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Characterization of phosphorus doped amorphous carbon and construction of n-carbon/p-silicon heterojunction solar cells

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Undoped amorphous carbon (a-C) is weakly p-type in nature [1] and the complex structure and presence of high density of defects restricts its ability to dope efficiently and is the main barrier for its application in various electronic devices.

In this report, the phosphoros doped carbonaceous (n-C) films were deposited on silicon (p-Si) and quartz substrates at room temperature by excimer laser pulsed laser deposition technique (PLD) (NISSIN 10X, XeCl, λ = 308 nm, τ = 20 nsec, repetition rate = 2 Hz, spot size = 5.5 mm^2, shot number = 900 shots) using camphoric carbon ($C_{10}H_{16}O$) (CC) target, which is focused on the target at an incident angle of 45° to the target normal. The substrate was mounted parallel to the target at a distance of 45 mm. The laser pulse energy was 150 mJ on the window. In order to dope, the CC soot was mixed with varying amount of red phosphorus (P) powder (1, 3, 5 and 7 %P by mass) and compressed into pellets. Effect of P content in the carbonaceous layer is investigated and some photovoltaic properties of this n-C/p-Si heterostructure solar cells are also studied.

The P atoms are incorporated in the films in the range of about 0.29 - 2.0 atomic percentages, obtained from X-ray photoelectron spectroscopy (XPS). Figure 1 shows the current-voltage (I-V) characteristics are improved remarkably with P incorporation in the carbon films. The slope of curves (semi log scale) are increased with the P content in carbon layer of n-C/p-Si junction indicate improvement of the quality factor (n) with P addition. The decrease of the deviation

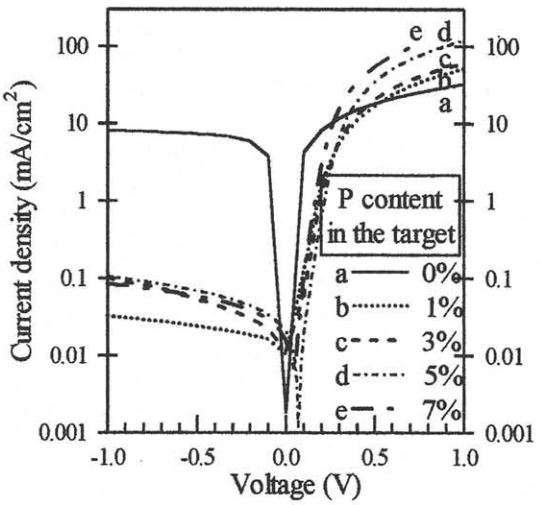

FIG. 1. The I-V characteristics of the n-C/p-Si junction with P doped carbon layers.

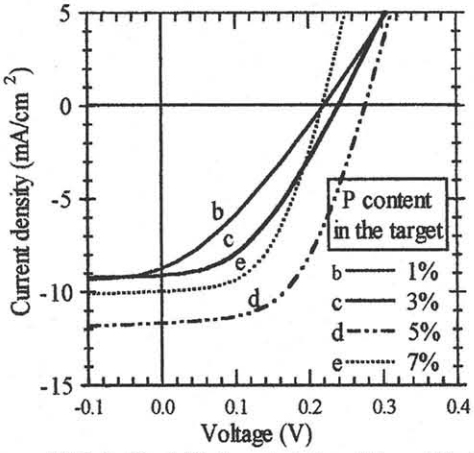

FIG. 2. The I-V characteristics of the n-C/p-Si junction with P doped carbon layers under illumination.

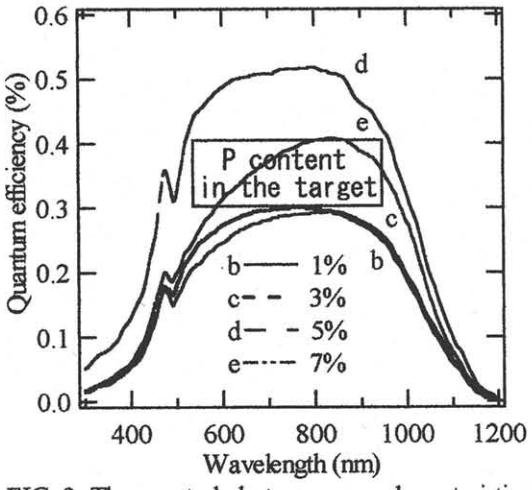

FIG. 3. The spectral photoresponse characteristics of the n-C/p-Si junction with P doped carbon layers.

from the exponential region with P content indicates reduction of the series resistance loss with P content in the film. The reverse saturation current also reduced remarkably with P addition. Figure 2 shows the I-V voltage characteristics of the n-C/p-Si hetero-structure solar cells under AM 1.5 illumination condition (100 mW/cm^2, 25 ℃). The photovoltaic characteristics are improved with the amount of P content up to 5 %P and deteriorate thereupon. The open circuit voltage (V_{oc}) and short circuit current density (J_{sc}) are vary from 0.22 to 0.27 V and 9 to 12 mA/cm^2, respectively. The cell with 5 %P shows highest efficiency, η = 1.25 % and fill factor, FF=0.53 %.

The quantum efficiency (QE) of the cells is observed to improve with P content (Fig. 3). The contribution of quantum efficiency in the lower wavelength region (below 750 nm) may be due to photon absorption by carbon layer and in the higher wavelength region is due to Si substrates.

We found the shape and position of raman spectra and optical band gap are almost unchanged for the n-C films deposited from the targets containing up to 5 %P. up to We also have seen that with P incorporation, the spin density is decreased and conductivity is increased for the n-C films deposited from the targets containing up to 5 %P. The improvement of the photovoltaic properties including photoresponse characteristics could be related to the successful doping and decrease of the defects in the gap states with P addition.

The decrease of efficiency and other photovoltaic characteristics might be due to the creation of gap states and decrease of optical band gap for higher amount of P content (above 5 %P). A detailed study of the junction characteristics is under progress.

Keywords: photovoltaic; solar cell; phosphorus; carbon; pulsed laser deposition.

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