Magnetic tunnel junctions with alloys of Fe and 4*f* rare-earth metals

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MgO-based magnetic tunnel junctions (MTJs) have been investigated in a past decade since large tunnel magnetoresistance (TMR) and magnetization control by spin- and/or voltage toque showed high potential for the non-volatile memories. So far voltage-induced magnetization control, where energy consumption is quite small as compared to the spin-torque induced one, is investigated using 3*d* transition ferromagnetic materials. [1] We have recently reported the MTJs with $Fe_{90}Gd_{10}$ free layer where 4*f* rare-earth material is employed, and showed the large anisotropy field change under voltage application. [2] In this study, we have conducted detailed study of MgO-based MTJs whose magnetic free layers are alloys of Fe and 4*f* rare-earth metals.

V (30 nm)/Fe_{100-x}(Gd_x, or Tb_x or Nd_x) [x = 0-30]/MgO (1.6 nm)/Fe (10 nm) multilayer was fabricated by molecular beam epitaxy method on MgO [001] substrate. (Fig. 1) The Fe-4*f* metal alloy layer was prepared using co-evaporation of pure Fe and 4*f* metals. The film was patterned into MTJs by using electron-beam lithography and an Ar ion-milling. Figure 2 shows TMR curves in FeGd. TMR ratio decreases as Gd concentration increases. Voltage induced anisotropy energy changes were 23 fJ/Vm for Fe, 19 fJ/Vm for $Fe_{90}Gd_{10}$. There was no distinct voltage effect in $Fe_{80}Gd_{20}$. In the presentation, we will also show the results of MTJs with FeTb and FeNd.

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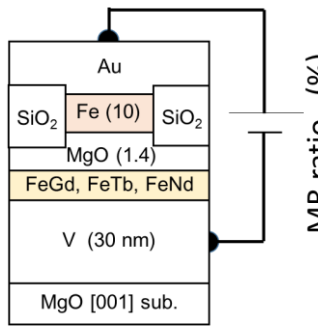

Fig. 1 sample structure

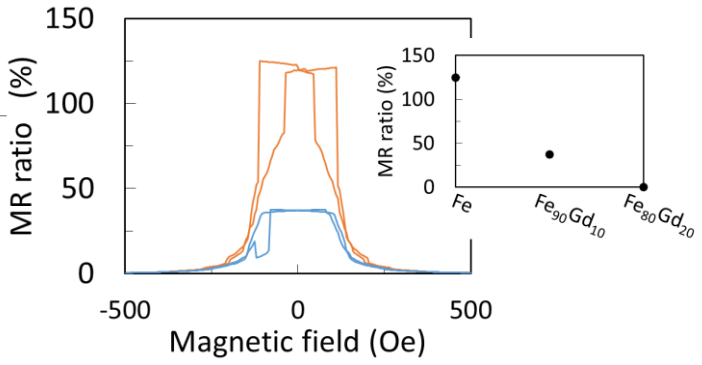

Fig. 2 magnetoresistance of FeGd/MgO/Fe junctions

[1] Y. Shiota *et al.*, Nature Materials.

[2] K. Tanaka et al., JSAP autumn meeting 2014, 19a-S2-3.

[3] P. Hansen *et al.*, *J. Appl. Phys.* **66**, 756 (1989)