Heating equipment with carbon heating tube used to activate silicon and fabricate solar cells

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Introduction

We have proposed a new heating systems with a lamp of carbon heating tube (CHT) for rapid thermal heating [1]. The CHT consists of 2-μm-diameter-carbon powders with a 0.1-g weight in quartz tubes with 60-mm long and 4-mm inter diameter with a packing density of 0.08 [2]. It is heated to 1279ºC by irradiatoin of 2.45 GHz microwave at 200 W. In This paper, we report development in CHT heating system for activation of silicon implanted boron and phosphorus atoms. We also report solar cell fabrication by the CHT heating system.

Experimental

We prepared 4-inch-diameter 17-Ωcm n-type silicon substrates with a thickness of 500 μm with 100-nm-thick thermally grown SiO_2 layers. The ion implantation of boron atoms was conducted with a dose of $2x10^{15}$ cm^{-2} at an acceralation energy of 25 keV to the top surface of the silicon substrates. The peak concentration at the interface of the thermally grown SiO_2 and silicon. Boron atoms at 1.0 x 10^{15} cm^{-2} were effectively implanted in the silicon substrates. The ion implantation of phosphorus atoms at 75 keV was also conducted for the rear surface of the silicon substrates with an effective dose of 1.0 x 10^{15} cm^{-2}. A silicon substrate was cut to four pieces for activating implanted regions.

8 numbers of CHTs with 60-mm long and 4-mm inter diameter and a 0.1-g carbon powders and Ar insert gas at 10.5 Torr were prepared. Two quartz rods were jointed at the edges of the each CHT by thermal welding to hold the CHT in the chamber. The 8 CHTs were placed in parallel with no gap among the CHTs in the microwave cavity. A sample piece was placed on the 8 CHTs and heated with continuous microwave irradiation at 700 W for 150 s. The CHT tempurature was controlled by propotional-integrated-differential feedback method. The temperature increased at 32 K/s and heated to 1200ºC for 100 s and decreased at 23 K/s. After heating, the thermally grown SiO_2 layer was removed using hydrofluoric acid. Microwave transmittance measurement resulted in a sheet resistivity of 79 Ω/sq and an effective lifetime of 115 μs [3]. Comb-type Al electrodes were formed on the top surface and the rear surface was entirely coated with Al electrodes by vacuum evaporation. 100-nm-thick AlO_x layer was deposited on the top surface as anti-reflection layer. The sample was heated by H_2O vaper at 230ºC at 0.8 MPa for 3 h to decrease defect states at the doped and the surface of silicon substrate [4]. The electrical current density as a function of voltage (J–V) was measured in dark and under illumination of air mass (AM) 1.5 light at 0.1 W/cm^2.

Results and Discussions

Figure 1 shows (a) logarithmic plots of absolute electrical current density as a function of voltage under conditions of the dark and illumination of AM 1.5 light and (b) solar cell characteristic. Typical diode rectified characteristics with a low reverse bias current density of $1.3x10^{-3}$ A/cm^2 at -1 V and a high forward bias current density of 0.19 A/cm^2 at +1 V were observed in the dark, as shown in Fig. 1(a). Light illumination clearly showed a photovoltaic characteristic. Typical solar cell current voltage characteristic was obtained as shown in Fig. 1(b). The short circuit current density J_{sc}, open circuit voltage V_{oc}, fill factor FF, and conversion efficiency were 34 mA/cm^2, 0.52 V, 0.63, and 11.28%, respectively. These results indicate that implanted regions were activated well and the build-in potential was formed well in the depletion region.

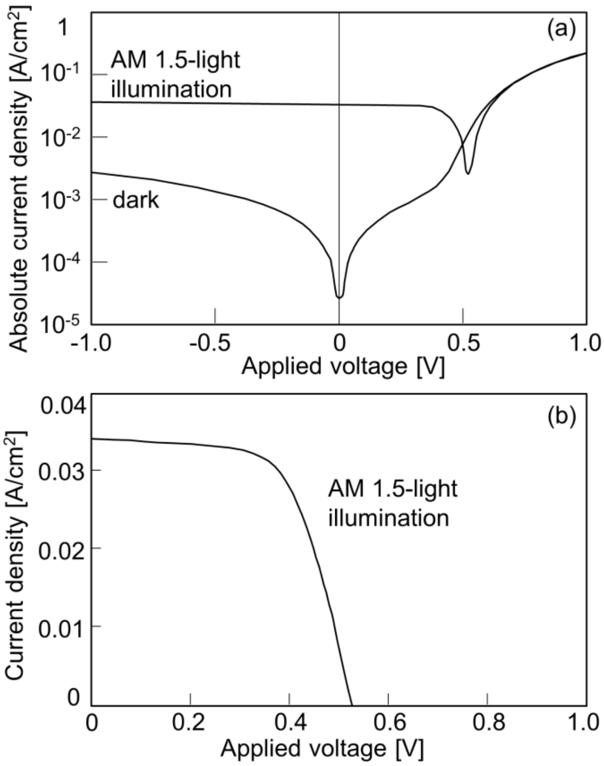

Fig.1 (a) logarithmic plots of absolute electrical current density as a function of voltage under conditions of the dark and illumination of AM 1.5 light at 0.1 W/cm^2 and (b) solar cell characteristic

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