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Properties of an n-C:P/p-Si carbon-based photovoltaic cell grown by radio frequency plasma-enhanced chemical vapor deposition at room temperature

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Abstract

The phosphorus-doped amorphous carbon (n-C:P) films were grown by radiofrequency (RF) power-assisted plasma-enhanced chemical vapor deposition (PECVD) at room temperature using a solid phosphorus target. The influence of phosphorus doping on the material properties of n-C:P based on the results of simultaneous characterization are reported. Moreover, solar cell properties such as series resistance, short-circuit current density, open-circuit current voltage, fill factor and conversion efficiency along with the spectral response are reported for the fabricated carbon-based n-C:P/p-Si heterojunction solar cells by standard measurement technique. The cells' performances have been given in the dark I–V rectifying curve and I–V working curve under illumination when exposed to AM 1.5 illumination condition (100 mW/cm^2, 25 °C). The maximum open-circuit voltage (V_{oc}) and short-circuit current density (J_{sc}) for the cells are observed to be approximately 236 V and 7.34 mA/cm^2, respectively, for the n-C:P/p-Si cell grown at a lower RF power of 100 W. The highest energy conversion efficiency (η) and fill factor (FF) were found to be approximately

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0.84% and 49%, respectively. We have observed that the rectifying nature of the heterojunction structures is due to the nature of n-C:P films.

Keywords: Photovoltaic; Solar cell; Phosphorus doping; n-C:P; PECVD

1. Introduction

Amorphous carbon (a-C) shows semiconducting nature, which promotes its application in the field of semiconductor technology, such as fabrication of photovoltaic solar cells [1]. A large variety of a-C thin films with and without hydrogen due to the difference in bonding and degree of disorder are expected to become very important class materials because of their semiconducting properties. In the past decade, the application of a-C films in the field of semiconductors was the subject of many investigations [1,2]. However, undoped a-C is weakly p-type [3] in nature and the complex structure and presence of a high density of defects restricts its ability to dope efficiently and is the main barrier for its application in various electronic devices. Therefore, when we attempt to utilize such carbon as an alternative material in optoelectronic devices, control of the conduction type through doping of carbon film is indispensable.

The doping mechanism of amorphous semiconductors has always been an interesting issue. Observations from the literature show that semiconducting carbon films can be either intrinsic or they can be doped during or after growth to make them extrinsic semiconductors. Effective doping can modify electronic properties, specially gap states, conductivity, etc., in semiconductor materials. Many attempts have been made to dope carbon films using various elements. It has been reported that phosphorus (P) is the widely used n-type impurity in silicon [4] and is a possible alternative to N in carbon [5]. The optical, electrical and photovoltaic properties of phosphorus doped a-C:H leading to the possibility of device fabrication are studied, which is thought to be promising for n-type conductivity control. An attempt has been made on device fabrication with P-doped a-C thin films (n-C:P) deposited on p-type Si (1 0 0) by radiofrequency (RF) plasma-enhanced chemical vapor deposition (PECVD).

2. Experimental

The P-doped n-C:P thin films were deposited in a 13.56 MHz RF-powered PECVD system, at room temperature, with CH_4 and H_2 as the source gas, in a clean room setup [6]. The distance between substrate stage and top plate was set at 49 mm. Substrate temperature was kept at 20 °C. Base vacuum was typically set at pressure of lower than 2×10^{-4} Pa using a turbomolecular pump and oil diffusion pump. After that, the chamber pressure was maintained at a setting pressure of 20 Pa and