

All Si Tandem Solar Cells by PECVD Epitaxy

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Abstract

Tandem c-Si/c-Si solar cells have the capacity to overcome Shockley–Queisser limit and reach conversion efficiencies up to 30.7% based on the modeling performed by F. J. Haug & Ch. Ballif [1]. According to them high excess carrier density in the top-cell allows for a voltage in the tandem device that is more than twice the voltage of an equally thick single junction solar cell. In this work, we used plasma enhanced epitaxial growth to experimentally investigate this type of tandem device. As the first step, intrinsic, n-type, and p-type epitaxial layers of different thicknesses were deposited on c-Si substrates. The crystallinity and thickness of these layers have been verified by Ellipsometry measurements. Next, epitaxial solar cells were fabricated in order to measure their performance and to compare them with similar ones reported by Romain Cariou [2]. Having found that we have electronic quality material ready to be used in tandem devices, epitaxial stacks containing p-type, n-type and intrinsic epitaxial layers were grown over a c-Si substrate as shown in the schematic diagram in Figure 1. These stacks were then completed by depositing passivation and doped a-Si:H layers. Finally, ITO and Ag contacts were deposited by sputtering. The Fig. 1 shows the structure and the performance of best tandem solar cell in its as-deposited state and after annealing in air at 275°C for 10 minutes. It can be seen that annealing increases the open circuit voltage (V_{oc}), which can be attributed to the activation of boron atoms in the p-type epitaxial layer [3]. This device provides a proof of concept for a working tandem solar cell. Further experiments are necessary to optimize its performance having in mind the tradeoff between the activation of boron, the passivation of defects upon annealing but also their formation if the temperature is too high.

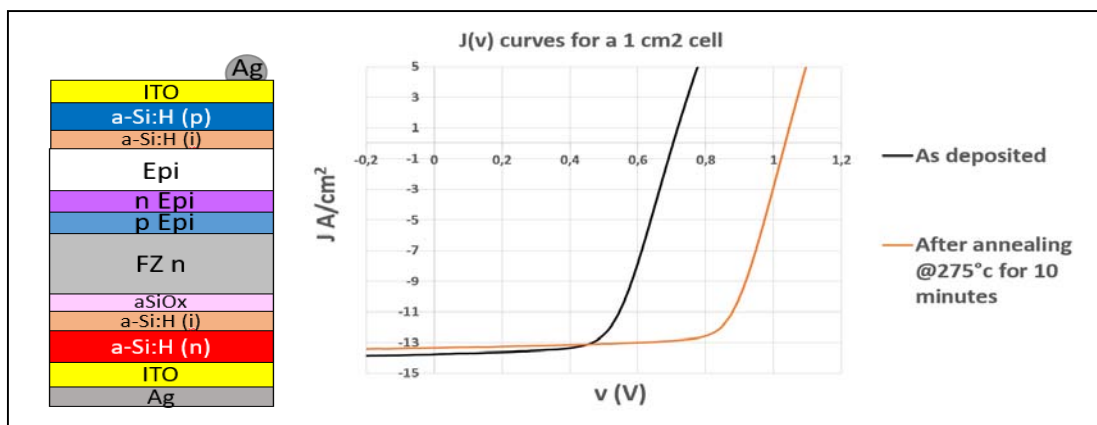


Figure 1. Schematic diagram of a tandem c-Si/epi c-Si solar cell and its corresponding J(V) characteristics in the as-deposited state and after annealing.

References

- [1] F.-J. Haug and C. Ballif: "A recalculation of the efficiency limit in crystalline Si/Si tandem solar cells» Solar Energy Materials and Solar Cells 224 (2021) 111008
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- [3] M. Chrostowski, J. Alvarez, A. Le Donne, S. Binetti, and P. Roca i Cabarrocas: "Annealing of Boron-Doped Hydrogenated Crystalline Silicon Grown at Low Temperature by PECVD" Materials. 12 (2019) 3795