Room Temperature Laser-Induced Crystallization of Amorphous Silicon Thin Films Grown by PECVD

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Abstract. Semiconductor structures containing hydrogenated amorphous silicon (*a*-Si:H) thin films prepared by plasma enhanced chemical vapor deposition (PECVD) are widely applied in microelectronics devices, such as displays, thin-film transistors or solar cells. Crystallization of these thin films with laser pulses is a rapidly developing field of material science in last decades and currently developable technique for nanocrystalline silicon production for optoelectronics applications. The significant advantage of this post-deposition step is the hydrogen losses upon laser treatment of the film, while certain hydrogen concentration is essential to obtain high-quality material. This non-thermal and fast laser-induced crystallization might benefit low-temperature annealing process required in large-scale and complex silicon-based devices.

In this work, we focused on the description of relationship between laser treatment conditions (laser input power density) and properties of treated thin silicon films. The influence of laser-induced dehydrogenation and crystallization of amorphous silicon films on properties of these films are presented. The treatment was realized even at room temperature and air ambience. Surface morphologies (laser confocal and scanning electron microscopy), microstructural properties (XRD), chemical bonding configuration (FT-IR and Raman spectroscopy), optical properties (UV-VIS spectrometry) of films were systematically studied and results and discussed

Initial amorphous silicon thin (500 nm) films were grown on Si(100) and Corning glass substrates using a rf (13.56 MHz) plasma enhanced deposition technique in silane (10% SiH4 diluted in Ar) discharge at low substrate temperature (250°C) and deposition rate of 37 nm/min. Subsequently, all the samples were treated by a Q-switched Nd:YVO_4 pulsed laser with beam shaping system introduced by lens array. Pulses with the wavelength of 532 nm and duration of 20 ns, pulse energy up to 0.16 mJ (input power density up to 264 mJ/cm^2), repetition rate of 60 kHz and laser beam overlap technique were employed.

The crystallization threshold was found to be of about 200 mJ/cm^2. When laser input power density was lower, no structural changes were observed. The presence of hydrogen atoms in the as-deposited specimen was confirmed by the Si-H_n absorption bands in the FTIR analysis. Laser crystallization lowers the H content significantly, as is shown in FT-IR spectra, where the disappearance of these hydrogen related bonds indicates the hydrogen effusion. For the as-deposited films and for the annealed films, Raman spectra show a band approximately at 480 cm^{-1}, related to amorphous silicon and a band at around 517 cm^{-1}, related to nanocrystalline silicon, respectively. Using laser pulses of different fluence we obtained two-phase films with different crystalline volume fraction up to 70% at the laser input power density of 264 mJ/cm^2. The optical band gap of the samples decreases after laser treatment and can be tuned from 1.79 to 1.64 eV by varying the laser input power density. The structural changes and the crystallization behavior were investigated as a function of laser input power density.