$Fe/MgAl_2O_4/Fe(001)$ のスピン依存伝導特性に対する電圧効果の理論解析

Theory for bias voltage effects on spin-dependent transport properties in $Fe/MgAl_2O_4/Fe(001)$ junctions

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Magnetic tunneling junctions (MTJs) with MgO barriers have been intensively studied and considered as hopeful systems for spintronic device applications due to their high magnetoresistance (MR) ratios. On the other hand, a series of experimental studies [1-3] have shown that the spinel oxides XY_2O_4 can also work as barrier layers of MTJs. Actually, recent experiments by Belmoubarik *et al*. [2] observed sufficiently high MR ratios of 436% at 3 K and 245% at room temperature in $Fe/MgAl_2O_4/Fe(001)$ MTJs. They also found that the $MgAl_2O_4$-based MTJs have high values of $V_{half} > 1$ V, which is about twice that for the MgO-based ones. Such a high V_{half} is advantageous for device applications because it gives a high output voltage. To get more insight into the bias voltage effects on spin-dependent transport properties in the $MgAl_2O_4$-based MTJs, further experimental and theoretical studies are required.

In the present work, we theoretically investigate bias voltage effects on tunneling magnetoresistive properties in $Fe/MgAl_2O_4/Fe(001)$ MTJs by comparing them with those in typical Fe/MgO/Fe(001) MTJs. We calculated bias voltage dependences of MR ratios in both the MTJs by using the density-functional theory and the nonequilibrium Green' function method, the results of which are shown in Fig. 1. We see that in both the MTJs, the MR ratio decreases as the bias voltage V increases and eventually vanishes at a critical bias voltage V_c. We also see that the $MgAl_2O_4$-based MTJ has a larger V_c than the MgO-based MTJ. Since the in-plane lattice constant of $Fe/MgAl_2O_4/Fe(001)$ is twice as that of Fe/MgO/Fe(001), the Fe electrodes in the $MgAl_2O_4$-based MTJ have an identical band structure to that obtained by folding the Fe band structure of the MgO-based MTJs in the Brillouin zone of the in-plane wave vector [4]. From detailed analyses of band-resolved transmittances, we clarified that the difference in V_c between the $MgAl_2O_4$- and MgO-based MTJs is attributed to such a band-folding effect [5].

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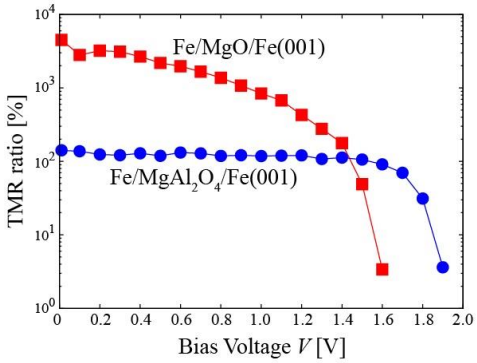

Fig. 1. Bias voltage dependences of MR ratios in $Fe/MgAl_2O_4/Fe(001)$ and Fe/MgO/Fe(001) MTJs.

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[5] K. Masuda and Y. Miura, arXiv: 1704.01401.