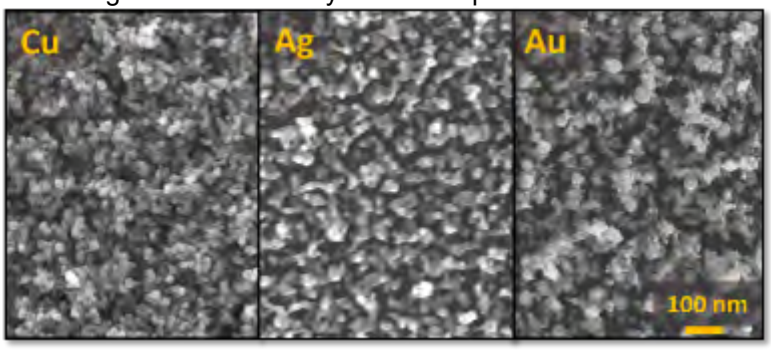
MS39-1-2 Thermal evolution of bilayers composed of f.c.c. nanoparticles studied by X-ray scattering methods #MS39-1-2

T. Košutová [1], L. Horák [1], Z. Krtouš [1], A. Kuzminova [1], N. Khomiakova [1], D. Nikitin [1], J. Hanuš [1], O. Kylián [1], M. Dopita [1]
[1]Charles University, Faculty of Mathematics and Physics - Prague (Czech Republic)

Abstract
In our study, we investigated thin layers consisting of face-centred cubic metallic nanoparticles. First, copper, silver and gold nanoparticle layers were studied individually. Subsequently, bilayers of these nanoparticles were deposited and analyzed. The deposition of studied nanoparticles was performed by the Haberland type gas aggregation cluster sources, which are using magnetron sputtering of single metallic targets. This physical bottom-up preparation method is environmentally friendly, scalable to industrial demands and provides high cleanness of the process.
Copper, silver and gold nanoparticles belong to plasmonic nanoparticles, in which it is possible to couple electromagnetic field with the collective oscillations of conduction electrons - plasmons. These nanoparticles have a great application potential because, for all of them, the localized surface plasmon resonance is in the region of visible light.
Our study is focused on the thermal stability of described nanoparticle layers in the air atmosphere and temperature changes in their optical properties. The thermal evolution of morphology, chemical and phase composition, size distribution and microstructure of Cu, Ag and Au nanoparticles was determined by combining in situ X-ray diffraction (XRD) and ex-situ small angle X-ray scattering and electron microscopies (SEM, TEM). The optical properties of layers were analyzed by UV-Vis spectroscopy and ellipsometry.
Copper nanoparticles are not stable in the air atmosphere, the oxidation process starts immediately after removal from the deposition chamber and core-shell Cu@Cu_2O nanoparticles are formed. Cu nanoparticles further oxidize during the heating procedure, but the size of nanoparticles is almost constant up to 200 °C. The additional layer of Au nanoparticles at the top of copper nanoparticles slows down the oxidation process. In contrast to copper nanoparticles, no oxidation was observed during the annealing of silver and gold nanoparticles up to 800 °C. SAXS and SEM measurements showed that the morphology of silver nanoparticles is less stable than for the gold ones, Ag nanoparticles start to coalesce around 100 °C. During annealing, the size of the crystallites increases but much slower in comparison to the overall size of nanoparticles. The amount of microstructural defects (microstrain, stacking faults) is reduced by annealing for all types of layers. It has been observed that the final layer architecture depends on the sequential order of the bilayers.

SEM images of individual layers of nanoparticles



XRD patterns measured during in situ annealing