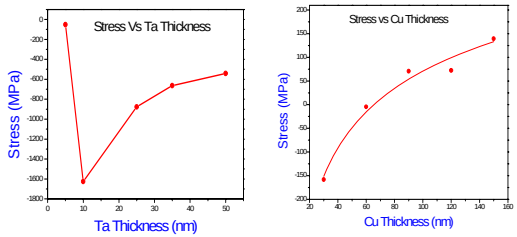
Characterization of surface roughness, stress and resistivity of Cu-Ta and Cu-Ru nanolaminates as a function of lamination frequency and thickness

Z. Tadisina, R. Thunuguntla, S. Gupta, C. Papusoi, H. Fujiwara, R. Morris, G.Thompson

Center for Materials for Information Technology, University of Alabama

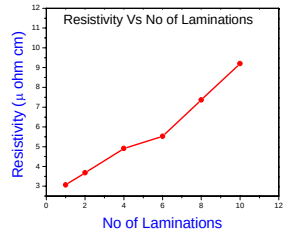
Introduction

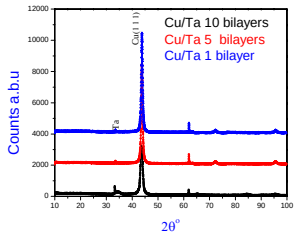
- Current-perpendicular-to-the-plane (CPP) giant magnetoresistive (GMR) read heads are being studied intensively for the next generation of disk drives.
- In CPP-GMR structures, the top and bottom current-carrying leads need to be approximately 100 nm thick layers of Cu in order to minimize the potential drop across the leads.
- The thick Cu layer generally grows with a (1 1 1) textured fcc structure. Thicker films have larger grain size, leading to greater interface roughness.
- The interface roughness and large grains of the thick Cu bottom lead seed large grains in the ferromagnetic layers in the GMR stack, thereby degrading both the GMR ratio as well as the soft magnetic properties.
- We have studied the change in roughness and the grain size with increasing frequency of laminations of the Cu/Ta films, keeping the total thickness of each material constant
- We also studied the effect of lamination frequency on the stress.

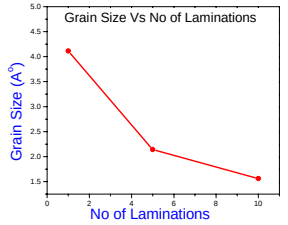


Experimental Details

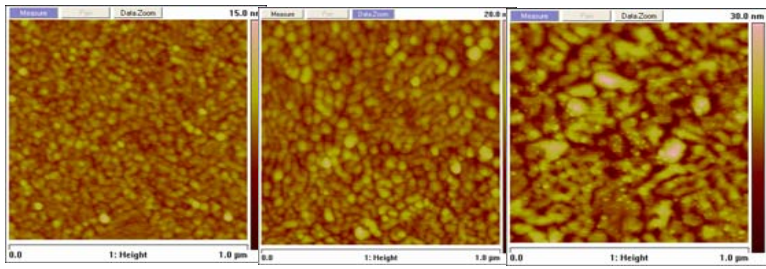
- $[Cu/Ta]_N$, N=1, 2, 4, 6, 8, 10, keeping the total thickness of Cu=150 nm and Ta=5nm. Conventional dc magnetron sputtering
- Sputtering Systems : Shamrock and Key
- Targets: Cu ,Ta, Ru
- ***Deposition conditions (Shamrock)***
  - Base pressure: $<5 \times 10^{-7}$ torr.
  - Power: Ta ~100 W DC; Cu ~450 W DC.
  - Pressure: 3 mTorr Ar.





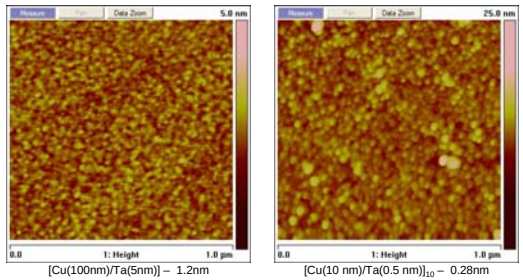


Cu Thickness Vs. RMS Roughness



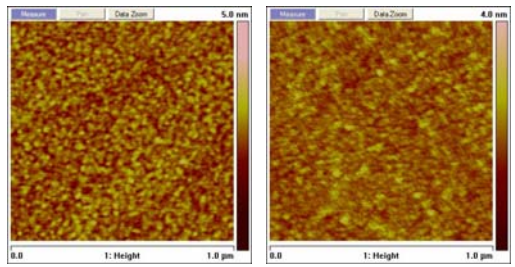
Cu (100nm) – 0.8 nm Cu (200nm) – 1.4 nm Cu (300nm) – 3.6 nm

Roughness Vs. Cu/Ta Laminations



$[Cu(100nm)/Ta(5nm)]$ – 1.2nm $[Cu(10\ nm)/Ta(0.5\ nm)]_{10}$ – 0.28nm

Comparison of Roughness of Cu/Ta and Cu/Ru Laminations



$(Cu/Ta)_{10}$ High Power Dep 0.28 nm $(Cu/Ru)_{10}$ High Power Dep 0.25 nm

Conclusions

- As the lamination frequency increases, roughness and grain size decrease.
- XRD spectra show that the grain size decreases from 0.4 nm to 0.1 nm as the laminations increase from 1 to 10.
- With a poorer base vacuum, the resistivity increases with lamination frequency => oxidation of each layer between depositions contributes to this (will be minimized at base vacuum $< 5 \times 10^{-8}$ torr).
- The roughness is almost same for both Cu/Ta and Cu/Ru laminations.
- The stress remains fairly independent of the number of laminations, as expected, since the thicknesses of each material are kept constant. The stress for Ta is compressive and for Cu tensile, leading to a low resultant stress.

Future Work

- Study microstructure and interface properties using transmission electron microscopy.
- Study effect on of roughness on magnetic properties and GMR ratio.

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The University of Alabama

For more information:
S. Gupta, MINT Center, University of Alabama
E-mail: sgupta@mint.ua.edu

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