OPTIMIZATION OF A-SIC: HASBUFFER LAYER FOR EFFICIENCY ENHANCEMENT OF AMORPHOUS SILICON SOLAR CELLS

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Abstract

Thin film single junction hydrogenated amorphous silicon (a-Si:H) solar cells have been fabricated using RF-Plasma Enhanced Chemical Vapor Deposition method. The p-,i-, and n-layers have been optimized individually for achieving cell efficiency of 5.11 %(V_{oc}=0.84 V, J_{sc}=10.13 mA/cm2, and FF=0.59). In this study an effort has been made to optimize and incorporate hydrogenated amorphous silicon carbide (a-SiC:H) layer as a buffer layer between the doped a-Si:H forming the emitter (p-layer) and the absorber layer (i-layer) to enhance the cell efficiency further.The buffer layer has been studied for electrical, optical, structural properties and layer thickness by varying the process parameters such as CH_4, SiH_4 and H_2 gas concentrations. The optimized buffer layer was about 12 nm thick with an optical band gap of 1.88 eV. Insertion of this film between the p- and i- layers resulted in an increased power conversion efficiency of 5.88% and J_{sc}=11.0mA, compared to the conventional cells. The observed improvement is related mainly to minimum absorption loss and capability of driving out the photo generated carriers with minimum recombination losses, with transportation of carriers to the outer circuit with minimum electrical resistance.

Keywords: *a-Si:H solar cell, a:SiC:H,Buffer Layer, PECVD.*

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1. INTRODUCTION

With worldwide attention on reducing consumption of non-renewable sources, solar cell industry is booming to provide the future with clean and in-exhaustible energy sources. Among various solar cells, thin film amorphous silicon solar cell has drawn attention due to its low cost of fabrication [1,2].

Amorphous Si (a-Si) is the most appropriate form for the light absorber in thin-film Si solar cells because it has high absorption coefficient in the visible range of the electromagnetic spectrum [3] compared to other forms such as polycrystalline [4] or mixed-phase Si [5]. This implies that a-Si absorber layer can be made thinner than other forms of Si in thin-film Si solar cells. However, the metastability of a-Si, called the Staebler-Wronski effect, limits the efficiency improvement of a-Si solar cells [6]. Another issue in a-Si solar cells is the large difference in the band gap between the p-layer and i-layer which leads to loss of photons.

Therefore in this research, a buffer layer (a-SiC:H) is incorporated between p- and i- layer. This buffer layer is chosen in such a way that its band gap lies between the above two layers in order to allow smooth transition of photons from the p-layer to i-layerthere byincreasing the efficiency of p-i-n type a-Si solar cells.

2. EXPERIMENTS

Coating experiments related to buffer layer optimization as well as fabrication of solar cell device have been conducted using Plasma Enhanced Chemical Vapor Depositionsystem (PECVD) which is schematically represented in figure 2.1. The fully automated PECVD system consists of 5 process chamberssupported by individual magnetic arms for handling the substrates, and a central transfer chamber. Each process chamber is equipped with an adjustable electrodes-gas shower facility connected to a 600W RF (13.56 MHz) power supply with matching network; substrate heater, and dry mechanical pump for maintaining the required process pressure. A common Turbo-Roots-Rotary pumping system connected to the central chamber has been used to create a base pressure of ~5x10^{-6}Torr prior to every deposition.

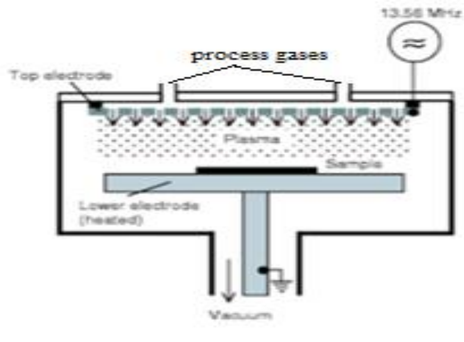

Fig 2.1 Schematic diagram of the parallel plate RF-PECVD system

Fabrication and Optimization of a-SiC:HBuffer Layer Buffer layer, composed of hydrogenated amorphous silicon carbide (a-SiC:H),has been deposited (figure 2.2) using SiH4(10-20sccm), H2 (100-200 sccm) and CH4 (1-10sccm) as process gasses at a temperature of 250 ℃ and at an operating pressure of 1 Torr.

Several buffer layer samples, deposited by varying the flow rate of the above mentioned process gases, have been characterized mainly for layer thickness, electrical and optical properties the results of which are discussed in the next section. Based on the achieved results, three optimized sets of buffer layer parameters have been chosen (as shown in Table 2.1) for incorporation and fabrication of the solar cell devices.

Table 2.1 Parameters of optimized buffer layers

S. NO	SiH4 (sccm)	H2(sccm)	CH4 (sccm)	TIME (min)	RF (W)	TEMP(°C)	PRESS. (torr)
1	10	150	3	4	7	250	1
2	10	100	2	6	7	250	1
3	10	175	1	8	7	250	1

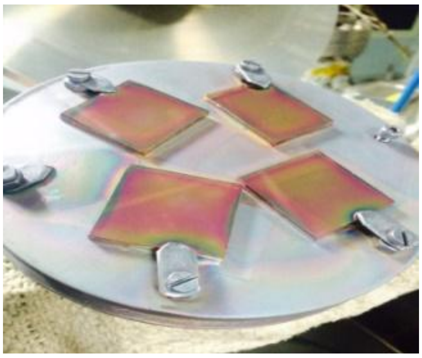

Fig 2.2 Deposited a-SiC:H buffer layer samples

Fabrication of a-Si:H Thin Film Solar Cell Incorporated with Optimized Buffer Layer

Hydrogenated amorphous silicon solar cells have already been fabricated by optimizing the p-,i- and n- layers [7].The sequence of deposition of solar cells incorporated with buffer layer, and the process parameters are shown in figure 2.3 and table 2.2 respectively.

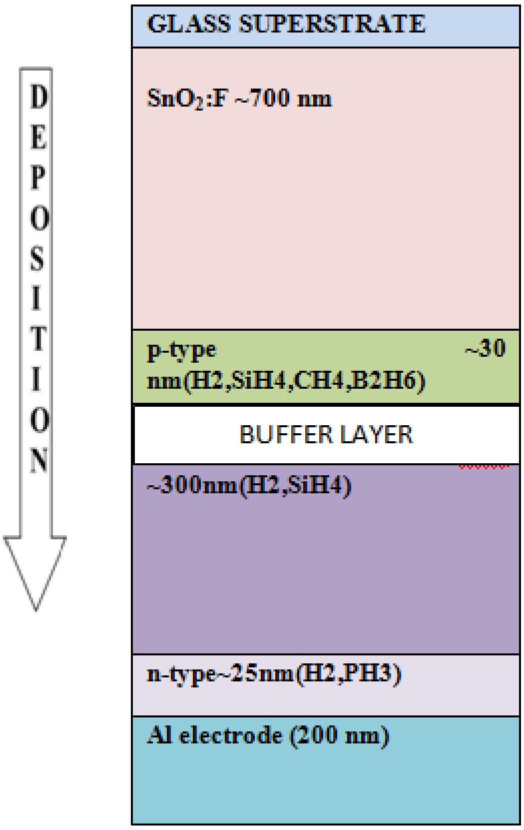

Fig 2.3 Deposition sequence of solar cell incorporated with buffer layer

Table 2.2 Parameters for fabrication of the cell.

Layers	H_2 (Sccm)	B_2H_6 (Sccm)	SiH_4 (Sccm)	PH_3 (Sccm)	Time (min)
P	100	6	8	10	4
BL-1	150	3	10	-	4
BL-2	100	2	10	-	6
BL-3	175	1	10	-	8
I	30	-	4	10	25
N	100	-	-	10	15

3. RESULTS AND DISCUSSION

BUFFER LAYER RESULTS

3.1 Film Thickness

The thickness of the samples, measured using Dektak 6M Profilometer was in the range 10 nm- 80 nm.

3.2 AFM Analysis

Figure 3.1 shows the surfacemorphology of deposited buffer layer sample. It represents uniformity in deposition of SiC onto the glass substrate.

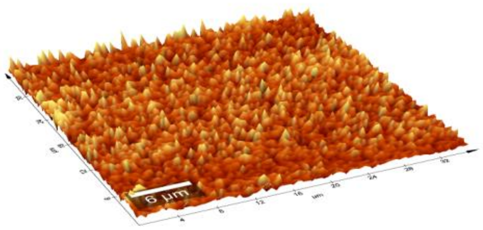

Fig 3.1 AFM image of a-SiC:H film

3.3 RAMAN Analysis

The Raman spectra of the three SiC:H films deposited at 250°C using PECVD method are shown in the Figures 3.2,3.3 and 3.4. The peaks are in the range 480 nm-550 nm which represents the presence of amorphous SiC.

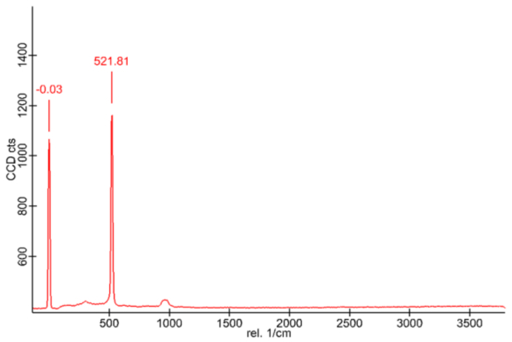

Fig 3.2 Raman pattern of sample BL-1

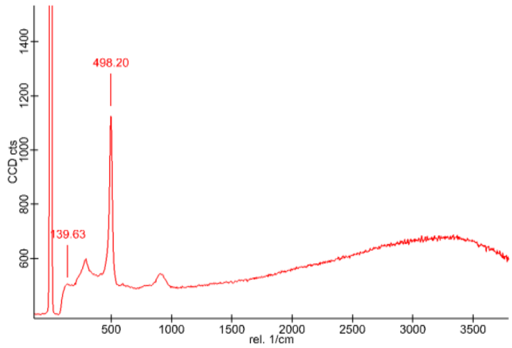

Fig 3.3 Raman pattern of sample BL-2

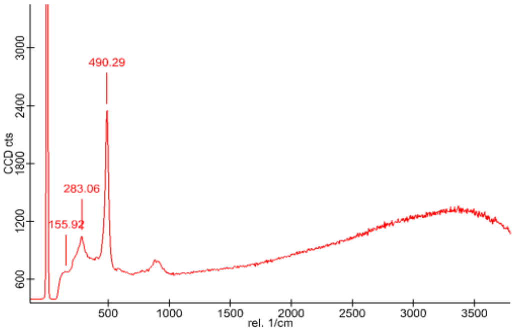

Fig 3.4 Raman pattern of sample BL-3

3.4 Electrical Characteristics

The electrical properties of the buffer layer samples, measured using B 1500 Semiconductor analyzer, are shown in Table 3.1

Table 3.1 Electrical characteristics of buffer layer samples

Property	Buffer sample 1	Buffer sample 2	Buffer sample 3
Dark conductivity (S/cm^2)	$8.44X10^{-10}$	$2.34X10^{-10}$	$1.75x10^{-9}$
Photo conductivity (S/cm^2)	$1.09x10^{-6}$	$4.75x10^{-6}$	$6.62x10^{-6}$
Gain	$1.29X10^{3}$	$2.03X10^{3}$	$3.78x10^{3}$

3.5 Optical characteristics

The optical transmittance spectra of the buffer layer films were recorded using UV-VIS-NIR spectrophotometer. And the band gapdata, calculated through the Tauc plots, is represented in Table 3.2

Table 3.2 Band gaps of buffer layer samples

SAMPLE NO	BAND GAP(eV)
BL-1	1.842
BL-2	1.880
BL-3	1.868

3.6 Solar Cell Study

Hydrogenated amorphous silicon (a-Si:H) solar Cells have been fabricated by incorporating the optimized buffer layer with thickness of around 12 nm. I-V characteristics of the standard as well as buffer layer incorporated solar cells measured by solar simulator are shown in figure 3.5 and 3.6. The achieved efficiency of the standard cell is 5.11% while that of the buffer layer incorporated solar cell is 5.88%. A relative increase in efficiency of 15.06% from that of the standard cell was observed. Theachieved efficiency improvement is mainly due to the reduction of absorption/reflection losses of the incident photons and the capability of driving out the photo generated carriers with minimum recombination losses.

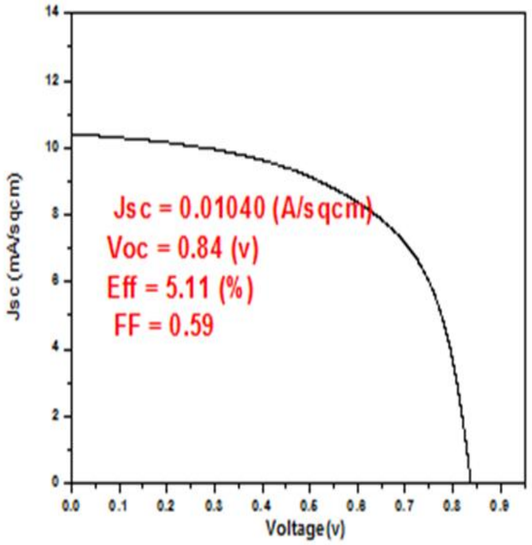

Fig 3.5 I-V curve of the standard cell

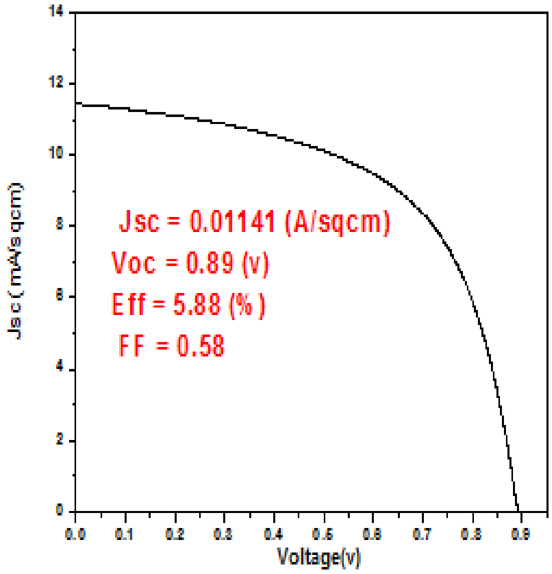

Fig 3.6 I-V curve of the cell with Buffer layer

4. CONCLUSION

RF-PECVD process has been used to fabricate and optimize the a-SiC:H buffer layer. The optimum layer thickness of 12 nm with band gap of 1.87 eV was incorporated into the solar cell of known efficiency (5.11%). Incorporation of this conductive a- SiC:H buffer layer between p- and i- layer resulted in enhancement of Jsc by 9.71% (10.13-11.0 mA) andVoc by 5.95 % (0.84-0.89 V). Therelative increase in energy conversion efficiency of the cell was found to be 15.06%.

ACKNOWLEDGEMENT

This research work is supported by Department of Science and technology (DST).We are grateful to Dr. A.R. Phani, INM Technology, Bangalore,and Mr.PawanKumar, Mr.Gautham andMrs.G.D.Shilpa, IDRC, RVCE for their timely help and co-operation in executing this work.

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