ABSTRACT

Recently, substrate-supported noble metal nanostructures have attracted significant attention due to their plasmonic properties and applications in biosensing, photovoltaics, and optoelectronic devices. The plasmonic effects primarily depend on nanostructures' material, size, shape, and spatial arrangement; therefore, controlling these aspects is essential. Fabrication of nanostructures by solid-state dewetting of thin metal films facilitates the cost-efficient solution over lithography-based methods. However, its large-scale implementation is limited by the inherent randomness in the resulting nanostructures. In order to gain control over the dimensional and form aspects of Au and Ag nanoparticles, this research study investigates the effect of film thickness and dewetting temperature. Moreover, mixing Au and Ag films resulted in the fabrication of monodispersed spherical alloyed (AuAg bimetallic) nanoparticles, facilitating linear tuning of their optical response in the visible range by varying thickness ratios.

When thermally annealed, the vicinal surfaces of sapphire undergo reconstructions to reveal periodic nanoscale step-terrace structures on their surfaces. In order to control the dimensions of such step-terrace structures, the effect of temperature on their morphology evolution is studied by multi-stage thermal annealing. It is shown that low-temperature annealing followed by high-temperature annealing in multiple stages resulted in the step-terrace structures with larger step heights.

The sapphire substrates with such nanoscale structures were then used to study their effect on the solid-state dewetting of Au and Ag thin films to fabricate ordered nanoparticles. It is observed that step-terrace structures with a step height comparable to the film thickness can induce spatial order in the resulting nanoparticles. The synergy between the two methods is achieved by combining two scalable and cost-effective processes, thermal annealing of sapphire substrates for fabricating periodic nanostructures and solid-state dewetting of thin metal films.

Keywords: Nanostructures, Plasmonic, Solid-state dewetting, Vicinal Sapphire, Thermal annealing, Step-terrace structures, Ordered nanoparticles