MANUFACTURING PHOTOVOLTAIC CELL WITH THE LOW COST AND HIGH EFFICIENCY USING HYPERTHERMAL NEUTRAL BEAM

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ABSTRACT

Low temperature and without damage of amorphous Silicon (a-Si), nano-crystal Si (nc-Si) and micro-crystalline (μc-Si) thin films deposition by controlling the energy of hyperthermal neutral beam (HNB) can lower the manufacturing cost of solar cell and can be utilized for various applications. The Si thin films on corning glass deposited at room temperature without any damage using $SiHB_{4B}$ gas and Ar gas by HNB chemical vapor deposition (CVD). The properties of Si deposited films investigated by Raman spectra, field emission transmission electron microscopy (FE-TEM) image and conductivity, etc. The Si deposited films phases are varied a-Si, nc-Si, and μc-Si according to variation HNB energy by reflector voltage

1. Introduction

Interests on the solar energy, especially solar cell, has been increased tremendously during recent years. It is difficult for the micro-crystalline (μc-Si) thin film to be grown by the normal PECVD, which is usually for the amorphous Silicon (a-Si) thin film from Silane (SiH_4) gas, since the low impact mobility of Si particles on the surface of substrate [1]. Generally the sun light causes damage on a-Si:H solar cell because of the Staebler-Wronski effect [2]. However, it has been reported that the nano crystalline-Si:H thin film is not caused any damage by sun light and has the same energy band-gap as the single crystalline Si (c-Si) and higher absorption coefficient than a-Si:H and c-Si. The thin film deposition at the room temperature using HNB, which is generated by the Auger neutralization and has energy between 1 eV and 100 eV, has been developed to remove the UV and charge damages due to plasma and the Staebler-Wronski effect. During the deposition by HNB, instead of heating the substrate to supply reaction energies to the reactive atoms on the substrate, we produce reactive atomic beams which are already accelerated enough for the reaction energy in the neutral beam source earlier before they reach the substrate [3].

The growing of a-Si, nc-Si, and μc-Si thin films at the room temperature without any damage by using the cheap substrates, which are usually damaged thermally, and controlling the energy of HNB can lower the manufacturing cost and increase the efficiency of solar cell and can be utilized for various applications such as flexible display, Organic LED and TFT, etc. Since HIT (Heterojunction with Intrinsic Thin layer) cell is simple in the structure, which has intrinsic a-Si thin film between p-type a-Si and n-type c-Si, and shows the maximum 21% efficiency. In this work, the characteristics of solar cell with a-Si and nc-Si thin films, namely, HIT cell on the glass substrate using HNB sputtering and HNB CVD will be reported.

2. Experiment

HNB Chemical Vapor Deposition (CVD) system have been prepared. The nc-Si films are deposited on the corning 1737 glass substrate at room temperature by experimental conditions as follows.

The nc-Si films are deposited by HNB CVD method with the working pressure at 2 mTorr, RF power 1KW (13.56 MHz), Gas flow rate: Ar (25 sccm)/ SiH4 (2.58 sccm)=9/1, process time: 60 min, HNB reflector bias 0~-60V. HNB energy varied with plasma limiter, with various reflector bias (V) to see how HNB influences deposition process. The thickness of the deposited nc-Si films, which was measured by α-step, was used for Raman spectroscopy and FE-TEM for the film crystallites. The photo conductivity and dark conductivity were also investigated by four-point probe.

3. Results and discussion

Crystallites of the Si films by HNB CVD are investigated by Raman spectra, TEM image and deflection pattern analysis. Figure 1 shows the Raman spectra of the films formed by HNB CVD method at room temperature. Usually in poly-Si films, their Raman spectra consist of a narrow band around 520 cm^{-1} arising from crystalline phases and a broadband around 480 cm^{-1} arising from the amorphous phases[4]. In figure 1, Raman spectra shows nano-crystal phases of amorphous-like [5].

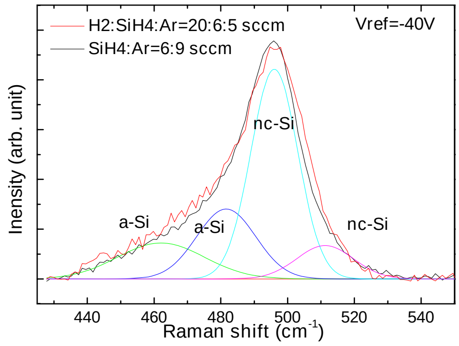
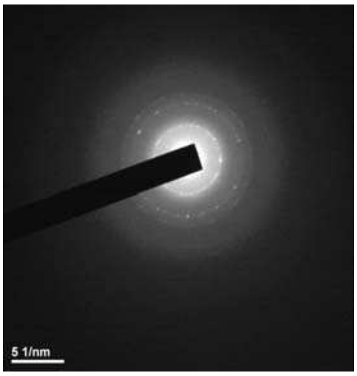


Fig. 1 Raman spectra of the nc-Si films by HNB CVD and.



(a) TEM image (b) Deflection pattern

Fig. 2 (a) TEM image and (b) Deflection pattern of the nc-Si films by HNB CVD at reflector bias voltage of -40V.

Nano-crystal properties were confirmed by FE-TEM image. In figure 2, the TEM image of the Si film by HNB CVD shows that the Si film was formed nano-crystal structure of the size of 5 nm. The transmission electron deflection pattern of figure 2 (b) looks like poly crystalline pattern and the pattern range is about 30 nm of the film thickness.

The photo conductivity and dark conductivity was also investigated to electric properties of the film and applicable possibility to HIT cell. Usually, the photo conductivity of a-Si and μc-Si is 10^{-5}~10^{-6} S/cm and 10^{-4}~10^{-5} S/cm, the dark conductivity of a-Si and μc-Si is 10^{-8}~10^{-9} S/cm and 10^{-5} ~10^{-6} S/cm, respectively. Photo and dark conductivity have different value according to variation reflector voltage; the values are between the a-Si and μc-Si. The highest photo conductivity value is 1.08×10^{-5} S/cm, lowest dark conductivity value is 3.14×10^{-9} S/cm at 20V of reflector voltage.

4. Conclusion

The Si films have been deposited at room temperature by HNB CVD. The crystallites and the electrical properties of the Si deposited films investigated by Raman spectra, TEM image and conductivity, the Si deposited films show nano-crystal structure about 5 nm size.

Finally, the growing of a-Si, nc-Si, and μc-Si thin films at the room temperature without any damage by controlling the energy of HNB is possible and can lower the manufacturing cost and increase the efficiency of solar cell. Also HNB deposition, which makes the deposition with good control of film crystallite in the room temperature possible, can be utilized for various applications such as flexible display, Organic LED and TFT, etc.

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