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Activation of Silicon Implanted with Dopant Atoms by Microwave Heating

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I. Abstract

We report a simple heating method with a commercial microwave oven at 1000 W for 9 min with no substrate heating for activation of silicon implanted with boron atoms a doze of 1.0x10^{15} cm^{-2}. Non destructive microwave transmittance measurement revealed that boron doped region had a sheet resistance of 1080 Ω/sq and an activation ratio of 30 %. Minority carrier effective lifetime measured by 635 nm light illumination was increased 5.1x10^{-6} s (as implanted) to 5.2x10^{-5} s (microwave heated). Recrystallization of the implanted amorphous surface region was also achieved. Typical PN diode and solar cell characteristics were obtained.

II. Experimental

18-Ωcm-n-type 500 μm thick silicon substrates were prepared. The top and rear surfaces were coated with 100-nm-thick thermally grown SiO_2 layers. Boron atoms at a dose of 1.0x10^{15} cm^{-2} were implanted at 25 KeV to the top surface of n-type silicon substrates. The samples were heated with microwave irradiation using a 2.45 GHz commercial microwave oven at 1000 W for 9 min [1]. The sheet resistance and minority carrier effective lifetime τ_{eff} was investigated by the 9.35 GHz microwave transmittance measurement system in the dark field and 635 nm continuous light illumination at 1.5 mW/cm^2 to the top surface [2]. Optical reflectivity spectra were also measured and analyzed to estimate the crystalline volume ratio [3]. Thermally grown SiO_2 layers were subsequently removed by hydrofluoric acid. Comb-type Al electrodes were formed on the top and bottom surfaces by vacuum evaporation. PN diode and Solar cell characteristics were measured using air mass AM 1.5 solar simulator at 100 mW/cm^2.

III. Results and discussion

The sheet resistance obtained from the microwave transmissivity measurement in the dark field was decreased from 360 (initial) to 270 Ω/sq by the microwave heating, as shown in Fig.1 (a). This means that boron atoms were activated with a sheet resistance 1080 Ω/sq in the implanted surface regions. The analysis using the mobility of doped silicon concluded that 30 % of boron atoms were activated via heating samples to high temperature by microwave irradiation at 1000 W. τ_{eff} was very low of 5.1x10^{-6} s because of substantial carrier recombination defects caused by boron implantation. It was markedly increased to 5.2x10^{-5} s by the microwave heating, as shown in Fig. 1(b). The recombination velocity estimated from experimental τ_{eff} decreased from 10000 (as implanted) to 800 cm/s (microwave heated). The density of recombination defect was decreased by the microwave heating. The analysis of optical reflectivity spectra revealed that the crystalline volume ratio in the top 96 nm deep region was decreased by the boron implantation. Especially, the crystalline volume ratio in the top 5 nm deep region was low of 0.23 for the as-implanted sample. It was increased to 0.76 by microwave heating. The microwave heating also increased the crystalline volume ratio to almost 1.0 in the deep region from 5 to 96 nm. The surface region was well recrystallized by microwave heating.

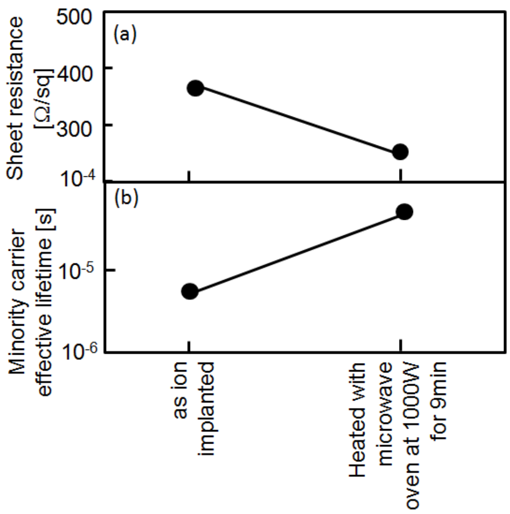

Fig.1: sheet resistance (a) and minority carrier effective lifetime (b) for samples as-implanted and microwave heated at 1000 W for 9 min.

Typical rectification characteristic was observed in electrical current as a function of voltage in the dark field for the samples formed with Al electrodes on top and rear silicon surfaces. Photo-induced current and photovoltaic effect were observed in the case of AM 1.5 light illumination at 100 mW/cm^2. Precise analysis of solar cell characteristic gave the short circuit current density, open circuit voltage, fill factor of 1.4x10^{-2} mA/cm^2, 0.44 V, 0.59, respectively. Those results indicate that microwave heating has a possibility of heating of silicon substrate for activating implanted dopant atoms and recrystallizing the implanted region. We will discuss physics of activation of dopant atoms and surface passivation by the method of microwave heating.

References

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