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Residual Gas and Self-bias Voltage Effect in MgO Tunnel Barriers in Spin Valves

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Abstract – Influence of base and residual gas content of deposition system before and during the deposition of MgO spacer layer for the tunnel type bottom spin valve systems has been investigated. Low self bias voltages, base pressures lower than $1x10^{-8}$ mbar and low O_2 partial deposition gas pressures (<%10 Ar/O_2) result in more homogeneous growth and better coverage of MgO films (Fig. 1). Most stable structure has been obtained for deposition power of 120 W at DC self bias of 100 V and without O_2 reactive gas for barrier of 2nm MgO barrier thickness (Fig. 2).

Theoretical investigations predicted the system Ferromagnetic/MgO/Ferromagnetic exhibit very large tunneling magnetoresistance [1-3]. Recently a careful control of the growth conditions of MgO spacers for the case of Fe/MgO (001)/Fe resulted in very high tunneling magnetoresistance of more than $\Delta R/R_0 > 300$ % at cryogenic temperatures and $\Delta R/R_0 = 220$ % at 300 K [3]. Consequently, deposition methods for high quality MgO insulator layer have gained great interest. The MgO spacer layers were developed using reactive magnetron sputtering (MS) techniques, since the common technique by deposition of Mg and post-oxidation can lead to vacancies and scattering centers [1]. MgO barriers were also investigated using RF-MS technique besides of DC and Reactive DC-MS Deposition. An improving of the MgO texture and TMR effect has been reported in CoFeB/MgO/CoFeB magnetic tunnel junctions where the MgO spacer was deposited using RF-MS technique [4].

In this study, our aim was to investigate the influence of base and partial gas content of deposition system before and during the deposition of MgO spacer layer for the tunnel type bottom spin valve systems (SVSs). Additionally, the effect of self bias voltage by RF-MS technique has been investigated. Tunnel SVSs with structure of Si/SiO_2/underlayer/IrMn(10nm)/CoFe(2nm)/MgO(x-nm)/CoFe(2nm)/Ta(5nm) were fabricated by RF-MS for MgO barriers and by the DC-MS for the rest of the layers. A process monitoring system has been used to determine the process gas change during the sputtering deposition of SVS, especially for MgO layer. Systematically, temperature and thickness dependence of MgO spacer of the SVSs were investigated. Their structure determined by means of an X-Ray Diffraction, Rocking curve method and X Ray Reflection and its electrical properties by Four Point Probe technique and magnetic properties determined using vibration sample magnetometer. Correlations to reach the best MgO spacer layer thickness, structure and surface/interface roughness and Ar/O_2 deposition gas partial pressures and their dependence on deposition gas content have been discussed. We have observed that low self bias voltages, base pressures lower than $1x10^{-8}$ mbar and low O_2 partial gas pressures (<%10 Ar/O_2) result in more homogeneous growth and better coverage of MgO barrier of 2nm thickness. Most stable structure has been obtained for deposition power of 120 W at DC self bias of 100 V and without O_2 reactive gas. The results indicate a potential for improving of tunnel SVSs for the memory applications.

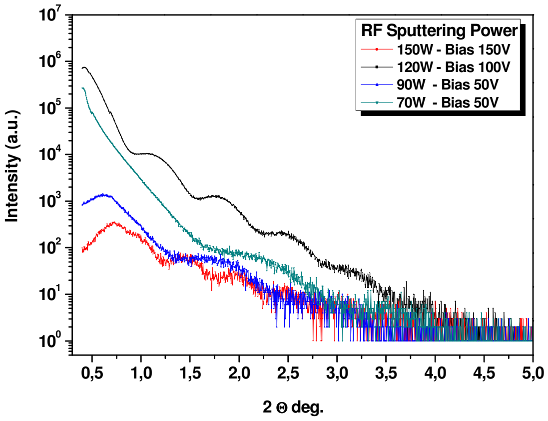

Figure 1: X-Ray reflectivity of MgO films deposited by different RF Bias Voltage. Best value is obtained for 120W and 100 V.

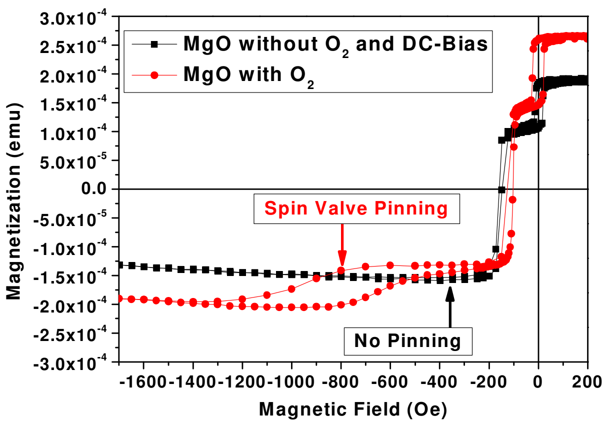

Figure 2: Hysterese curves of SVSs with and without Ar/O_2 partial deposition gases.

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