A Hydrogenated Amorphous Silicon (a-Si:H) Thin Films for Heterojunction Solar Cells: Structural and Optical Properties

Ayse Seyhan\textsuperscript{1,2}, Tolga Altan\textsuperscript{2}, Ömer Can Ecer\textsuperscript{1,2}, Recep Zan\textsuperscript{2}

\textsuperscript{1}Department of Physics, Nigde Omer Halisdemir University, Nigde-Turkey
\textsuperscript{2}Nanotechnology Application and Research Center, Nigde Omer Halisdemir University, Nigde-Turkey
Email: aseyhan@ohu.edu.tr

Abstract: Heterojunction solar cells composed of hydrogenated amorphous silicon (a-Si:H) and c-Si has been widely studied due to its excellent photovoltaic characteristics. In this study, we studied the structural and optical properties of a-Si:H thin films for heterojunction solar cells by using SEM, TEM and ellipsometry. We found that uniform deposition of a-Si:H thin film on substrate is crucial to reach high solar cell efficiencies.

1. Introduction

Current photovoltaic trends shows that both improved efficiency and lowered cost can be obtained by heterojunction solar cell technology [1]. Silicon heterojunction solar cells consist of crystalline silicon (c-Si) wafers with typically 3-15 nm thick amorphous silicon layers deposited on both sides to form electrically passivated contacts. A hydrogenated i/p layer stack forms the emitter at the front side and a hydrogenated i/n layer stack forms the back-surface field. The use of such layers in heterojunction cells has many advantages such as low process temperatures, low cost, large area deposition and high cell efficiencies. Such a device structure has been pioneered by Sanyo [2] starting in the early 1990s increasing efficiency steadily to currently 24.7% [3] and 26.6% [4] with a double-sided heterojunction and an IBC-SHJ cell, respectively.

Here we present a scanning electron microscopy study of the a-Si:H/c-Si Heterojunction solar cell which has revealed that the uniform deposition of thin films has critical importance to get high cell efficiency.

2. Experimental

In order to obtain a-Si:H thin films, the plasma enhanced chemical vapor deposition (PECVD) technique has been used, which is well known for thin film growth [5]. The a-Si:H layers were deposited in a radio frequency (13.56 MHz) PECVD reactor. The temperature for the cell fabricating processes was around 200°C. The a-Si:H precursor gases were semiconductor grade silane (SiH\textsubscript{4}), phosphine (PH\textsubscript{3}) diluted to 1\% in hydrogen, trimethyboron (TMB) diluted to 1\% in H\textsubscript{2} and 5N H\textsubscript{2}.

The structure of the 156 mm x156 mm a-Si:H/c-Si -Heterojunction solar cell is shown in Figure 1. First n-type c-Si wafers were cleaned with HF just before the deposition. Intrinsic a-Si:H layer (5-10nm) deposited in one reactor and then n (p) type a-Si:H layer (5-10 nm) deposited in an another reactor to get rid of contamination. Both ITO and back contact Ag were deposited by Physical Vapor Deposition (PVD). A front grid was printed with silver (Ag) paste. All these steps were characterized by spectroscopic ellipsometer and profilometer. All layer properties of Si heterojunction solar cell have...
been studied by SEM (HITACHI SU5000, for front side of solar cell 100 k magnification, obtained at 5.0 kV; for back side of solar cell 11 k magnification, obtained at 10.0 kV).

![SEM image of a-Si:H/c-Si heterojunction solar cell](image)

**Figure 1.** The structure of the a-Si:H/c-Si heterojunction solar used in this (left). Current-voltage (I-V) performance of optimized a-Si:H/c-Si heterojunction solar cell obtained on commercial 156 mm pseudo-square n-type Cz c-Si substrate (right).

### 3. Result and Discussion

It is well-known that by adding the high-quality i-a-Si:H layer, the defect density of the a-Si:H/c-Si interface can be reduced, resulting in a high conversion efficiency, high $V_{oc}$ and excellent temperature coefficient [6,7]. However, the surface morphology on the textured substrate must be considered in order to obtain high conversion efficiency. There can be no doubt that the quality and uniformity of thin films on texturized wafer dominates the performance of the a-Si:H/c-Si heterojunction solar cell.

a-Si:H thin films have been deposited on textured c-Si wafer with different thickness which are 5, 10, 15, and 20 nm. The deposition of high quality a-Si:H layers reduced surface recombination, thus improving the junction properties. $V_{oc}$ values were improved with increasing a-Si:H layer thickness. However, samples with thicker layer shown a large decrease in FF which can be attributed to an increase in series resistance. The a-Si:H thin films with different thickness were deposited quite uniformly on the c-Si wafer. The results summarized table 1.

Table 1. Solar cell characteristics as a function of a-Si:H thickness. Each data represents the average value of some cells.

| PV parameters | 5 nm | 10 nm | 15 nm | 20 nm |
|---------------|------|-------|-------|-------|
| $V_{oc}$ (mV) | 680.0| 700.0 | 715.7 | 715.0 |
| $J_{sc}$ (mA/cm²) | 35.7 | 36.2  | 36.3  | 36.2  |
| FF (%)        | 78.5 | 78.0  | 77.0  | 76.8  |
| Efficiency (%) | 19.2 | 19.7  | 19.9  | 19.6  |

The SEM images and EDS mapping of the front and back side contacts are shown in Figure 2(a-b) and Figure 3, respectively. The front contact was fabricated by PVD- 80nm thick ITO film- on the top side of the a-Si:H/c-Si heterojunction solar cell. The rear contact was then deposited (ITO-50nm/Ag 240nm) on the back side of the solar cell. The thin films composition can be seen clearly on the EDX mapping.

It can be clearly observed in the SEM images (figure 2) that the thin film thickness is quite uniform all over the textured surface of a-Si:H/c-Si heterojunction solar cells. EDS maps in figure 3 also provide a clear distinction between deposited thin films.
Figure 2. (a) Front side, and (b) Back side SE and BSE HR-SEM image of a- Si:H/c-Si -Heterojunction solar cell at 100 k magnification, obtained at 5.0 kV, at 11 k magnification, obtained at 10.0 kV, respectively.

Figure 3. EDS mapping of Si-Heterojunction solar cell (front side) at 35 k magnification, obtained at 10.0 kV.
The photovoltaic properties of the a-Si:H/c-Si heterojunction solar cell were studied by using current-voltage (I-V) measurements. The heterojunction solar cell showed a good photovoltaic behaviour with energy conversion efficiency 20% on 6” n-type c-Si. The obtained photovoltaic parameters are found to be open circuit voltage Voc = 715.7 mV, short circuit density Jsc = 36.3 mA/cm², and fill factor FF = 77%, Figure 1 (right).

4. Conclusion

In conclusion, we used an SEM operated at 5 and 10 kV to investigate thin films uniformity in Si a-Si:H/c-Si heterojunction solar cells. The SEM images reveal that all thin films on the heterojunction solar cells are deposited uniformly. This shows that the optimized thin film growth parameters have a critical importance to get high conversion efficiency from solar cells.

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