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Report:

The present focus of the spintronics community is on $Co_{60}Fe_{20}B_{20}$/MgO based magnetic tunnel junctions (MTJs) in which tunnelling magnetoresistance (TMR) values above 200% have been reported at room temperature with a crystalline MgO tunnel barrier. Interfaces in MTJs barriers and electrodes, together with microstructure and morphology, are of crucial importance in the achievement of high values of TMR and thus in the overall performance of MTJ-based devices [1]. In MTJs based on $Co_{60}Fe_{20}B_{20}$/MgO, low temperature annealing at about 200°C can result in a drop in the tunnelling magnetoresistance (TMR). Grazing incidence x-ray scattering during *in-situ* annealing has been used to study the interface stability in MgO-based electrodes and barriers used in magnetic tunnel junctions. Experiments were performed on $[Co_{60}Fe_{60}B_{20}/MgO]_{x14}$ multilayers prepared by three different techniques (Table 1). No change in the specular Bragg peaks with no loss of Kiessig fringe structure on crystallization and no change in the diffuse scatter up to 200°C indicates that these interfaces are stable and not responsible for the changes in magnetotransport.

Sample ID	Multilayer structure	Mg oxidation conditions
NAT	$[Co_{60}Fe_{20}B_{20}(30)/Mg(16)+Ox.]_{x14}/Co_{60}Fe_{20}B_{20}(30)$ /MgO(30)	Natural oxidation 20 sccm O_2, 120 s
REM	$[Co_{60}Fe_{20}B_{20}(30)/Mg(16)+Ox.]_{x14}/Co_{60}Fe_{20}B_{20}(30)$ /MgO(30)	Remote Plasma, 2 sccm Ar + 10 sccm O_2, 45 s
REA	$[Co_{60}Fe_{20}B_{20}(30)/MgO(12)]_{x14}/$ $Co_{60}Fe_{20}B_{20}(30)/MgO(30)$	Reactive MgO deposition natural flow O_2, 4 sccm Xe, 100 s.

Table 1

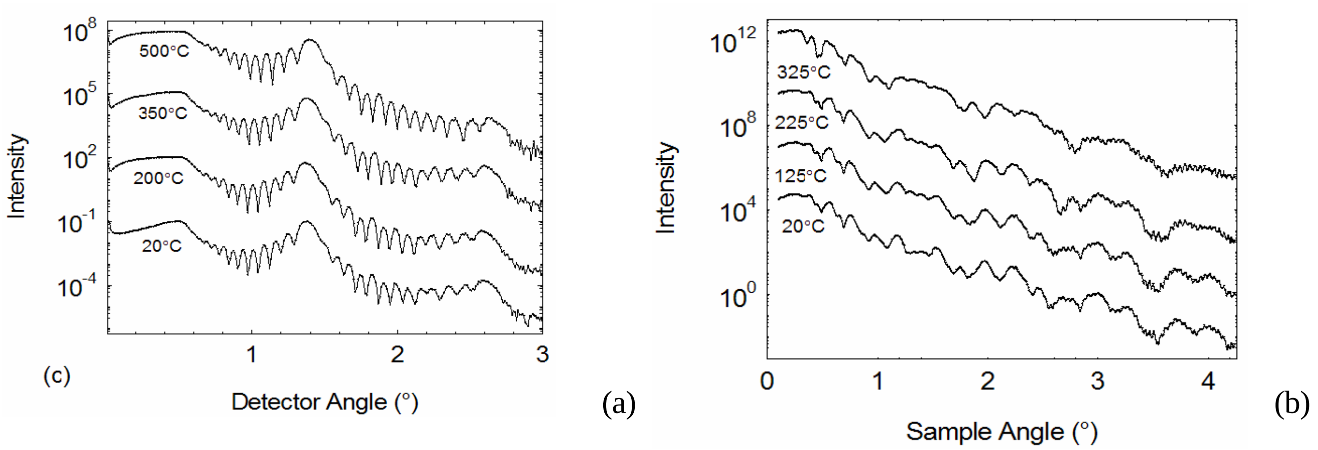

Fig 1. Specular scatter acquired during annealing of (a) sample REA and (b) an MTJ

Within the scatter of the data points, the thickness does not change through the annealing process, remaining around 23Å for CoFeB and 14Å for MgO layer respectively in the REM sample and 30Å for CoFeB and 28Å for MgO layer in the REA sample. The interface width deduced from fitting the simulations to the data from sample NAT at 23°C is 10(±1)Å for CoFeB/MgO and 8(±1)Å for MgO/CoFeB interfaces respectively. The width of the CoFeB/MgO and MgO/CoFeB interfaces remained unchanged at 30(±1)Å and 10(±1)Å respectively up to 200°C in the case of sample REM. A substantial decrease was observed for the CoFeB/MgO interface with a correspondent increase in the MgO/CoFeB interface roughness, when the sample was annealed to 400°C. There does not appear to be a systematic change of the interface width in sample REA and the data lie scattered around the value of 6.5Å for both interfaces during the annealing (Fig 2(a) [2]. Devices fabricated from REA material have the best performance [3].

In-situ specular reflectivity measurements of MTJs incrorporating an IrMn bias layer (Fig 1(b)) show a change in fringe structure at high scattering vector at about 200°C, the temperature at which the TMR drops. A change in diffuse scatter relative to the specular scatter is also observed and Born analysis shows that an increase in topological roughness occurred (Fig 2(b). In view of the observed interface stability in the multilayers, we suggest that diffusion of Mn from the IrMn pinning layer, present in the MTJs but not in the multilayers, may be responsible for the differences in TMR behaviour. However, we observed no significant variation in the scattered intensity as the x-ray energy was scanned across the Mn edge at fixed scattering vector. This was in marked contrast to simulations of the effect of moderate changes in the Mn distribution. The origin of this discrepancy is presently unclear.

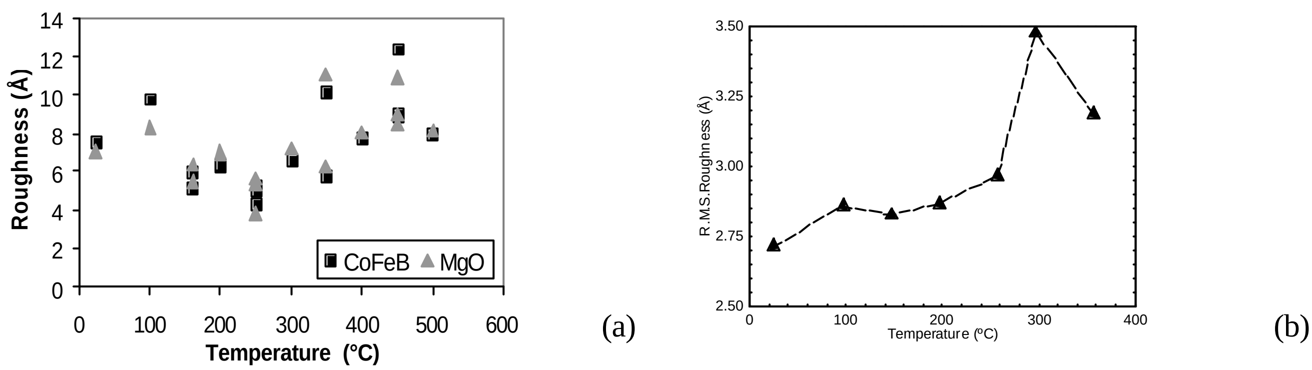

Fig 2. Change in roughness during annealing of (a) multilayer REA and (b) an MTJ.

[1] A. T. G. Pym, A. Lamperti, B. K. Tanner, T. Dimopoulos, M. Rührig and J. Wecker, Appl. Phys. Lett. **88** (2006) 162505
[2] A. Lamperti, A.T.G. Pym, D.S. Eastwood, S. Cardoso, P. Wisniowski, P.P. Freitas, G.I.R. Anderson, C.H. Marrows and B.K. Tanner submitted to Phys. Stat. Sol (a), X-TOP2006 conference special issue
[3] S. Cardoso, P. Wisniowski, P.P. Freitas, A. Lamperti, A.T.G. Pym, D.S. Eastwood, and B.K. Tanner in preparation