Controlling magnetic proximity effect in CoFe$_2$O$_4$/Pt by applying voltage on Pt layer

Hokkaido Univ., CSE,\(^1\) Hokkaido Univ., Eng.\(^2\)

\(^1\)Shoto Noda\(^3\), Takumi Yamamoto\(^1\), Takashi Yanase\(^2\), Toshihiro Shimada\(^2\), Taro Nagahama\(^2\)

E-mail: punkan-369@eis.hokudai.ac.jp

Introduction

Recently, the interface of nonmagnetic heavy metal/ferromagnetic insulator (HM/FMI) such as Pt/CoFe$_2$O$_4$ has been investigated extensively. Especially, the magnetic proximity effect in HM/FMI has attracted a great deal of attention as the spin manipulation method of nonmagnetic materials. In the Platinum, ferromagnetism via magnetic proximity effect is easily induced because it has the DOS nearly Stoner criterion\(^1\). Therefore, it is considered that the induced magnetism in Pt could be controlled by modifying the $E_F$ in Pt by voltage. In this study, we report the control of the magnetic proximity effect in Pt by using ionic gate technique\(^2\).

Experiments

The film was grown on an MgO (001) substrate by reactive molecular beam epitaxy method. The film structure was MgO (001) /NiO (5 nm) /CoFe$_2$O$_4$ (50 nm) /Pt (0.5 - 3.5 nm). The CoFe$_2$O$_4$/Pt film was patterned into 100-µm-wide Hall bars by using standard photolithography system with Ar-ion milling. The Ionic Liquid, [EMI]$^+$[TFSI]$^-$ gel sheet (TA210 : EMI-TFSI = 1 : 1) was put on the Hall bars directly.

Results and Discussion

Figure 1(a) shows the resistance modulation of CoFe$_2$O$_4$/Pt (2.5 nm) by the gate voltage. It suggested that the carrier density of platinum was modified by the applied gate voltage. Figure 1(b) shows Hall measurements of CoFe$_2$O$_4$/Pt with various gate voltage at room temperature. The Hall resistivity exhibited hysteretic signal, implying that ferromagnetism was induced in Pt via magnetic proximity effect. Because the electric conductivity of Pt was approximately $10^8$ times as high as that of CoFe$_2$O$_4$, any magnetic signal in electrical measurement could be attributed to Pt layer. Moreover, the magnitude of Hall resistivity depended on gate voltage. It suggested that the induced magnetism in Pt was modified by the applied gate voltage.

Reference