Perpendicular magnetic tunnel junctions with the p-SAF structure having strong interlayer exchange coupling by the iridium spacer layer and their spin-transfer-torque switching properties

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A perpendicularly magnetized magnetic tunnel junction (p-MTJ) is promising for a memory cell of spin-transfer-torque switching magnetic random access memory (STT-MRAM). For steady read and write operation of the cell, perpendicularly magnetized synthetic antiferromagnetic (p-SAF) coupling in the reference layer is one of the key technologies. So far, p-SAF with a Ru spacer layer has been intensively developed because of the high AF exchange coupling field (H_{ex}). Although there have been other candidates such as Ir and Rh besides Ru, they have not been extensively investigated yet. In this study, we systematically investigated magnetic properties of the p-SAF films with an Ir and Rh spacer layer. We also evaluated STT-switching properties in the p-MTJs with an Ir spacer layer.

The p-SAF films whose structure is Si-O substrate / Ta(50) / Ru(60) / Pt(20) / $[Pt(1.6)/Co(2.4)]_{n=6}$/ Spacer(t) / $[Pt(1.6)/Co(2.4)]_{n=6}$ / Pt(20) / capping layer (thicknesses are in Å) were fabricated, where n is repetition number. Figure 1(a) shows the antiferromagnetic exchange coupling energy (J_{ex}) for Ir, Ru, and Rh spacer layers as the functions of t and the *M-H* curve for the Ir at t = 4.5 in the inset. The maximum H_{ex} and the maximum J_{ex} values achieved 12 kOe and 2.6 erg/cm^2, respectively, being over 20% higher than that for the Ru.[1)] Furthermore, the width of the first peak in fig.1 and annealing tolerance (not shown) for Ir spacer layer is greater than those for Ru, suggesting that Ir has very high potential for manufacturability of STT-MRAM because they give wider process window than that for Ru.

We also fabricated p-MTJ stacks with the Ir spacer layer and microfabricated them into nano-pillars (18 - 60 nm in diameter (ϕ)) to evaluate their STT-switching properties. The TMR ratio, RA-product, and H_{ex} were observed to be 133%, 5.2 Ωμm^2, and over 8 kOe, respectively. Figure 1 (b) and (c) show STT switching properties of the nano-pillar whose size is 25 nmϕ. Average switching current (I_{c0}) and thermal stability factor (Δ) were estimated to be 43 μA and 85 by fitting from theory.[2)] The switching efficiency which is calculated from the I_{c0} and the Δ achieved high value of about 2.[3)] These results indicate that the Ir has more suitable properties and no disadvantage compared with Ru for the spacer layer in p-SAF structure for STT-MRAM.

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References

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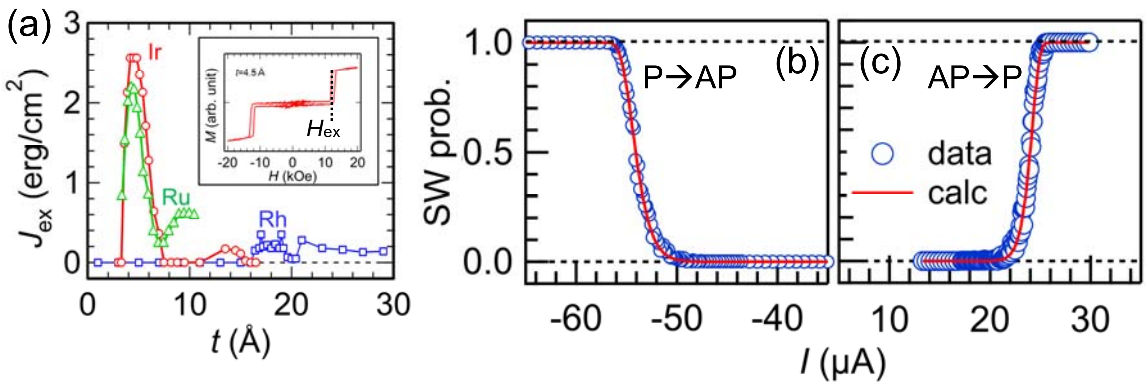

Fig.1 (a) Antiferromagnetic exchange coupling energy (J_{ex}) for functions of spacer layer thickness (t) and magnetization (*M-H*) curve for the p-SAF film with a 4.5 Å-thick Ir spacer layer (inset). The STT switching properties of the nano-pillar with an Ir spacer layer for (b) the parallel to antiparallel (P→AP) and (c) the antiparallel to parallel (AP→P) configuration.