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SUBSTRATE BIASED PLASMA ETCHING TECHNIQUE FOR FABRICATION OF SPINTRONIC DEVICES

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For the development of various spintronic device, it is very important to optimize the property of interface between ferromagnet and non-magnet layers. There are several reports that magnetic tunnel junction(MTJ) device, one of representative spintronic device, with sub-micron scaled junction area can be fabricated by using various dry-etching techniques, *i.e.* ion beam milling or reactive ion etching[1]. However, as far as we know, this etching process necessary to define the junction area makes the fabrication process more difficult and may be an additional limiting factor for the reproducibility of MTJ device. Although MTJ structures have been fabricated in many research groups there is no result that nanometer scaled junction with vacuum breaking and without dry etching process because whole stacks of MTJ have to be grown in-situ and followed by dry etching process In this study, MTJs have been fabricated by using conventional lift-off technique and lithography process with substrate-biased plasma etching process. Other spintronic devices *i.e.* spin-injection device or device using nanowires, as well as MTJ device have been fabricated by using this *ex-situ* plasma treatment technique.

The exchange-biased type MTJs were prepared on a thermally oxidized Si(100) substrate. SiO_2/Ta(50Å)/$Ni_{81}Fe_{19}$(60Å)/$Ir_{50}Mn_{50}$(80Å)/FM_{BOTTOM}(40Å)/Al_2O_3(12-16Å)/FM_{TOP}(100Å)/ Ta(20Å). After deposition of bottom ferromagnetic(FM) electrode($Ni_{81}Fe_{19}$ or $Co_{84}Fe_{16}$) by dc magnetron sputtering, surface of FM layer was naturally oxidized in the air. This oxidized FM layer acts as a magnetically dead layer which is very harmful for the spin-dependent transport as well as lowers the effective polarization value of bottom electrode. The insulating capping layer(TaO_x) was deposited by sputtering and nano-scaled hole for the junction formation were defined by e-beam lithography and lift-off process. The naturally oxidized FM layer could be removed by using Ar plasma etching process. This plasma etching effect could be realized by applying the RF bias filed to the substrate. The rest parts of MTJ structure, i.e. Al_2O_3 tunnel barrier and FM top electrode, were grown by sputtering and O_2 plasma oxidation technique after the plasma etching process without vacuum breaking. The size of junction area was varied from few microns to few hundreds of nanometer. Figure 1 demonstrates schematically the fabrication procedure. In addition, several spintronic devices were fabricated by using this plasma etching technique.

In this work, we have been investigated the effect of substrate-biased plasma etching process and the magnetotransport properties in fabricaed MTJs compared to that of the device prepared by conventional way. The magnitude of bias voltage applied to the substrate during plasma etching process has been varied and the breakdown voltage in the MTJ related with morphology of plasma etched FM surface has been studied. The low temperature property and annealing effect have been characterized to confirm the spin-dependent transport properties of fabricted MTJs. Several device properties, *i.e.*TMR ratio and junction resistance, magnetization switching behavior, in the MTJs fabricated by this procedure are very analogous to those in MTJs grwon by conventional way. These result implies that the formed FM oxide layer due to vacuum breaking can be effectively removed by substrate biased Ar plasma and expected spin-dependent tunneling effect is preserved. Transport properties of spin injection device and nanowire devices fabricated by using this plasa etching technique were investigated.

The future integration for high-density MRAM requires the reduction of junction size with more simplified fabrication process in conjuction with appropriate substrate etching treatment is very promissing. This *in-situ* substrate-biased plasma etching technique is very useful and easily acceptable for any other spintronic devices in which oxidized FM layers restrict the spin-dependent properties.

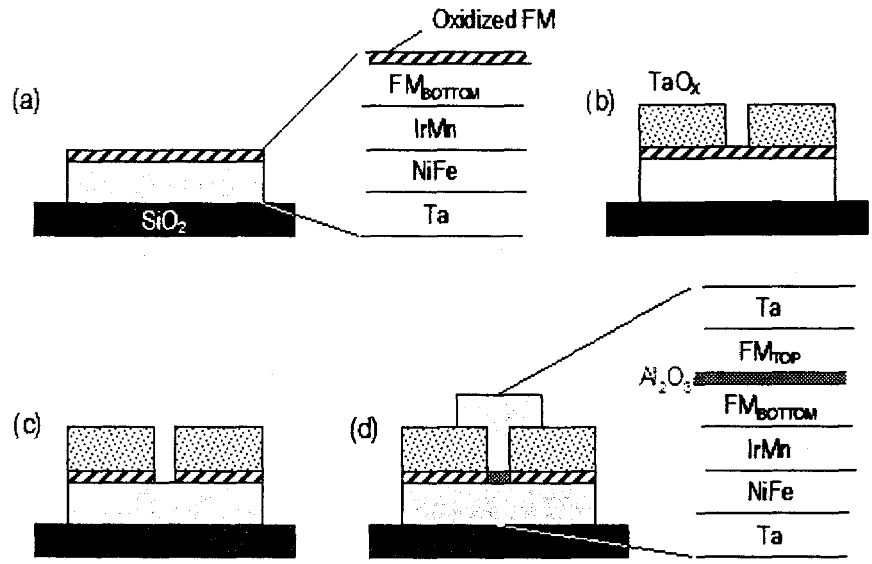

Fig. 1. Schematics for MTJ device fabrication procedure. (a) after bottom FM layer deposition(vacuum breaking) (b) after capping layer deposition and formation of the hole for junction structure (c) removal of oxidized FM layer by plasma etching process. (d) completed MTJ structure.

[1] E. Chen, B. Schwarz, C. J. Choi, W. Kula, J. Wolfman, K. Ounadjela, S. Geha, J. Appl. Phys. 93, 8379 (2003)