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Structural size effect with altered temperature on MgO-based magnetic tunnel junction device during current flow

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Abstract

Recently, the increase in high areal density of hard disk drive with the small bit cells affects the structural variation in the magnetic recording head. Therefore, the structural size effect on the altered temperature in the tunneling magetoresistance (TMR) head with the MgO-based magnetic tunnel junction structure was investigated. Results indicate that the temperature increment in the MgO layer and the antiferromagetic layer decreases significantly with decreasing the thickness of the MgO barrier. This is because the generated heat during the current flow is proportional to the TMR resistance which can be estimated by the resistance of the MgO barrier layer. The efficiency of the write/read process with the thermal effect in the magnetic recording head is the important parameter realized for development of the storage technology.

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Keywords: Structural size effect; Magnetic tunnel junction; Heat Transfer; Joule heating

1. Introduction

Magnetic tunnel junction (MTJ) devices with MgO barriers are widely used in storage technology[1,2]. This is because the high TMR ratio achieved by CoFeB/MgO/CoFeB MTJ structure is significant to increase efficiency of

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the write/read process. Development of the hard disk drive by increasing the areal density is required with the very small bit cells[3]. Consequently, the structure size of magnetic recording head is reduced. Therefore, the effect of the structural variation is interesting to study the reliability of the write/read process. Additionally, the high sensitivity requirement for write/read process is related to the thickness of the magnetic layers in TMR device[3]. The recent researches reported that the temperature increment in TMR device caused by the current flow from the electrostatic discharge and the switching process affects to the magnetic degradation in the ferromagnetic (FM) and antiferromagnetic (AFM) layers and the highest temperature appears in the MgO barrier layer[4,5]. The initial magnetic damage is occurred to the AFM layer[4]. Thus, in this study, the thickness of the magnetic layers and the MgO barrier layer was varied for investigating the temperature increase in the TMR junctions.

2. Materials and Methods

The temperature increment in MgO-based MTJ device during current flow was performed by a commercial program package (multiphysics finite-element method COMSOL). The three dimensional (3D) finite element method (FEM) was used for the thermal calculation with the heat transfer analysis undergoing Joule heating and heat conduction. The structural system for this simulation includes the Al_2O_3 insulator layers, the NiFe shields and the TMR multilayer structure, as shown in Fig. 1. Details of the structure and material properties are similar to the previous report[4].

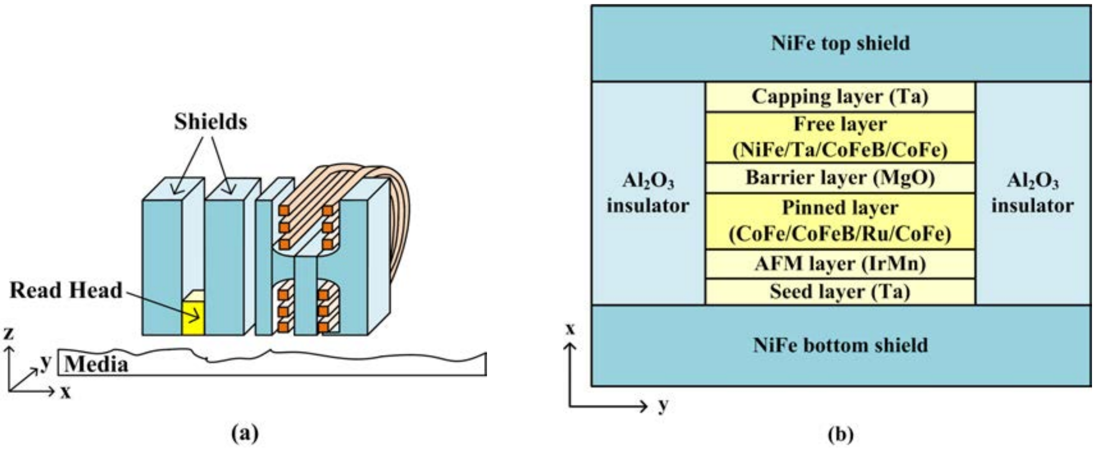

Fig. 1. Schematic diagram of (a) the read head to fly close to the media surface and (b) detials of TMR head including MgO-based MTJ device.

In the simulation, it was assumed that the current of 4.5 mA flows from the bottom shield to the top shield with duration of 14 ns and the initial temperature is the room temperature[4]. This is because this condition is cause of the initial magnetic degradation in the IrMn AFM layer[4]. Moreover, the thickness of each FM layer, AFM layer and MgO berrier layer was decreased in order to study the altered temperature in the MgO layer and the IrMn AFM layer.

3. Results and Discussions

Results of the temperature increment in MgO barrier layer, ΔT_{MgO}, and IrMn AFM layer, ΔT_{IrMn}, with the different thickness values for the FM layers, the AFM layer and the berrier layer are presented in Fig. 2. The ΔT_{MgO} and ΔT_{IrMn} vary directly with the MgO layer thickness. Meanwhile, the altered temperature results are not significant to the thickness of the magnetic layers in TMR head.