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Fabrication of ferromagnetic nano-bridge embedded in nano-oxide-layer

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Recently, the Nano-Oxide-Layer (NOL) which has metallic conductive channels with nano-meter size in the ultra thin oxidized insulator is attracting greatly for the new applications in ultra-high-density recording. For example, the MR ratio is enhanced by the Al-Cu NOL inserted to the spacer in CPP-GMR (Current-Perpendicular-to-Plane Giant Magneto-resistance) spin-valve film [1]. The enhancement is due to the confinement of the current inside a spin-dependent scattering unit. We have already reported the formation mechanism of the Cu-AlO_x NOL [2] and the self aligned periodic Ni nano-dots embedded in nano-oxide-layer [3] by using conductive AFM. Further, the nano-contact MR with NOL was shown from our group [4]. It is important to fabricate well defined ~ 1 nm size nano-constriction. We are thinking that this is the new approach to the data storage field. However, it is difficult to control the size and alignment of metallic channels because the formation mechanism of the channels is not well known. The pumping-up mechanism is one of the candidate for the fabrication of the ferromagnetic nano-bridge embedded in nano-oxide-layer. It is expected that the atoms of bottom layer will seep out at the triple point of the grain boundary after some heat treatment, when the surface energy of bottom layer is lower than top layer. We call this mechanism "Atom Pumping-Up". After the atom pumping-up only nonmagnetic metal should preferentially oxidized to form insulator. Ta was selected because of its low formation energy of oxygen and high surface energy compare to Fe. The mechanism "Atom Pumping-Up" was successfully confirmed by the Auger Electron Spectroscopy (AES), the in-situ Scanning- Tunneling-Microscopy (STM) and TEM observation after heat-treatment of 400°C×30 min for Ta on epitaxial Fe bilayer[5]. The size of Fe bridges was estimated to be 2 nm-5 nm. If the top layer could be preferentially oxidized, the nano-constriction embedded in the insulator could be formed. The motivation of this study is how to make well defined nano-constriction in the stacked film.

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$L1_0$-FePt as a Material for Spin-electronics

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L_{10}-FePt has attracted much attention in recent years for the application to magnetic recording media because of the high uniaxial magnetic anisotropy ($K_u = 7 \times 10^7$ erg/cm^3) leading to excellent thermal stability of magnetization. L10-FePt is also one of the potential materials for future spin-electronics devices with nanometer-sized magnets for large-scale integration, since in addition to the high Ku the high spin polarization of conduction electrons is predicted from a theoretical calculation[1]. However, only a few studies on the spin-dependent transport properties of $L1_0$-FePt have been reported to date. In this paper, the spin-dependent transport properties of L10-FePt including tunnel magnetoresistance (TMR), current-perpendicular-to-plane giant magnetoresistance (CPP-GMR), and current-induced magnetization reversal are investigated, and the potential of L10-FePt as a material for spin-electronics devices is discussed.

FePt thin films were prepared on a MgO (001) or MgO (110) single crystal substrate. All metallic layers were deposited by ultrahigh vacuum magnetron sputtering. For a magnetic tunnel junction (MTJ), Al-O or MgO was used as a barrier. Al-O barriers were formed by a multiple oxidation process[2] in the sputtering chamber; on the other hand, MgO barriers were deposited by electron beam evaporation. MTJs and CPP-GMR pillars were fabricated using electron beam lithography and Ar ion etching.

In-plane magnetized FePt/Al-O/FeCo MTJs prepared on a MgO(110) substrate showed TMR of 18 % and 40 % at room temperature and 4.2 K, respectively[2]. For the MTJs with FePt/MgO/FePt layered structure prepared on a MgO (001) substrate, the epitaxial growth was achieved and the preferential crystallographic orientation normal to the film plane was the [001] direction. Both FePt layers showed perpendicular magnetization, and a definite coercivity difference between the FePt layers was successfully observed, although no TMR was observed possibly because of the effect of pinholes.

CPP-GMR pillars with FePt/Au/FePt layered structure were used for the study of current-induced magnetization reversal. The pillar size was 0.1 × 0.2 or 0.1 × 0.25 mm^2. CPP-GMR pillars prepared on a MgO (110) substrate showed in-plane magnetization, and the magnetic field dependence of the current density for magnetization reversal was interpreted by a conventional theory for spin-transfer torque[3]. For CPP-GMR pillars on a MgO (001) substrate with perpendicularly magnetized FePt layers, current-induced magnetization reversal was also successfully observed. However, the magnetic field dependence of the current density is larger than that expected from the conventional theory, suggesting that the magnetization reversal occurs through an incoherent rotation mode at a high magnetic field[4]. Furthermore, it was also found that a combination of in-plane and perpendicularly magnetized FePt layers, where the spin-transfer torque acted on the in-plane magnetized free layer from the perpendicular spin-polarizer in 90° configuration, reduced the current density for magnetization reversal.[5]

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