c-Si tunnel junctions obtained by proximity rapid thermal diffusion for tandem photovoltaic cells

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1. INTRODUCTION

2-terminal c-Si based tandem solar cell is an approach to overcome the Shockley-Queisser efficiency limit of single junction Si solar cell. III-V semiconductors, perovskites and copper indium gallium selenide (CIGS) with flexible bandgaps are good candidates for top cell to achieve optimal bandgap matching between sub-cells [1]. Considering the electrically connection of two sub-cells, low-resistance c-Si Esaki tunnel junctions is an attractive method. Various techniques can be used to fabricate Si tunnel junctions, such as ion implantation [2], molecular beam epitaxy (MBE) [3], plasma-enhanced chemical vapor deposition [4], etc. The technique adopted here is proximity rapid thermal diffusion (RTD), which has an advantage of low-cost because of no vacuum requirement and low thermal budget.

2. EXPERIMENTS AND RESULTS

A Cz silicon (111) wafer with n^+ emitter realized by standard LYDOP process was used as target wafer. The difficulty to realize p^{++}/n^{++} tunnel junction is that the solid solubility of B in Si is 4 times less than the one of P in Si [6]. Therefore, we use a 2-steps annealing process to facilitate the B compensation by decreasing P concentration on the surface. Electrical capacity voltage (ECV) profiler was used to measure the activated dopants concentration of the sample.

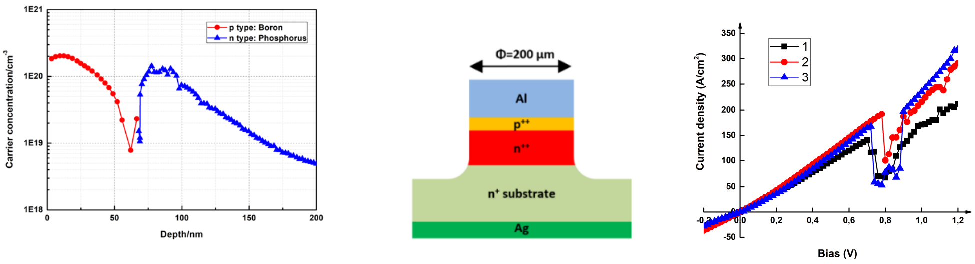

FIG.1. Carrier concentration of a p^{++}/n^{++} type tunnel junction measured by ECV. Schematic and I-V characteristics of p^{++}/n^{++} single tunnel diode on (111) Si substrate

The concentration of holes and electrons were both higher than 10^{20} cm^{-3} at the p^{++}-n^{++} interface. The doping profile indicates that this junction implemented by proximity RTD is suitable for interband tunneling. Tunnel diodes were fabricated by photolithography process after ECV characterization. The peak current density is 140-192 A/cm^2 and the peak to valley ratio is 1.91-3.15. The series resistance at low bias is $4\text{-}5\times10^{-3}$ $\Omega\cdot cm^2$. The results are comparable to the results of tunnel diodes obtained by other methods [2]. This p^{++}/n^{++} Si tunnel junction is feasible for the application in tandem solar cell. We will also present results with n++/p++ (100) Si tunnel diodes, showing the interest of this method whatever crystalline orientation and doping sequence are.

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