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Fabrication of *n*-DLC/*i*-SiC/*p*-Si Photovoltaic Cells by Pulsed Laser Deposition at the Electrical Field

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Abstract: We report on the fabrication of *n*-DLC/*i*-SiC/*p*-Si photovoltaic cell by pulsed laser deposition at electrical field. Raman spectra showed that the *I*(D)/*I*(G) ratio of *n*-DLC increased from 0.32 to 0.79 with increasing temperature. As well as, open voltage and current density were increased from 2.4 mV, 0.03 μA/cm^2 to 68.2 mV 325 μA/cm^2 with increasing temperature, respectively. The SiC layers were analyzed under irradiated by ESCA. Our PLD method could synthesize *i*-SiC layers between n-DLC and p-Si.

1. Introduction

Photovoltaic cells attract attention as measures of the issue of drying up of energy resources, and they are now a required new material. Si are investigated, have a theoretical efficiency of approximately 26 % [1]. On the other hand, carbon materials are development to good efficiency photovoltaic cells. In a previous study, we had been synthesized the hetero-junction of P-doped *n*-DLC and *p*-Si as a photovoltaic cell by pulsed laser deposition (PLD) [2]. This paper shows that efficiency of photovoltaic cells are increased by infrared (IR) light heating. In order to more increase, we attefmpted to synthesize SiC layer between DLC-layer as a tandem photovoltaic cells. SiC layer was grown by PLD at an electrical field. Because carbon plumes, which ablated by laser irradiation, are acceleration in this field. Therefore, carbon and the surface of a Si substrate are combined and grown SiC layers. In this study, we repot on the growth technique of the *n*-DLC/*i*-SiC/*p*-Si layers by PLD at the electrical field.

2. Experiment

Figure 1 shows an IR assisted PLD at the electrical field system for P-doped DLC. Silicon substrates (*p*-Si: 1-10 Ω. 10 × 10 mm) were cleaned by ultrasonic washing system with ethanol and acetone, and silicon dioxide films were chemical etched using ammonium fluoride (NH_4F) at 343 K. The graphite powder and P powder (1.0 wt%) were mixed, pressed and formed bar-sharped as a laser target. The Si substrate and the laser target were set into the Ar atmospheric vacuumed chamber, whose pressure was 30 mTorr. A distance between the target and substrate was 25 mm. Anode and cathode electrodes were attached back of the targets and Si substrate, respectably. Direct voltage was applied the electrodes. IR light was irradiated to the laser target and the substrate, whose temperatures were controlled from 300 K to 673 K by IR system (ORIENTAL MOTOR MB520-B). A focused Nd: YAG laser (LOTIS TII-LS 2147, wave length: 355 nm, pulse width: 20 ns, laser fluence: 8.8 J/cm^2) was irradiated to the laser target. Ablation plumes were emitted from the laser target by laser irradiation, and were deposited on the substrate. Crystallizations of deposited films were measured by Raman spectroscopy (Renishaw System-1000). The chemical compositions of the *n*-DLC/*i*-SiC/*p*-Si layers were analyzed by electron spectroscopy for chemical analysis (ESCA Shimazu ESCA-850). Current–voltage (*I*-*V*) characteristics of the DLC films were measured by a two-probe method under an illuminated Xe lump. Ion sputtering was used for forming an Au ohmic contact between the anode and the cathode of the cell.

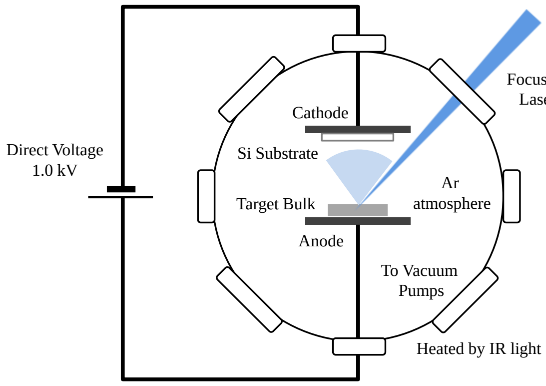

Figure 1 PLD system to form DLC film

3. Results and Discussion

Typical Raman spectra of DLC are presented in Figure 2. The Raman spectra of DLC showed two sharp modes, the G peak around 1580-1600 cm^{-1} and the disorder peak (D peak) around 1350 cm^{-1} [3]. The graphite peak (G peak) occurs because of bond stretching of all pairs of sp^2 atom sites in both rings and chains. The D peak occurs because of the breathing mode of peaks sp^2 atoms the in rings. To exam the crystallization of DLC films, the intensity ratio of the peaks is denoted as *I*(D)/*I*(G). This ratio increases from 0.32 to 0.79 with increasing temperature and saturates above 473 K. This means that heating over 473 K can affect the graphite rich DLC structure.

Dependence on temperature and open voltage, current density

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are shown Figure 3. The open voltage of films increases with increasing in substrate temperature. The open voltage of 773 K films was 68.2 mV, while that of 373 K films was 2.4 mV. As well as, those of current density are increased 0.03 μA/cm^2 and 325 μA/cm^2, respectively. Increasing the substrate temperature shows growth films have a positive influence on the solar cell properties.

In order to examine relationships between crystallization of growth films and solar cell properties, we measured the cross-section structure of those films by ESCA as shown in Figures 4. The binding energies of C-C, Si-Si, and C-Si are 284.3, 99.3, and 100.4 eV, respectively. The growth films were etched for 240 min (45 cycles) by Ar-ion sputtering. All films had C-C bond, Si-C bond and Si-Si bond. This suggested the growth films were consisted DLC/SiC/Si layer. C-C bond of 573 K and 773 K films were observed from 1 cycle to around 25 cycles. Si-C bond of 773 K films was observed from 19 cycles to 39 cycles, while that of 573 K films was from 18 cycles to 29 cycles. It should be note that SiC layer of 773 K films were longer than that of 573 K. This result indicates that increasing substrate temperature can control the thickness of SiC layer.

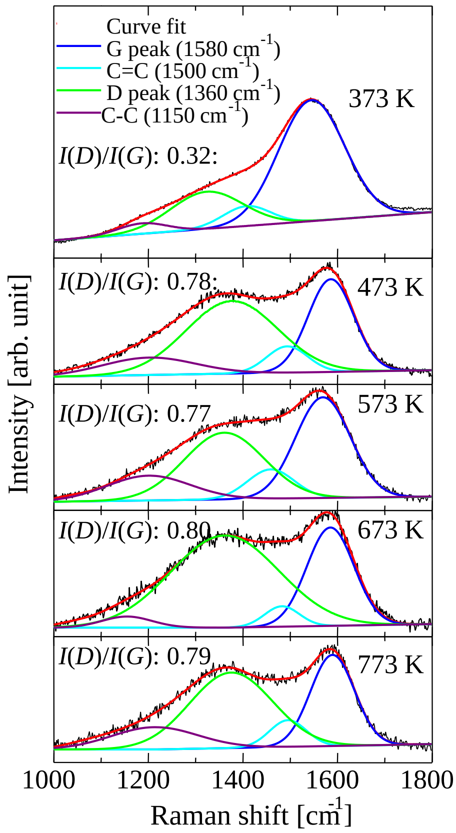

Figure 2 Raman spectra of DLC films

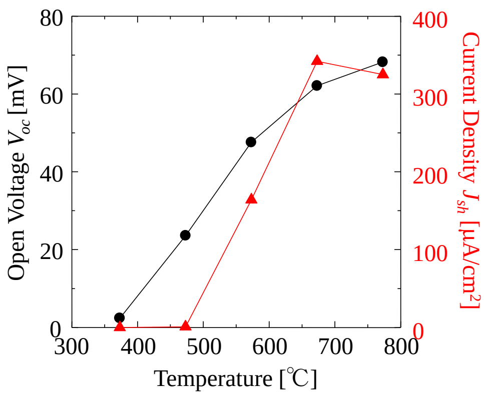

Figure 3 Relationships between temperature and open voltage, current density of films

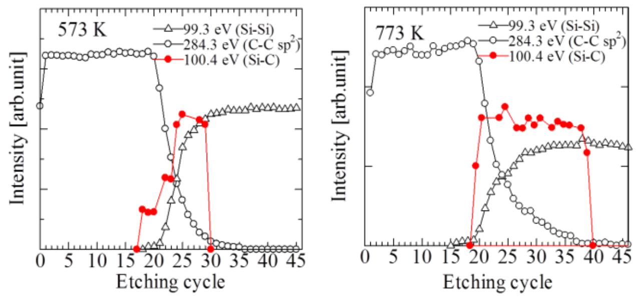

Figure 4 Cross-Section structure by ESCA

4. Conclusions

We report on the fabrication of *n*-DLC/*i*-SiC/*p*-Si photovoltaic cell by pulsed laser deposition at electrical field. Raman spectra showed that the *I*(D)/*I*(G) ratio of *n*-DLC increased from 0.32 to 0.79 with increasing temperature. As well as, open voltage and current density were increased from 2.4 mV, 0.03 μA/cm^2 to 68.2 mV 325 μA/cm^2 with increasing temperature, respectively. The SiC layers were analyzed under irradiated by ESCA. Our PLD method could synthesize *i*-SiC layers between n-DLC and p-Si.

Reference

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