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Photovoltaic properties of n-C:P/p-Si cells deposited by XeCl eximer laser using graphite target

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Abstract

This paper reports on the successful deposition of phosphorous (P)-doped n-type (p-C:P) carbon (C) films, and fabrication of n-C:P/p-Si cells by pulsed laser deposition (PLD) using graphite target at room temperature. 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 n-C:P/p-Si cell fabricated using target with the amount of P by 7 weight percentages (Pwt%) shows highest energy conversion efficiency, $\eta = 1.14\%$ and fill factor, FF = 41%. The quantum efficiency (QE) of the n-C:P/p-Si cells are observed to improve with and Pwt%. The dependence of P content on the electrical and optical properties of the deposited films and the photovoltaic characteristic of the n-C:P/p-Si heterojunction solar cell are discussed.

Keywords: Heterojunction; Phosphorus; Carbon; Pulsed laser deposition

1. Introduction

Silicon (Si) and compound semiconductor based devices are dominated in the solar cell technology. However, the cost of these solar cells is much high to reach for daily life. The

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Si has also drawback of using under illumination due to the degradation, which limits its lifetime and stability. Therefore, it is imperative to find a new kind of clean and cheap energy resource in the 21st century. In the search for alternative materials, carbon—group IV element existing in many forms with a wide range of optoelectrical properties is highly attractive for its possible application in opto-electric devices such as photovoltaic solar cells. At present, carbon-based heterostructures such as, metal insulator semiconductor (MIS) diodes, Schottky diodes, MIS field effect transistor (MISFET) and heterojunction diodes on Si have already been reported and thereby demonstrates the potentiality of carbon materials in electronic devices. Amorphous carbon (a-C) shows semiconducting nature, which promotes its application in the field of semiconductor technology, such as fabrication of photovoltaic solar cells.

However, undoped 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, and so, when we attempt to utilize such carbon as alternative material in opto-electronic devices, control of the conduction type of carbon film is indispensable.

Several authors have reported on carbonaceous films in heterojunction diodes [4–7] and solar cells [8–10], which are quite encouraging in terms of their opto-electronic applications. Veerasamy et al. [4,5] and Silva and Amaratunga [11] have reported significant amount of work on tetrahedral a-C (ta-C, $E_g = 2\,\text{eV}$) and for its use with Si in heterojunction bipolar transistor through successful n-type doping of ta-C using solid phosphorus (P) and nitrogen (N) [1]. N is the common dopant in C films with few exceptions [12,13]. P is widely used as n-type of doping impurity in Si [14] and is a possible alternative to N in carbon [15].

Furthermore, Yu et al. [8] have made a photovoltaic solar cells of configuration of carbonaceous film on n-type Si (n-Si), obtained from 2, 5-dimethyl-*p*-benzoquinone as a source of carbonaceous film by a CVD process. They also have studied the junction characteristics of their cells [16] and reportedly increased the power conversion efficiency from 3.8% to a significant value of 6.45% [17,18].

In this paper, we report our recent findings of photoelectrical properties of pulsed laser deposited n-C:P films deposited at room temperature on single crystal (1 0 0) of p-Si. The measurements on current–voltage (*I–V*) characteristics under dark and AM 1.5 illumination conditions at room temperature ($100\,\text{mW/cm}^2$, $25\,^\circ\text{C}$) of n-C:P/p-Si are conducted. The opto-electrical properties and photovoltaic characteristics of the n-C:P films based solar cells are reported.

2. Experimental

The n-C:P films were deposited on single crystalline Si (1 0 0), n-C:P/p-Si, and quartz substrates by PLD (NISSIN 10X, XeCl excimer laser, $\lambda = 308\,\text{nm}$, $\tau = 20\,\text{ns}$, repetition rate $= 5\,\text{Hz}$, spot size $= 5.5\,\text{mm}^2$), which is focused on the target at an incident angle of 45° to the target normal [a1]. In order to dope, target was prepared by mixing the graphite powder with varying amount of P powder in the range from 1 to 10 Pwt%, and compressed into pellets. Before deposition, the substrates were cleaned with acetone and methanol in a hot water bath at 55 °C for 5 min. After cleaning, they were etched with $HF:H_2O$ (1:10) in order to remove the resistive native oxide formed over the surface, and quickly transferred into the PLD chamber. The films were deposited at room temperature at a base pressure of