Low Temperature Cat-Doping of Phosphorous Atoms into Crystalline Silicon through Ultrathin SiO_2 Layer

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Cat-doping is a novel doping method to dope phosphorous (P) or boron (B) atoms into crystalline silicon (c-Si) at temperatures as low as 80°C, by exposing the c-Si to species generated by catalytic cracking reaction of phosphine (PH_3) and diborane (B_2H_6) with heated tungsten (W) catalyzer[1]. The method is expected to be used for improvement of solar cell efficiency through potential control of c-Si surface. However, some of c-Si surface may be covered with ultra-thin silicon dioxide (SiO_2) passivation layers, and also, the coat of c-Si surface by thin SiO_2 layers is more effective to avoid epitaxial growth of Si when a-Si layers are formed on c-Si to make hetero-junction. Thus, it is important to know the performance of Cat-doping through such thin SiO_2 layers.

Here, we attempted to cover the surface of the c-Si with ultra-thin SiO_2 layers. These SiO_2 layers were fabricated by thermally oxidized c-Si in dry oxygen (O_2) at temperature from 400 to 700 °C. Thickness of the SiO_2 layers as a function of oxidation temperature is shown in Figure 1. The ultrathin SiO_2 films with thickness varied in a range from 1.0 to 1.7 nm and good uniformity were obtained. Thickness of the SiO_2 can be controlled by varying oxidation temperature. Figure 2 shows relationship between the sheet carrier density and oxidation temperature of SiO_2 films after p-type c-Si samples are Cat-doped by P atoms at temperature of catalyzer (T_{cat}) of 1800 °C for 30 min through the SiO_2 layer. Sheet carrier density shown in this figure is for c-Si samples before and after removing the SiO_2 layers. The SiO_2 was removed by dipping in HF 5%. As can be seen, the surface of all p-type c-Si covered with SiO_2 films was converted to n-type. Sheet carrier density likely increased when oxidation temperature of SiO_2 film and thickness decreased. For the c-Si covered with the SiO_2 film oxidized at 400 °C sheet carrier density was about 4.2×10^{-12} and 5.1×10^{-12} cm^{-2} before and after removing the SiO_2, which are comparable with sample was not covered with SiO_2.

From these results we can conclude that Cat-doping can achieve even through the SiO_2 film, and thus, it is apparent for Cat-doping to be applied in various devices fabrication.

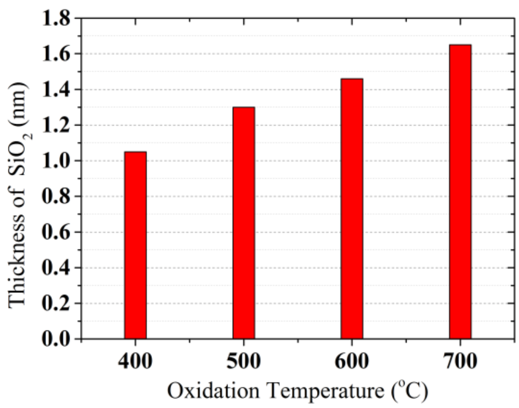

Figure 1: Thickness of the SiO_2 as a function of oxidation temperature.

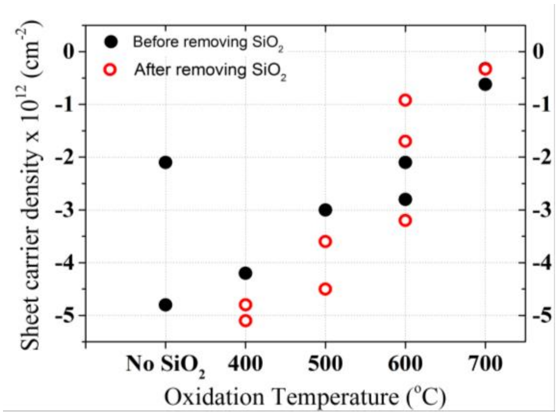

Figure 2: Sheet carrier density of p-type c-Si samples P Cat-doped through SiO_2 as a function of oxidation temperature of the SiO_2

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[1] H. Matsumura et al., J. Appl. Phys., **116**, 114502, 2014.