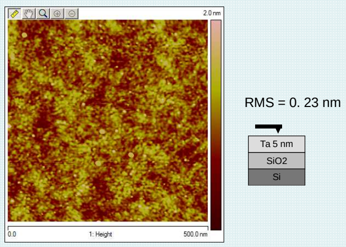


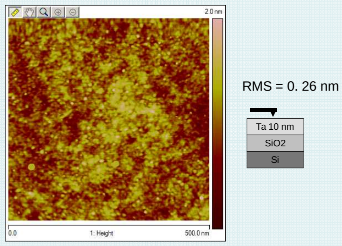
Rocking curve FWHM values obtained from fittings versus Ta buffer layer thickness.

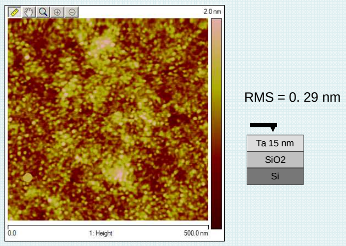


AFM measurements



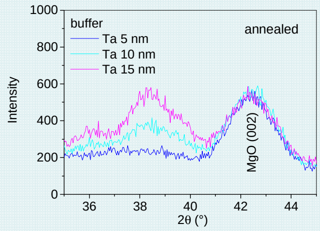






X-ray diffraction

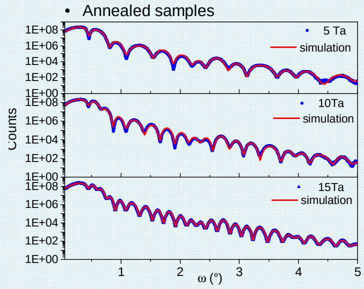
XRD θ-2θ profiles measured for annealed samples with thickness of CoFeB 2.1 nm.

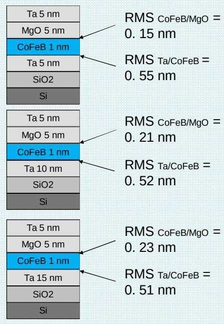


- Highly (001)-oriented texture of MgO layer
- Broad peaks at left side of MgO (002) come from disoriented tetragonal β-Ta structure

X-ray reflectivity

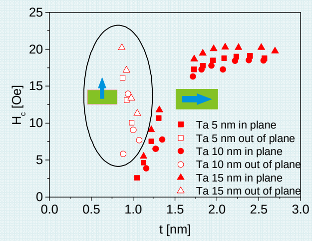
- Annealed samples





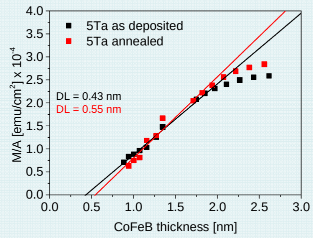
- Roughness at Ta/CoFeB interface is a combination of topological roughness and interdiffusion between Ta and CoFeB layers.
- Mixing at Ta/CoFeB interface is assumed to be induced by a large negative interfacial enthalpy.

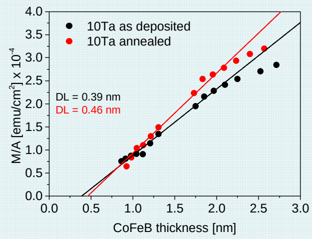
Coercivity fields

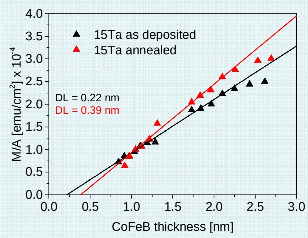


- In annealed CoFeB layers the transition from IP to PMA takes place at 1nm.

Magnetic moment







- Magnetic dead layer thickness decreases as Ta buffer thickness increases.
- Dead layer thickness increases after annealing.

Conclusions

- XRD analysis shows that Ta in buffers has grown in amorphous phase or disoriented β structure and MgO has grown with highly (001)-oriented texture.
- The strongest MgO texture was for buffer Ta 5 nm and it decreased successively with increasing of Ta thickness.
- The smallest topological buffer roughness determined from AFM was for Ta 5 nm thick and then increased with the thickness of Ta.
- It was found that the thickest dead layer (determined from magnetic moment measurements) and the highest $RMS_{Ta/CoFeB}$ interface roughness/intermixing (determined from XRR) was for the topologicaly smoothest buffer Ta 5 nm, while for the roughest buffer Ta 15 nm the dead layer was the thinnest.

Acknowledgment

Project was financed by the Polish National Science Center Grant DEC-2012/05/E/ST7/00240. T.S. acknowledges Swiss Contribution by NANOSPIN PSPB-045/2010 grant.