

Structural Analysis of Thin Amorphous- Nano-Crystalline Thin Films by HRTEM, GISAXS and Raman Spectroscopy

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The series of amorphous- nano-crystalline silicon films, deposited on glass using plasma enhanced chemical vapor deposition (PECVD) method, were analysed by Raman, HRTEM (High Resolution Transmission Electron Microscopy) and GISAXS (Grazing Incidence Small Angle X-ray Scattering) spectroscopy. The crystal to amorphous volume fraction ratios, estimated from the areas under corresponding TO-like (Transversal Optical) phonon bands in Raman, varied from few to 70%. The crystalline TO peak positions were between 500 and 521 cm^{-1} which corresponds to average crystal sizes between 2 and 20 nm, considering only phonon confinement due to nano-size of crystals. However, the TO line was asymmetric and line-width was broad suggesting also the existence of smaller and larger crystals.

The size and size distribution of nano-crystals were estimated from HRTEM and compared with Raman. The results show excellent match in average individual sizes. However, the distribution was slightly different than those obtained by Raman and suggested larger contribution of smaller crystals.

GISAX of deposited samples indicated particles with Gyro radii between 2 and 6 nanometers. Larger particles are present in the samples with higher degree of crystal fraction and larger crystals. However, the samples are porous to certain degree (as concluded from optical measurements) and direct correlation between particles and crystals are not easy to establish. GISAXS obtained under variation in incidence angle allowed estimating in depth distribution of particles. For growing conditions that favor smaller nano-crystals, the individual sizes of particles were uniform going from surface towards depth of the sample and shape was spherically symmetric. For growth that resulted in larger crystals the particles were elongated parallel to the surface and smaller in the "bulk" of the samples. These results were used in discussion of difference in distributions of individual crystal sizes obtained by HRTEM and Raman.