HIGH MAGNETIC STABILITY IN p-SAF TYPE PERPENDICULAR MAGNETIC TUNNEL JUNCTIONS FOR SPIN-TRANSFER-TORQUE MAGNETIC RANDOM ACCESS MEMORY BY UTILIZING Ir SPACER LAYER

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I. INTRODUCTION

A perpendicularly magnetized magnetic tunnel junction (p-MTJ) is a promising candidate as a memory cell of spin-transfer-torque switching magnetic random access memory (STT-MRAM). To yield steady read and write operation of the STT-MRAM's memory cells, perpendicularly magnetized synthetic antiferromagnetic (p-SAF) structure in the reference layer should have sufficient stability of antiferromagnetic (AF) exchange coupling which depends on the spacer layer material. So far, mainly Ru has been employed as the spacer layer material because of its high potential for strong AF exchange coupling [1, 2]. In this study, we studied AF coupling in p-SAF structure with Ir and Rh spacer layer as another candidate and also evaluated STT-switching properties in the p-MTJs [3].

II. EXPERIMENTS

Stacking structure of the p-SAF-structured films 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), where n is repetition number. AF exchange coupling energy (J_{ex}) for each film was estimated from *M-H* curves. The p-MTJ films based on the p-SAF structure with Ir spacer layer were microfabricated into nano-pillars (18 - 60 nm in diameter(ϕ)) to evaluate the STT-switching properties.

III. RESULTS AND DISCUSSIONS

Figure 1 shows *M-H* curves for Ir, Ru, and Rh spacer layer whose thickness (t) is 4.5, 4.3 and 19 Å. The t value is selected to show best J_{ex} value for each material. The J_{ex} value was estimated from the formula of $J_{ex} = M_s \cdot t_{FM} \cdot H_{ex}$, where M_s and t_{FM} are saturation magnetization and thickness of the [Pt/Co] layer and H_{ex} is AF exchange coupling field which is found as a shift of hysteresis in the *M-H* curve as shown in Fig.1. The largest H_{ex} value for Ir in Fig.1 (12 kOe) indicates that Ir shows maximum J_{ex} value in this work. On the other hand, no large H_{ex} was found for Rh spacer layer.

Figure 2 shows the J_{ex} for various spacers as the function of t and the magnified image for the range of t = 3 - 7.5 Å in the inset. The maximum J_{ex} values were 2.6 erg/cm^2, which is over 20% higher than that for the Ru [2]. Moreover, the first peak for the Ir is broader than that for the Ru, suggesting that Ir has very high potential for manufacturability of STT-MRAM because it tolerates the thickness variation of the spacer layer.

Figure 3 and Fig.4 show a minor loop of an *R-H* curve and switching properties for the 25 nmϕ nano-pillar with 4.8 Å-thick Ir spacer layer. The H_{ex} exceeding 8 kOe and the high TMR of 133% at low RA-product of 5.2 Ωμm^2 are achieved. Moreover, switching efficiency was estimated to be about 2, which is rather higher than that for Ru spacer layer. These results indicate that the p-SAF with Ir spacer layer is superior to that with Ru spacer layer and more suitable for STT-MRAM.

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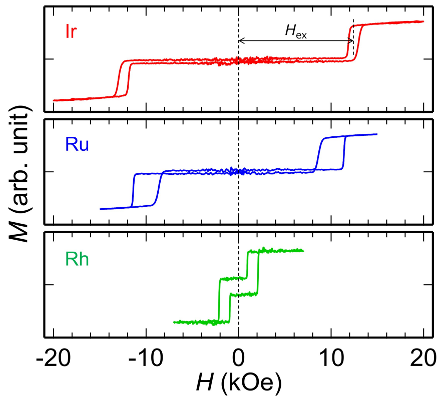

Fig.1 Magnetization curves for p-SAF structures with the Ir, Ru, and Rh spacer layers. Spacer layer thickness (t) of the each layer is t = 4.5, 4.3 and 19 Å, respectively.

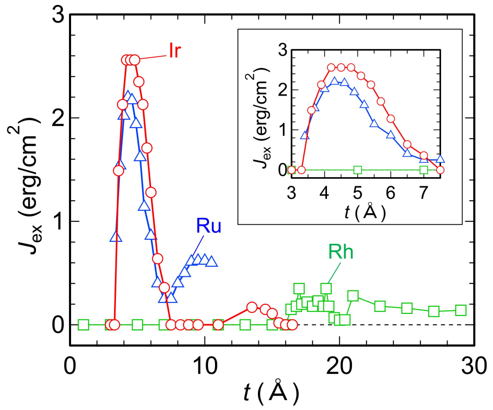

Fig.2 Antiferromagnetic exchange coupling energy (J_{ex}) for functions of t. The inset shows magnified image for the range of t = 3 – 7.5 Å.

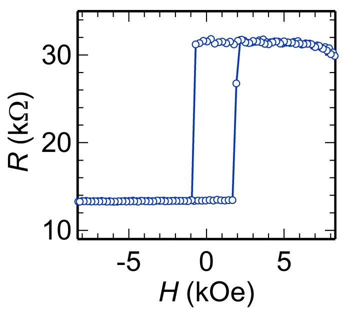

Fig.3 Minor loop of an *R-H* curve for the 25 nmϕ nano-pillar with the Ir-spacered p-SAF reference layer.

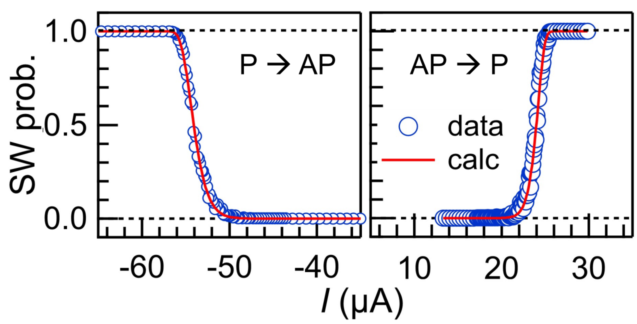

Fig.4 STT-switching properties for the nanopillar with Ir spacer layer whose size is 25 nmϕ.