Extended Abstracts of the 2004 International Conference on Solid State Devices and Materials, Tokyo, 2004, pp. 698-699

P13-14L

The physical and micro structural properties of PECVD grown amorphous carbon films on the contribution to n-C:P/p-Si solar cells

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The control of the p- and n-type doping as well as optical band gap, residual defects and chemical bonding must be achieved to realize high performance electrical and optical devices [1]. We have performed a systematic study of growing phosphorus (P) doped n-type amorphous carbon (n-C:P) films by 13.56 MHz radio frequency (r.f.) plasma enhanced chemical vapor deposition (PECVD) techniques from hydrocarbons using solid P target that put in the distance of 20 mm on the top of the substrates. The distance between substrate stage and top plate was set at 49 mm. Substrate temperature was kept at 25 ^oC. Base vacuum was typically set at the pressure of lower than 2 x 10^{-4} Pa using a turbomolecular pump and oil diffusion pump. The chamber pressure was allayed at setting pressure of 20 Pa and the flow rate of feed source gas mixtures of CH_4 and H_2 respectively was optimized at 5 and 50 Sccm. The r.f. power (P_{rf}) was the variable condition from 100 to 300 watt. The undoped a-C film was also deposited using the above deposition procedure without solid phosphorus target for comparison. The changes in the physical and microstructure properties of n-C:P films as a function of P_{rf} has been determined and the photovoltaic properties of fabricated n-C/p-Si solar cells are also investigated.

The paramagnetic defects in the films were studied by electron spin resonance (ESR) [2]. The effect of p-doping on the ESR parameters of a-C:P reveals that there is a decreased in the g value from 2.0036 to 2.0021 and increased of ESR linewidth ($\triangle H_{PP}$) with increase of P_{rf} from 100 to 300 W. The increase in $\triangle H_{PP}$ of n-C:P films with increase of $\triangle H_{PP}$ is attributed to spins which are no longer localized at a single C-P cluster but able to pass to neighboring C-P clusters as the ESR peak is shown unsaturation behavior [3].

The optical gap (E_g) is obtained from the extrapolation of the linear part of the curve at the absorption coefficient α = 0, using the Tauc relation [4], $(\alpha hv)^{1/2} = B(E_g\text{-}hv)$, where, B is the Tauc parameter. The E_{opt} is almost unchanged when increased of $P_{r.f.}$ up to 200 W. There are step decreases of E_g from approximately 2.0 to 0.8 eV as $P_{r.f}$ increase from 200 to 300 W (Fig. 1). It is known that, the E_g influenced by the hybridization state of carbon atoms. The larger E_g of a-C film reveals more diamond-like nature and hence more sp^3- bonded structure.

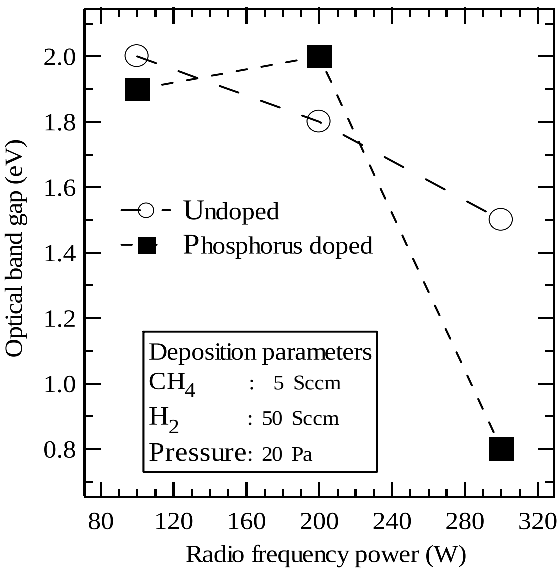

Figure 1: The Tauc optical band gap of undoped a-C and n-C:P films grown at various radio frequency power.

The cells performances have been given under illumination when exposed to AM 1.5 illumination condition (100 mW/cm^2, 25 ^oC). The maximum open circuit voltage (V_{oc}) and short circuit current density (J_{sc}) are observed to be approximately 236 V and 7.34 mA/cm^2, respectively for the n-C:P/p-Si cell grown at lower P_{rf} of 100 W (Fig. 2). The highest energy conversion efficiency (η) and fill factor (FF) were found to be approximately 0.84% and 49%, respectively. The rectifying nature of the heterojunction structures is due to the nature of n-C:P films are observed.

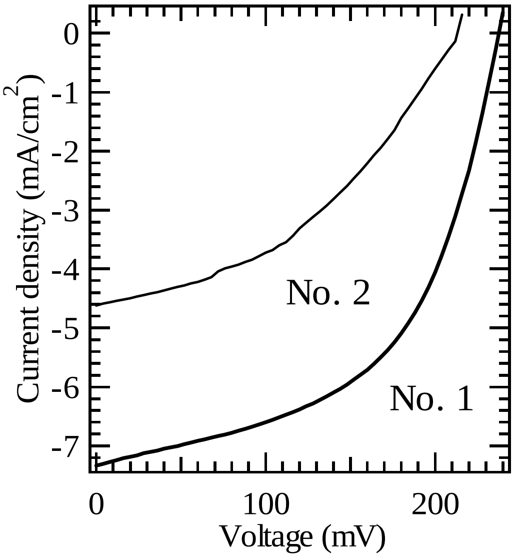

Figure 2: The current-voltage characteristics of n-C:P/p-Si cells for No. 1 (Deposited at CH_4 = 5 Sccm, H_2 = 50 Sccm, and r.f. power = 100 W), and No. 2 (Deposited at CH_4 = 5 Sccm, H_2 = 50 Sccm, and r.f. power = 200 W).

The quantum effieciency (QE) of the n-C:P/p-Si cells is observed to improve with lower P_{rf} and deteriorate with further increase P_{rf} over 200 W. The QE spectral characteristics of the n-C:P/p-Si cell grown at 100 W and 200 W of P_{rf} are compared (Fig. 3). The QE contribution in the short wavelength region is believed resulting from n-C:P/p-Si cell, as when the light is incident on the front of the C layer surface, the photons with high energies are strongly absorbed by the C layer and the generated electron-hole pairs are driven by built-in field.

The conclusions reached in the present studies may do not certainly apply to other samples directly, but allowed us to confirm that this parameter is indeed very important for the film physical and microstructure, and hence for its electronic properties.

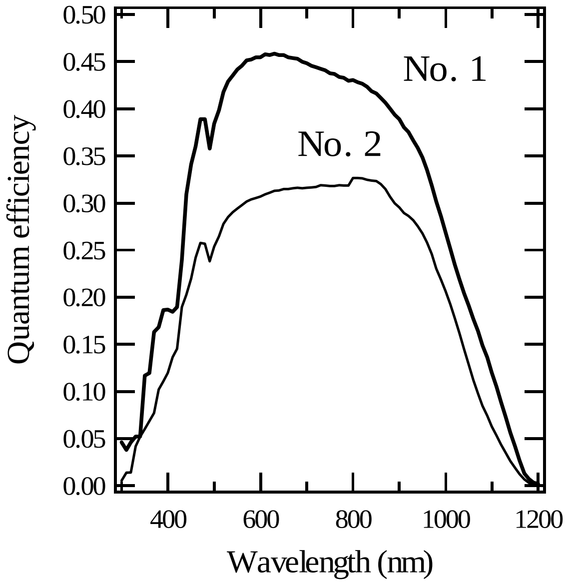

Figure 3: The spectral photoresponse characteristics of n-C:P/p-Si cells for No. 1 (Deposited at CH_4 = 5 Sccm, H_2 = 50 Sccm, and r.f. power = 100 W), and No. 2 (Deposited at CH_4 = 5 Sccm, H_2 = 50 Sccm, and r.f. power = 200 W).

Acknowledgements
This work was supported by the Incorporated Administrative Agency New Energy and Industrial Technology Development Organization (NEDO) under Ministry of Economy, Trade and Industry (METI) and 21st century COE program at NIT.

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