ピエゾエレクトロニック磁気抵抗素子における円環型圧電印加構造が誘起する応力の有限要素法解析 2

FEM analysis of induced stress in the piezoelectric ring structure of piezoelectronic MTJ 2

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Stress-assist magnetization reversal (SAMR) using magnetostrictive (MS) materials is an attractive method to reduce magnetization switching energy in spintronics-based memories [1]. We have been proposed the piezo-electronic magnetic tunnel junction (PE-MTJ) as an integrated memory element capable of realizing SAMR [2]. This device consists of an MTJ pillar with a MS free layer surrounded by a piezoelectronic (PE) ring. Previously, we introduced finite element method (FEM) to analyze induced stress in a PE-MTJ [3]. The FEM calculation gave different stress from the firstly proposed analytical method [4]. In this study, we analyze the stress distribution in the MS pillar calculated by FEM and found that the effect of deformation like beam bending significantly contributes to the stress distribution, which is not included in the analytical model. The thicknesses dependence of stress is clearly explained by the effect of deformation like beam bending and distribution of electric field vector.

Figure 1 shows schematics of a simplified model structure consisting of a MS plain pillar surrounded by a PE ring. The standard dimensions, materials, voltage V_{PE} applying to the PE ring for both calculations are described in Fig. 1. Figure 2 shows stress distribution when V_{PE} = 0.1 V. Overall, compressive stress is induced, which can be explained by the conventional model [4]. On the other hand, the stress in the MS region is non-uniform. The stress distribution in the MS, i.e., high compressive stress at the top and bottom of the MS pillar and low compressive stress at 2-3 nm from the MS/PE interface is mainly caused by tensile stress near the interface caused by the piezoelectric ring stretching (Deformation like beam bending).

Figure 3 shows induced compressive stress at the center of the pillar as a function of the thickness of PE. From w_0 = 7 nm to 30 nm, the stress decreases because of the increase of tensile stress by the beam-bending effect due to the increasing aspect ratio (w_0/R), and the decrease in electric field in the PE ring. Above w_0 = 30 nm, the stress for FEM calculation increases because the contribution of electric field from the top/bottom of PE-ring to the MS pillar becomes larger.

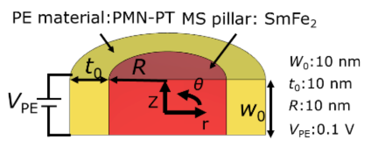

Fig. 1 Schematic structure of a simplified model.

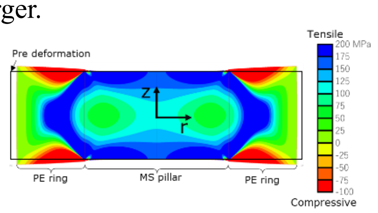

Fig. 2 Stress distribution in the cross section of the simplified model

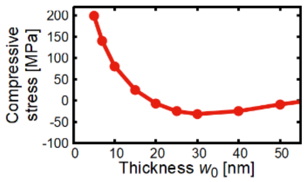

Fig. 3 w_0 dependence of stress in the $SmFe_2$ pillar.

Refs: [1] N. Saito, et al., J. Appl. Phys. **103**, 07A706 (2008). [2] Y. Takamura, et al., Sold-State Electron. **128**, 194 (2017). [3] K. Yamada, et al., JSAP Autumn Meeting, 16a-D61-4 (2024). [4] Y. Shiotsu, et al., IEEE Trans. on Electron Devices. **67**, 3852 (2020).