

Controlled Crystallization of Hydrogenated Amorphous Silicon Thin Films by Nanocrystallite Seeding

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Microcrystalline silicon thin films have attracted much attention in recent years in active matrix-liquid-crystal displays and photo-voltaic solar cells. This is due primarily to their superior transport over amorphous alternatives while maintaining a significantly lower manufacturing cost over conventional wafer-grown silicon. The general goal of current microcrystalline development efforts is to achieve further enhanced transport properties by creating films with larger grains. Recently, numerous studies have shown that the highest quality microcrystalline thin films are obtained from solid-phase-crystallization of hydrogenated amorphous thin films at sub-melting point temperatures. Control of final grain structure is often attempted through control of the nucleation rate; however, since nucleation rate is sensitive to several factors, reproducible grain structures through annealing of pure amorphous films can often be difficult.

In this paper, we discuss a new method for more effectively controlling the crystallization of hydrogenated amorphous films, through seeding of the bulk matrix with nanocrystallites. Films were deposited through PECVD methods using a system in which two plasmas were operated to produce crystallites and amorphous films separately. Unlike previous methods in which both plasmas have been run simultaneously to produce a somewhat continuous crystallite distribution throughout the amorphous film, the current method utilizes a multi-stage process in which particle and film plasmas are run at separate times. This layered approach allows for separate conditions to be present in each plasma, thus allowing for greater control of particle size, shape, and concentration within the film. The resulting films consist of a structure in which a single layer of crystallites exists between two layers of hydrogenated amorphous film.

Several single “seed-layer” films were deposited with varying concentrations of cubic structured seed crystallites with sizes ranging between 20-30nm in edge length. Samples were subsequently annealed, along with unseeded control samples, in a quartz furnace under nitrogen flow for extended time periods, and crystallization kinetics were monitored through Raman spectroscopy. Results showed that all seeded samples showed substantially reduced crystallization compared to non-seeded samples, with crystallization onset in seeded samples monotonically decreasing with increasing seed density. Furthermore, films crystallized from seeded structures exhibited a monotonic decrease in electronic transport with increasing initial seed density, suggesting that final grain size is controlled by seed concentration.

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