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3-D Strain Imaging of Nanostructures Synthesized via CVD

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Abstract : CVD techniques have emerged as a promising approach in the formation of a broad range of nanostructured materials. The realization of many practical applications will require efficient and economical synthesis techniques that preferably avoid the need for templates or costly single-crystal substrates and also afford process adaptability. Towards this end, we have developed a single-step route for the reduction-type synthesis of nanostructured Ni materials using a thermal CVD method. By tuning the CVD growth parameters, we can synthesize morphologically dissimilar nanostructures including single-crystal cubes and Au nanostructures which form atop untreated amorphous SiO2||Si substrates. An understanding of the new properties that emerge in these nanostructures materials and their relationship to function will lead to for a broad range of magnetostrictive devices as well as other catalysis, fuel cell, sensor, and battery applications based on high-surface-area transition-metal nanostructures. We use coherent X-ray diffraction imaging technique to obtain 3-D image and strain maps of individual nanocrystals. Coherent x-ray diffractive imaging (CXDI) is a technique that provides the overall shape of a nanostructure and the lattice distortion based on the combination of highly brilliant coherent x-ray sources and phase retrieval algorithm. We observe a fine interplay of reduction of surface energy vs internal stress, which plays an important role in the morphology of nano-crystals. The strain distribution is influenced by the metal-substrate interface and metal-air interface, which arise due to differences in their thermal expansion. We find the lattice strain at the surface of the octahedral gold nanocrystal agrees well with the predictions of the Young-Laplace equation quantitatively, but exhibits a discrepancy near the nanocrystal-substrate interface resulting from the interface. The strain in the bottom side of the Ni nanocube, which is contacted on the substrate surface is compressive. This is caused by dissimilar thermal expansion coefficients between Ni nanocube and Si substrate. Research at UCSD support by NSF DMR Award # 1411335.

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