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Effects of Neutral Particle Beam on Nano-Crystalline Silicon Thin Film Deposited by Using Neutral Beam Assisted Chemical Vapor Deposition at Room Temperature

Dong Hyeok Lee[1], **Jin Nyoung Jang**[1], **Hyun Wook So**[1], **Suk Jae Yoo**[2], **Bon Ju Lee**[2], **Mun Pyo Hong**[1]*

[1]Department of Display and Semiconductor Physics, Korea University, [2]National Fusion Research Institute

Interest in nano-crystalline silicon (nc-Si) thin films has been growing because of their favorable processing conditions for certain electronic devices. In particular, there has been an increase in the use of nc-Si thin films in photovoltaics for large solar cell panels and in thin film transistors for large flat panel displays. One of the most important material properties for these device applications is the macroscopic charge-carrier mobility. Hydrogenated amorphous silicon (a-Si:H) or nc-Si is a basic material in thin film transistors (TFTs). However, a-Si:H based devices have low carrier mobility and bias instability due to their metastable properties. The large number of trap sites and incomplete hydrogen passivation of a-Si:H film produce limited carrier transport. The basic electrical properties, including the carrier mobility and stability, of nc-Si TFTs might be superior to those of a-Si:H thin film. However, typical nc-Si thin films tend to have mobilities similar to a-Si films, although changes in the processing conditions can enhance the mobility.

In polycrystalline silicon (poly-Si) thin films, the performance of the devices is strongly influenced by the boundaries between neighboring crystalline grains. These grain boundaries limit the conductance of macroscopic regions comprised of multiple grains. In much of the work on poly-Si thin films, it was shown that the performance of TFTs was largely determined by the number and location of the grain boundaries within the channel. Hence, efforts were made to reduce the total number of grain boundaries by increasing the average grain size. However, even a small number of grain boundaries can significantly reduce the macroscopic charge carrier mobility.

The nano-crystalline or polymorphous-Si development for TFT and solar cells have been employed to compensate for disadvantage inherent to a-Si and micro-crystalline silicon (μ -Si). Recently, a novel process for deposition of nano-crystralline silicon (nc-Si) thin films at room temperature was developed using neutral beam assisted chemical vapor deposition (NBaCVD) with a neutral particle beam (NPB) source, which controls the energy of incident neutral particles in the range of 1～300 eV in order to enhance the atomic activation and crystalline of thin films at room temperature. In previous our experiments, we verified favorable properties of nc-Si thin films for certain electronic devices. During the formation of the nc-Si thin films by the NBaCVD with various process conditions, NPB energy directly controlled by the reflector bias and effectively increased crystal fraction (～80%) by uniformly distributed nc grains with 3～10 nm size. The more resent work on nc-Si thin film transistors (TFT) was done. We identified the performance of nc-Si TFT active channeal layers. The dependence of the performance of nc-Si TFT on the primary process parameters is explored. Raman, FT-IR and transmission electron microscope (TEM) were used to study the microstructures and the crystalline volume fraction of nc-Si films. The electric properties were investigated on Cr/SiO2/nc-Si metal-oxide-semiconductor (MOS) capacitors.

Keywords: NBaCVD, nano-crystalline silicon, room temperature