Abstract
A new nanoparticle deposition technique, Aerosol Impaction-Driven Assembly (AIDA), was extensively characterized for material structures and properties. Aerogel films can be deposited directly onto a substrate with AIDA without the long aging and drying steps in the sol-gel method. Electron microscopy, pore size analysis, thermal conductivity, and optical measurements show the nanoparticle (NP) films to be similar to typical silica aerogel. Haze of nanoparticle films modeled as scattering sites correlates strongly with pore size distribution. Supporting evidence was obtained from particle sizes and aggregates using electron microscopy and small-angle X-ray scattering. NP films showed interlayers of higher porosity and large aggregates formed by tensile film stress. To better understand film stress and NP adhesion, chemical bonding analyses were performed for samples annealed up to 900 °C. Analysis revealed that about 50% of the NP surfaces are functionalized by hydroxyl (-OH) groups, providing for hydrogen bonding. Ellipsometric porosimetry was used to further understand the mechanical properties by providing a measure of strain upon capillary pressure from filling pores. Upon annealing to 200 °C, the films lost water resulting in closer bonding of NPs and higher Young’s modulus. Upon further annealing up to 900 °C, the films lost hydroxyl bonds while gaining siloxane bonds, reducing Young’s modulus. The application of ellipsometric porosimetry to hydrophilic coatings brings into question the validity of pore size distribution calculations for materials that hold onto water molecules and result in generally smaller calculated pore sizes. Doped hydrogenated microcrystalline silicon was grown on crystalline silicon NPs, as a test case of an application for NP films to reduce parasitic absorption in silicon heterojunction solar cells. Parasitic absorption of blue light could be reduced because microcrystalline silicon has a mix of direct and indirect bandgap, giving lower blue absorption than amorphous silicon. Using Ultraviolet Raman spectroscopy, the crystallinity of films as thin as 13 nm was determined rapidly (in 1 minute) and non-destructively. A mono-layer of nanocrystals was applied as seeds for p-doped microcrystalline silicon growth and resulted in higher crystallinity films. Applications of the method could be explored for other nanocrystalline materials.