Passivation of silicon surfaces by heat treatment in liquid water at 110°C

TUAT¹, Kanagawa Univ.², Tomohiko Nakamura¹, Toshiyuki Sameshima¹, Masahiko Hasumi¹, and Tomohisa Mizuno²

E-mail: tsamesim@cc.tuat.ac.jp

I. Introduction

We have developed a simple and effective passivation method of silicon surfaces by heating silicon substrates in liquid water at a low temperature of 110°C for the purpose of application to fabrication of photo-sensors and photovoltaic devices [1]. We demonstrate a high value of the photo-induced minority carrier effective lifetime $\tau_{\text{eff}}$. We also show that the $\tau_{\text{eff}}$ maintains high values for a long time. We discuss the structural analysis of the passivation layer. We will also report MIS type solar cell fabrication using the present passivation method.

II. Experimental

500-μm-thick 4-inch sized n- and p-type single crystalline silicon substrates were prepared as the initial samples. 1) Native oxide layers of the surfaces of some samples were initially removed by dipping the samples in 5%-diluted hydrofluoric HF acid. The other samples maintained their surfaces with native oxide layers. They all were placed in a pressure proof chamber with pure water and heated in liquid water at 110°C for 1 h. $\tau_{\text{eff}}$ spatial distribution was investigated by the 9.35 GHz microwave transmittance measurement system under 635 nm continuous light illumination. To analyze the thickness and structure of the passivation layers, in-depth profiles of the atomic concentration of silicon, Si, oxygen, O, and hydrogen, H, atoms for the n-type initial and heat treated samples were measured by High Resolution Rutherford Backscattering Spectrometry (HR-RBS) and High Resolution Hydrogen Forward Scattering Spectrometry (HR-HFS).

III. Results and discussion

1) $\tau_{\text{eff}}$ values were markedly increased in the range from 8.3x10⁻⁴ to 3.1x10⁻³ s by treatment with HF dipping followed by heating in liquid water at 110°C for 1 h, as shown by $\tau_{\text{eff}}$ spatial distribution for the 4-inch sized n-type sample in Fig. 1. This result clearly shows that the silicon surfaces were well passivated by the heat treatment in liquid water at 110°C for 1 h over 4-inch-sized area. 2) The average of $\tau_{\text{eff}}$ for n- and p-type samples was maintained a high value of 1.2x10⁻³ s and 2.7x10⁻⁴ s at 1900 h and 1400 h after 110°C heat treatment in liquid water. 3) HR-RBS and HR-HFS analysis results in formation of thin oxide layer with a thickness of approximate 0.7 nm for the n-type sample treated with HF dipping followed by heating in liquid water at 110°C for 1 h, as shown by in-depth profiles of the atomic concentration of Si (solid black curve), O (solid gray curve), and H atoms (dashed curve) in Fig. 2. The thickness of the oxide layer was similar to that of the native oxide layer. 4) Although $\tau_{\text{eff}}$ values were very low in the range from 5.9x10⁻⁷ to 1.2x10⁻⁵ s and from 1.0x10⁻⁷ to 5.1x10⁻⁶ s for n- and p-type initial samples with native oxide layers, respectively, they were markedly increased to values ranging from 9.1x10⁻⁴ to 1.5x10⁻³ s and from 9.5x10⁻⁵ to 5.4x10⁻⁴ s, respectively, by directly heating samples with maintaining native oxide layers in liquid water. These results indicate that the present heat treatment improves native oxide layers and reduces silicon dangling bonds at the silicon surface region.

Reference