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Bilayer Self-Organization and Synthesis of Ferromagnetic-Plasmonic Nanocomposites

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Ferromagnetic-plasmonic nanomaterials exhibit characteristics of ferromagnetism, localized surface plasmon resonance (LSPR), and have potential to show resonant magneto-optical responses. Due to this capability to simultaneously control the polarization state and current of photons and electrons, these multi-functional materials could impact many applications, including high density magneto-optical recording, energy harvesting, biological sensing, and information processing [1-3].
Here we present the synthesis and characterization of nanocomposites of Ag and Co by pulsed laser-induced self-organization of bilayer thin films. Bilayer films of thermodynamically immiscible Ag and Co in various combinations of thickness were deposited on SiO_2 substrate [4]. Nanosecond pulsed laser melting results in spontaneous formation of a variety of complex morphologies, eventually leading to nanoparticles. Bilayers of immiscible metallic liquids show different self-organized patterning characteristics of nanoparticle arrays based on their order of arrangement on a substrate. These nanoparticles are nanocomposites having immiscible phases of pure Ag and Co, as we determined by microscopy analysis. This characterization includes EDX mapping in scanning electron microscope (SEM) using JEOL JSM - 7001 FLV field emission working at 20 KV, and Z-contrast imaging and electron energy loss spectroscopic (EELS) analysis in Scanning Transmission Electron Microscope (STEM) using VG501 operating at 100KV.
The composition dependent plasmonic and ferromagnetic behaviors were also investigated in the present study. Substantial shifts of ~100 nm in the LSPR location as well as systematic changes in magnetic saturation and coercivity with composition and size were observed by optical spectroscopy and surface magneto-optic Kerr effect measurements, respectively. These microscopic and functional investigations reveal that laser self-organization can be used to synthesize controllable ferromangeitc-plasmonic nanocomposites. Microscopic analysis also shows that EELS in STEM can be considered as a potential technique to explain the elemental information in nanocomposites.

References
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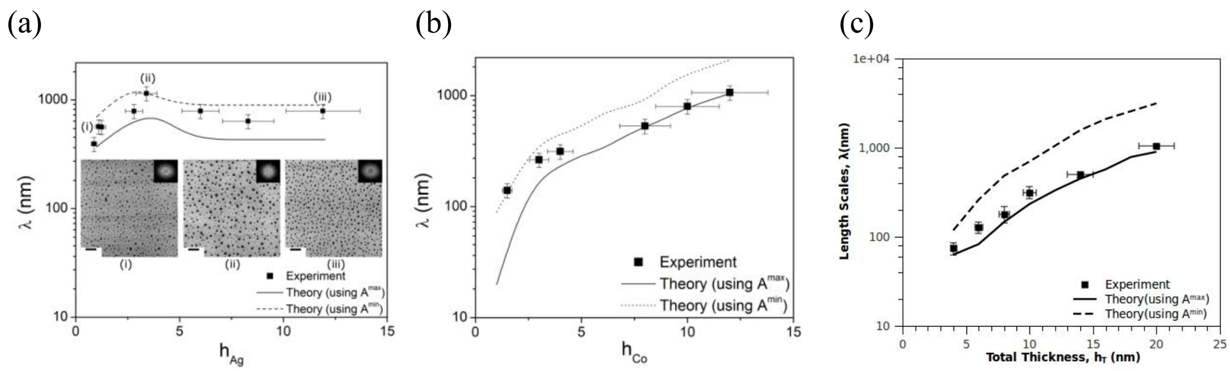

FIG. 1 Experimentally determined inter-particle spacing (closed squares) for (a, c) $Co/Ag/SiO_2$ and (b) $Ag/Co/SiO_2$.. The theoretical predictions are shown by the dashed and dotted lines, and correspond to the min. and max. magnitudes of the Hamaker coefficient. In the figures (a) and (b), the bottom layer thickness was kept constant at 5 nm and the top layer thickness was varied. In figure (c) film thickness is kept in equal ratios [4].

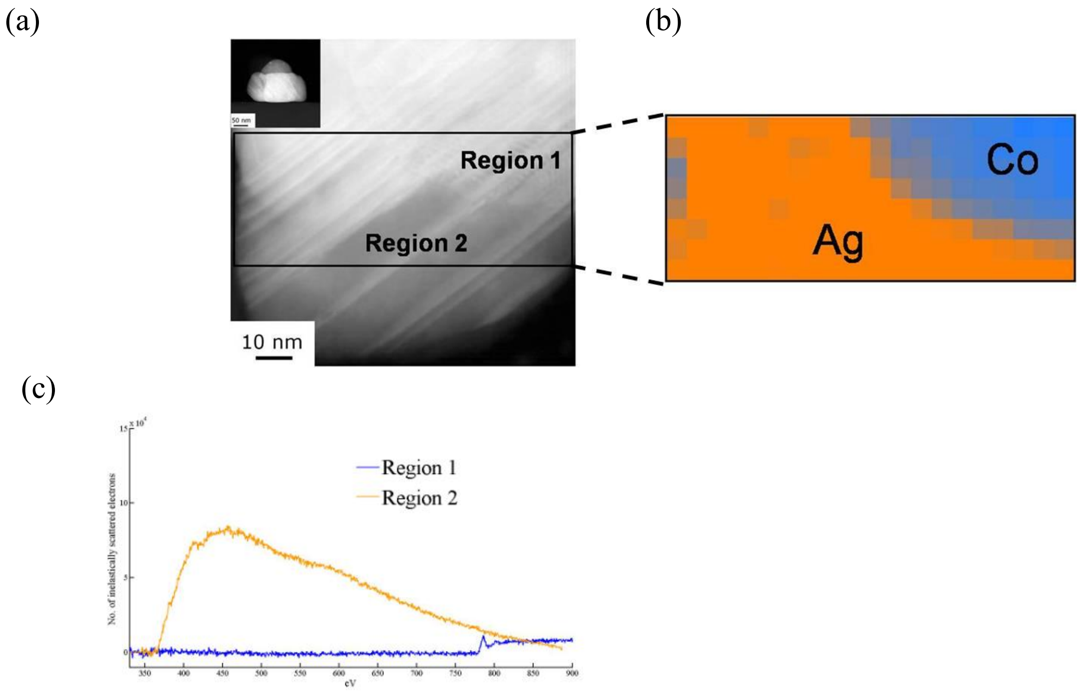

FIG. 2. (a) Cross-sectional HAADF image of Ag-Co nanoparticle showing contrast variation indicating polycrystallinity within particle. The inset shows the TEM micrograph of a nearly hemispherical shaped Ag-Co nanoparticle on SiO_2 substrate. (b) EELS compositional mapping of the enclosed region shown in image (a), exhibiting the immiscibility of Co and Ag in each other. The step size of compositional map is 1.8 nm x 1.8 nm. (c) Background subtracted EELS spectrum showing M3 edge energy peak of Ag in region 1 and L3 edge energy peak of Co in region 2, indicating the absence of other element in the same region.