World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:12, No:12, 2018

Comparison of Cu Nanoparticle Formation and Properties with and without Surrounding Dielectric

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Abstract : When grown only to nanometric sizes, metallic particles (e.g. Ag, Au and Cu) exhibit specific optical properties caused by the presence of plasmon band. The plasmon band represents collective oscillation of the conduction electrons, and causes a narrow band absorption of light in the visible range. When the nanoparticles are embedded in a dielectric, they also cause modifications of dielectrics optical properties. This can be fine-tuned by tuning the particle size. We investigated Cu nanoparticle growth with and without surrounding dielectric (SiO2 capping layer). The morphology and crystallinity were investigated by GISAXS and GIWAXS, respectively. Samples were produced by high vacuum thermal evaporation of Cu onto monocrystalline silicon substrate held at room temperature, 100°C or 180°C. One series was in situ capped by 10nm SiO2 layer. Additionally, samples were annealed at different temperatures up to 550°C, also in high vacuum. The room temperature deposited samples annealed at lower temperatures exhibit continuous film structure: strong oscillations in the GISAXS intensity are present especially in the capped samples. At higher temperatures enhanced surface dewetting and Cu nanoparticles (nanoislands) formation partially destroy the flatness of the interface. Therefore the particle type of scattering is enhanced, while the film fringes are depleted. However, capping layer hinders particle formation, and continuous film structure is preserved up to higher annealing temperatures (visible as strong and persistent fringes in GISAXS), compared to the non- capped samples. According to GISAXS, lateral particle sizes are reduced at higher temperatures, while particle height is increasing. This is ascribed to close packing of the formed particles at lower temperatures, and GISAXS deduced sizes are partially the result of the particle agglomerate dimensions. Lateral maxima in GISAXS are an indication of good positional correlation, and the particle to particle distance is increased as the particles grow with temperature elevation. This coordination is much stronger in the capped and lower temperature deposited samples. The dewetting is much more vigorous in the non-capped sample, and since nanoparticles are formed in a range of sizes, correlation is receding both with deposition and annealing temperature. Surface topology was checked by atomic force microscopy (AFM). Capped sample's surfaces were smoother and lateral size of the surface features were larger compared to the non-capped samples. Altogether, AFM results suggest somewhat larger particles and wider size distribution, and this can be attributed to the difference in probe size. Finally, the plasmonic effect was monitored by UV-Vis reflectance spectroscopy, and relative weak plasmonic effect could be explained by uncomplete dewetting or partial interconnection of the formed particles.

Keywords : coper, GISAXS, nanoparticles, plasmonics
Conference Title : ICAMN 2018 : International Conference on Advanced Materials and Nanotechnology
Conference Location : Bangkok, Thailand
Conference Dates : December 13-14, 2018