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a-C:H absorber layer for solar cells matched to solar spectrum

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Abstract

An a-C:H-based absorber layer for photovoltaic application was fabricated by a DC PECVD. The stepped voltage biasing of the deposition process makes it possible to tailor the bandgap of the manufactured layers and match them to the solar spectrum. Such system can be used as intrinsic layer in p–i–n solar cells as well as in converter solar cells.

Keywords: Solar cell; a-C:H; Thin film; Solar spectrum

1. Introduction

Over the last years carbon-based materials are extensively investigated for use in electronic applications as electron field emitters, in magnetic storage technology, etc. Among them thin films of amorphous carbon (a-C:H) are particularly attractive for the fabrication of photovoltaic cells because their optical bandgap E_g can be easily varied. This can be very important for thin film solar cells [1].

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For example, the conventional solar cell, made of crystalline silicon, has a single bandgap of 1.12 eV. When such a cell is exposed to the solar spectrum (1–3 eV) only the photons with energy equal to the optical bandgap contribute to the cell output. Photons with lower energies make no contributions and energy of photons greater than E_g are wasted as heat. Therefore, the efficiency of solar cells with a single bandgap is about 15%. An improvement can be achieved by using multijunction (tandem) solar cells [2,3]. In such cells a graded bandgap is employed in order to make use of a different portions of the solar spectrum. Usually, graded bandgaps are fabricated by changing the chemical composition of the film, e.g. 1.05 eV for $CuInSe_2$; 1.55 eV for $CuInS_2$; 1.68 eV for $CuGaSe_2$ and 2.3 eV for $CuGaS_2$, which is technically complicated [4]. Therefore, it is desirable to use a material whose graded bandgap is manufactured without alloying. Amorphous hydrogenated carbon is known to be such a material [5,6].

In this paper, we report our results from deposition of amorphous hydrogenated carbon films with graded bandgap obtained only by varying the voltage in the DC PECVD system and fabrication of a-C:H multilayer system with the solar light spectrum matched absorption.

2. Experiments

Hydrogenated DLC (a-C:H) thin films were deposited in a DC plasma CVD reactor. The processed hydrocarbon was benzene diluted with argon. The substrates (silicon wafers, glass or different metals) were placed upon the water-cooled cathode. The metal vacuum chamber acted as anode. Benzene vapors were obtained by boiling of benzene at constant temperature. Before the film deposition the substrates were cleaned in acetone, ethanol and deionized water in ultrasonic bath followed by a 10 min Ar ion sputtering at 2 kV.

Generally, the bandgap of an amorphous hydrogenated carbon film can be changed by changing every deposition parameter. The most interesting possibility is, however, the use of bias voltage variation. By changing this voltage one can vary the kinetic energy of the ionized particles bombarding the substrate

$$E \propto V/p^{1/2}, \tag{1}$$

where V is the voltage bias and p is the pressure in the reactor [7]. This leads to a change of the sp^3/sp^2 ratio and thus to change of the effective optical gap. The voltage variations in our deposition system were limited between 0.5 and 2.5 kV, which is enough to fabricate a-C:H films with optical gaps between 1.2 and 2.1 eV, thus covering practically almost the whole solar light spectrum.

During the deposition the system was continuously pumped and the ion current density was kept nearly constant at about 1 mA/cm^2 by controlling the total pressure at different DC voltages. Only the argon flow was adjusted at a constant benzene flow.

The optical transmission of the films deposited at different bias voltages was measured with a "Cary 5E" spectrophotometer in the 400–1400 nm range, which