

Effect of neutral beam treatment on nanocrystallization of silicon thin film by Neutral Beam assisted CVD at near room temperature

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The Hydrogenated amorphous silicon (a-Si:H) or polymorphous silicon is a basic material in thin film transistors (TFTs). The a-Si:H TFT is commonly used as a TFT-LCD backplane because of its proper performance and processibility as a simple switching device. 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 [1]. The basic electrical properties, including the carrier mobility and stability, of polymorphous silicon TFTs might be superior to those of a-Si:H thin film. However, certain intrinsic and critical problems must be overcome, such as the formation of an incubation layer between the gate dielectric and active layers, non-uniformity of grain size and very low deposition rate. The lower deposition rate, however, is mainly caused by process requirements for the qualified polymorphous silicon thin film, such as highly diluted silane gas with hydrogen gas and/or high process temperature.

The nano-crystalline silicon (nc-Si) development for TFT [2] and solar cells [3] have been employed to compensate for disadvantage inherent to a-Si:H and polymorphous silicon. Recently, we are developing a novel CVD technology with a neutral particle beam (NPB) source, named as neutral beam assisted CVD (NBaCVD), which controls the energy of incident neutral particles (mainly H and Ar) in order to enhance the atomic activation and crystalline of thin films at near room temperatures (<80°C) [4]. In traditional hydrogenated silicon deposition, the gas mixture ratio of hydrogen and silicon is main key in controlling the phases of thin films, such as a-Si:H, nc-Si and  $\mu$ c-Si. However, our deposition system controls the energy of hydrogen and argon, the energy of the incident atom work on depositing surface of thin film.

The deposition of polymorphous silicon film is an inhomogeneous growth process. Before nucleation, the deposition generally starts with an amorphous phase called incubation layer. The presence of incubation layer will deteriorate the carrier collection since the carriers are transported along the growth direction of the films. In order to reduce the thickness of the incubation layer and eliminate its negative effects on TFT/solar-cell performance, extensive efforts have been made such as decreasing the SiH<sub>4</sub>/H<sub>2</sub> flow ratio, increasing the working pressure or employing layer-by-layer growth. [5]

In our previous work, during the formation of the nc-Si thin films by the NBaCVD with various process conditions, neutral beam (NB) energy directly controlled by the reflector bias and effectively increased crystal fraction (~80 %) by uniformly distributed nano-crystalline grain with 3~10 nm size.

In this study, a new growth method was proposed to fabricate nc-Si thin films by the NBaCVD. A hydrogen NB treatment process was first performed for 1 minute, and then the nc-Si film was deposited. In order to

investigate the effect of hydrogen NB Treatment on the crystallization of nc-Si, nc-Si TFT prepared under various treatment conditions. TEM, Raman and the light soaking degradation of photoconductivity were used to study the nc-Si films.

TEM image shows that incubation layer does not formed between nc-Si film and SiO<sub>2</sub> under layer and highly crystallized nc-Si film is constructed with uniformly distributed nano-grains in polymorphous tissues.

In the evaluation of the light soaking degradation of photoconductivity, all of the nc-Si thin films processed by the NBaCVD show only a few % of degradation of it.

Finally, the very low temperature processed nc-Si TFT show much improved stabilities against severe positive bias light stress (PBIS; V<sub>g</sub>= 20 V, V<sub>d</sub>= 1 V, 100 mW/cm<sup>2</sup> Halogen Lamp) condition, while the field effect mobility was up to 1.5 cm<sup>2</sup>/Vs: threshold voltage shift was smaller than 1 V after 10<sup>4</sup> sec under the PBIS conditions.

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