Fabrication of Single Crystalline Magnetoresistive Sensors on Polycrystalline Electrode using Three-Dimensional Integration Technology

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Introduction

Recently, substantially large MR ratios (>60%) and low *RA* of 0.05 $\Omega\mu m^2$, which satisfy the requirements for >2 Tbit/in^2,[1] have been realized in CPP-GMR devices with Co-based Heusler alloys exhibiting half-metallic behavior such as Co_2MnSi and $Co_2Fe(Ga_{0.5}Ge_{0.5})$ (CFGG)[2,3]. However, some critical issues such as the requirement of high processing temperature hinder practical applications of the CPP-GMR devices. To overcome these critical issues, we develop new concept of processes: (i) epitaxial growth and high-temperature annealing of CPP-GMR multilayer on Si(001) substrate using NiAl buffer layer[4] (Fig. 1(a)), (ii) direct wafer bonding[5] (Fig. 1(b)), and (iii) removal of backside Si (Fig. 1(c)). These processes enable integration of the high-performance epitaxial CPP-GMR devices for sensor applications.

Experiment detail

Fully epitaxial multilayer stack films of NiAl(50)/CoFe(0 or 10)/Ag(50)/CFGG(10)/Ag(5)/CFGG(10)/Ag(5)/Au(5) (unit in nm) were deposited onto a ϕ2 inch single-crystal Si(001) wafer using the ultrahigh vacuum magnetron sputtering system. Crystalline structure, surface morphology, magneto-resistance properties and microstructures were analyzed by XRD, *in situ* RHEED, AFM, direct current four-probe method and cross-sectional TEM, respectively. Direct wafer bonding of the epitaxial CPP-GMR film wafer to the ϕ8 inch counter Si wafer was carried out using the room-temperature bonding apparatus (MWB-12ST Mitsubishi Heavy Industries).

Experiment result

Fig. 1(a)-(e) illustrate the details of the wafer bonding process. The epitaxial CPP-GMR multilayer film was bonded to a poly-crystalline permalloy electrode to simulate the real read head structure for HDD. After removing the Si wafer and NiAl and CoFe layers, the film was patterned into deep sub-micron sized CPP-GMR devices. Microstructure of the bonding interface was analyzed by high-resolution HAADF-STEM and EDS mapping (Fig. 1(f)-(h)). Smooth Ta/Au bonding interface without any defects is observed. In the magnified HAADF image of bonding interface region, a clear bonding is obtained while keeping the single-crystal structure of Au layer on top of the amorphous Ta layer. Note that this is the first demonstration of direct bonding epitaxial MR multilayer film on top of an amorphous layer without introducing any damages. The EDS mapping images show that the Au/Ta interface is sharp without any oxidation, which means the epitaxial CPP-GMR film is successfully bonded on top of the permalloy bottom electrode.

References

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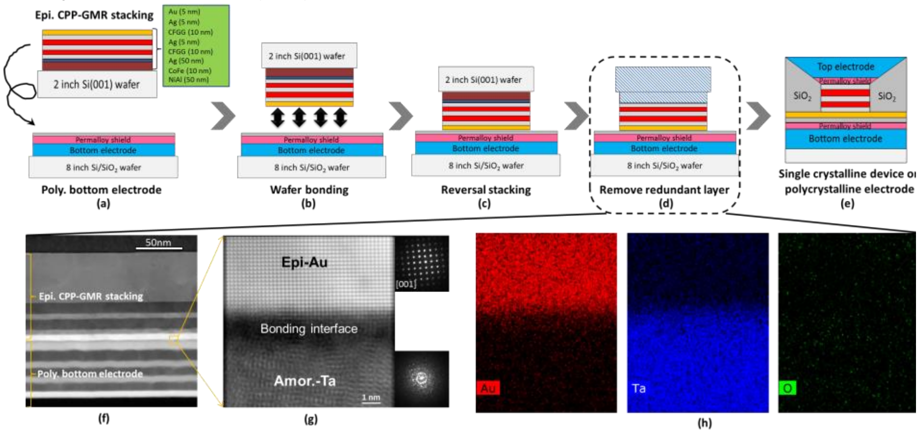

Fig.1 (a)-(e) Process in this study. Epitaxial CPP-GMR film on 2inch Si(001) substrate was bonded on poly-crystalline permalloy film deposited on 8 inch Si/SiO_2 wafer. (f)-(h) Microstructure analysis of the stacking film after bonding and bonding interface by HR-HAADF STEM.