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Spin Decay in a Bi-inserted Magnetic Tunnel Junction

Kyoung-il Lee[1]*, Kiyoung Lee[1], Kyung-Ho Shin[2], Mark Johnson[3], and Wooyoung Lee[1†]
[1]Department of Materials Science and Engineering, Yonsei University, Seoul 120-749, Korea
[2]Korea Institute Science and Technology, Seoul 136-791, Korea
[3]Naval Research Laboratory, Washington DC 20375, USA
(† Corresponding author: wooyoung@yonsei.ac.kr, Phone: +82-2-2123-2834, Fax: +82-2-312-5375)

The electrical spin injection and detection in the field of spintronics has continued to be of central importance over the past decade. A typical device structure for spin-injection experiment is a lateral spin-valve system consisting of laterally separated ferromagnetic electrodes and a spin-transport channel layer. It is essential to rule out plausible artefacts, e.g. anisotropic magnetoresistance (AMR), local Hall effect and other geometrical effects, in the lateral spin devices. By contrast, a magnetic tunnel junction (MTJ) is a kind of a vertical structure in which the geometrical artefacts may not be involved with tunneling effects. There have been several reports on the spin-dependent tunnelingand the spin decay length in non-magnetic interfacial layers in magnetic tunnel junctions (MTJs) [1, 2]. In this work, we present the spin-dependent tunnelingeffect in Bi inserted MTJs as a function of thickness of the Bi layer.

The generic structure of bismuth (Bi)inserted MTJs was [Ta(50)/$Ni_{81}Fe_{19}$(60)/$Ir_{50}Mn_{50}$(80)/$Co_{84}Fe_{16}$(40)/Al_2O_3(16)/Bi(t)/$Co_{84}Fe_{16}$(100)/Ta(50)] (in Å). The Al_2O_3 tunnel barrier was formed by using an in-situ DC plasma oxidation process after growing 16 Å-thick Al film. The thickness (t) of Bi layer inserted at insulator / ferromagnet interface was varied from 20 Å to 200 Å. The deposition of the whole stacks was followed by a combination of photolithography, ion milling, and lift-off process.

A 100 Å-thick Bi inserted MTJ was found to show 4.8 % tunneling magnetoresistance (TMR) at room temperature, indicating that effective spin tunnelinginto the Bi layer as well as spin transport via the inserted Bi layer give rise to the electrical spin detection in the MTJ. It was also found that TMR values exponentially decreases with the thickness of the inserted Bi layer. Interestingly, a MTJ with 200Å-thick Bi layer was found to still exhibit larger than 1 % TMR. The spin decay length (λ_{Bi}) in the Bi inserted MTJs was quantitatively estimated to be approximately 41 Å. It should be noted that the λ_{Bi}value is five times larger than that in a Cu inserted MTJ [1]. Our results contrast with a previous study [1] reporting that the estimated spin decay length in interfacial metallic layers is limited to only a few monolayers. The origin of the very long spin decay length in the Bi inserted MTJs is addressed. The temperature dependence of TMR and the annealing effects are also discussed. Our results demonstrate an extension of successful spin tunnel injection and detection to a novel material system, semi-metallic Bi.

References

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