Investigating the diffusion behavior of boron in MgO/$Co_{20}Fe_{60}B_{20}$ Magnetoresistance structures with Ta and Zr capping layers

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MgO/CoFeB magnetic tunnel junctions (MTJs) devices shows giant tunneling magnetoresistance due to the coherent tunneling mechanism. These MTJs properties are beneficial for applying in spintronic data-storage device technologies such as read heads and magnetic random access memories. However, boron will diffuse into MgO or other capping layers during annealing, which is likely to be detrimental to the coherent tunneling.

In order to enhance the coherent tunneling effect, it is necessary to suppress boron segregation to the MgO layer. So we utilize the boron "getter" layer (i.e. Ta and Zr capping layers) to achieve this goal. According to the XAS results, Fe^{3+} , Fe^{2+} , Co^{3+} $L_{2,3}$-edge and B^{3+} K-edge white line intensity decreasing uniformly as function of annealing time, it seems that annealing at 500°C will reduce the Co, Fe, and B oxides, and it is speculated that the electrons come from Ta and Zr transferred to CoFeB layer. From MOKE results, it can be observed that CoFeB surface coercivity enhances as a function of annealing time and the thickness of capping layer. Moreover, Zr capping sample have stronger coercivity than Ta capping sample, because more boron diffuses into the Zr layer to make CoFeBe more crystallized into CoFe.

Consider thermodynamic factors, Zr borides have larger negative formation enthalpies (-104 kJ/mol) than Ta borides (-74 kJ/mol). It demonstrated that thick Zr layer is more suitable to act as a boron sink than Ta during the thermal annealing of MgO/CoFeB MTJ multilayers. Recently, we utilize depth profile XPS to observe the boron diffusion into the Ta and Zr capping layers by sputtering etching the thin film layer by layer. The result is consistent with different enthalpies of Zr and Ta boride formations.

Keywords – magnetic tunnel junctions; tunneling magnetoresistance.