Rapid thermal processing of Al-Cu alloy thin films for control of Cu precipitation utilized for confined current paths in CPP-GMR devices


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Introduction

In current-perpendicular-to-the-plane giant magnetoresistive (CPP-GMR) devices, confinement of the current-carrying paths has proven very effective in enhancing the GMR effect.

Fukuzawa et al.⁹⁄¹¹² have used selective oxidation of Al in a deposited Al-Cu layer to form confined-current paths (CCP) in CPP-GMR devices.

Srivastava et al. used atom probe tomography to analyze as-deposited and furnace-annealed precipitates, which were found to be θ-phase Al₂Cu alloys.¹³

We are studying the size and distribution of the Cu precipitates as a function of processing conditions to see how they may affect the formation of the confined-current paths.

Rapid thermal annealing of sputtered Al-Cu films in argon and oxygen has been performed over a range of temperatures and film thicknesses.

We have performed SEM, EDX, and XRD analysis of the deposited and annealed films.

Experimental Details

Experiment 1

- Al-Cu(100 nm) sputter-deposited on SiO₂/Si substrates.
- RTA for 2 min at 400°C, 450°C, and 500°C in Ar.

Experiment 2

- Al-Cu(x)/Ta(5), where x = 10, 25, 50, 100 nm, sputter-deposited on Si substrates.
- RTA for 2 min at 450°C in O₂.

Deposition conditions (Shamrock)

- Base pressure: <5 × 10⁻⁷ torr.
- Power: Ta ~500 W DC; Al-Cu ~450 W DC
- Rotation speed= 22 rpm; Pressure: 3 mTorr Ar.
- Targets: Al-10 at% Cu; Ta

Annealing conditions (Jipelec RTA)

- Ramp up time RT-Annealing temp. in 30 seconds
- Hold at annealing temp. 2 minutes
- Cool down in 20 seconds.
- Gas flow (Ar, O₂) 1000 sccm

NW nano-oxide spacer (NOL) with current-confined path

With increasing annealing temperature, delamination of Al-Cu film from substrate occurs even with Ta underlayer.

Si precipitation dominates in the absence of a good barrier between Al-Cu and Si.

Increasing aluminum oxide peak intensity with thickness indicates full oxidation throughout layer.

The oxidation is selective to Al, but it is difficult to observe distinct Cu precipitates, except around delaminated regions.

Future experiments will focus on better barriers to Si diffusion, and in-situ annealing in sputter chamber.

Advanced characterization will include TEM and atom probe studies (R. Morris and G. Thompson).

Theoretical calculations of resistivity dependence on size and distribution of Cu precipitates is also ongoing (T. Xu and W. Butler).

Conclusions

References


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