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ScienceDirect

Energy Procedia 55 (2014) 589 – 595

Energy Procedia

4th International Conference on Silicon Photovoltaics, SiliconPV 2014

Towards 20 % solar cell efficiency using silicon from metallurgical process route

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Abstract

In this work we present high efficient silicon solar cells based on low-cost UMG-Si purified by the metallurgical process route of Elkem Solar with efficiencies close to 20 %. Solar cells were fabricated by two different PERC solar cell process sequences using only processes steps which are already well-known in industry and transferable to mass production. Simultaneously solar cells were fabricated by the state-of-the-art full Al-BSF process as reference. The investigated wafers were cut from a Cz grown crystal based on UMG-Si blended with 40 % poly silicon and were compared to 100 % poly-Si wafers. It is shown that applying PERC processes to the silicon wafers can enhance the cell efficiency by 0.8 % absolute to reach average cell efficiencies of 19.8 % and thus demonstrates the excellent quality of the fabricated c-Si solar cells. Furthermore it is proven that UMG-Si does not show feedstock-related limitations to high efficiency concepts such as the PERC process. To our knowledge these results present the highest obtained cell efficiencies for silicon solar cells based on UMG-Si so far.
Studies of light induced degradation of PERC and full Al-BSF solar cells from both kinds of feedstock were conducted to determine the influence of recombination active boron-oxygen complexes on the respective solar cell performance. The obtained results reveal higher losses for PERC solar cells, which can be explained by the higher sensitivity of PERC solar cells to changes of the bulk lifetime. This is also confirmed by PC1D simulations.

Peer-review under responsibility of the scientific committee of the SiliconPV 2014 conference

Keywords: UMG-Si, PERC, high efficiency, LID

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doi:10.1016/j.egypro.2014.08.030

1. Introduction

As the PV industry is targeting cost-reduction of PV modules towards 50 $c/Wp several key technologies such as PERC, PERL, HJT and IBC concepts recently attracted the attention of the PV community as feasible concepts to achieve this target. These technologies lead to higher solar cell conversion efficiency and power output at a moderate increase of production costs, thus enabling low specific costs of PV generated electricity. A further possibility to reduce the overall costs of PV modules is the use of low-cost silicon feedstock, such as UMG-Si, as it was introduced by different companies [1,2].

The utilization of such low-cost silicon materials of course only can contribute to cost reduction, if it enables similar efficiencies as high purity poly-Si. An equal performance of UMG-Si to poly-Si in both full Al-BSF and PERC process has previously been shown by [3,4], but on cell efficiency levels below 19 %. Nowadays second generation solar cell concepts aim for even higher efficiencies to further reduce the costs per watt-peak. As more and more second generation solar cells enter the market, it is inevitable to evaluate the potential of UMG-Si for such high efficiency concepts targeting 20 % solar cell efficiency. Especially the requirements for new PV factories or expansions released in China, the world's largest PV module manufacturing market, demanding 20 % cell efficiency for Cz silicon solar cells and 18 % cell efficiency for multicrystalline silicon solar cells raise the interest in high efficiency concepts.

The UMG silicon used in the presented experiment is Elkem Solar Silicon®, which is produced via three important subsequent process steps: slag treatment, leaching and directional solidification leading to high quality UMG-Si with a low carbon-footprint and a shorter energy payback time [5] compared to conventional poly-Si from Siemens-process route.

2. Experimental

Silicon wafers from a Cz grown UMG-Si crystal blended with 40 % virgin poly-Si were taken for the following experiments. The base resistivity of the wafers is in the range of 2.2 Ωcm after dissolving of thermal donors. As reference 100 % poly-Si wafers with a similar base resistivity of 2-3 Ωcm were chosen.

Two different PERC process routes (PERC-1 and PERC-2) with the intention to fabricate a sufficiently good rear side passivation on the flat etched surfaces with local Al back contacts were applied. The accordingly produced PERC solar cells were compared to solar cells processed by the full Al-BSF baseline process. The different process schemes are shown in figure 1.

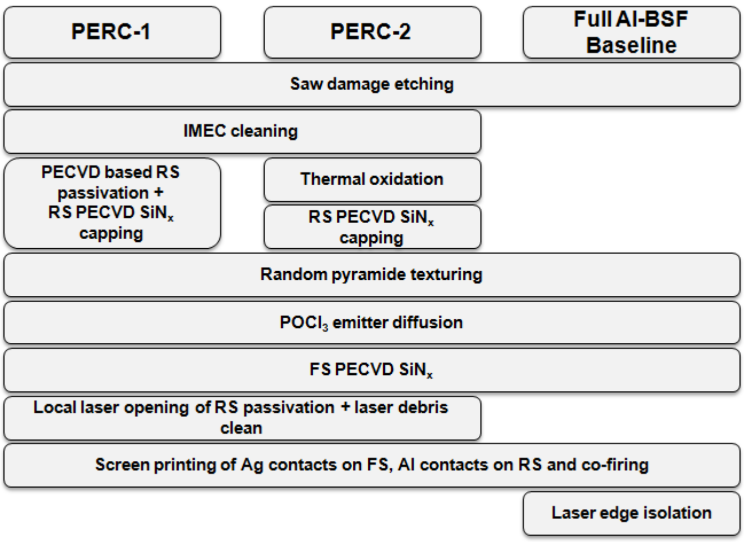

Fig. 1. Overview about applied process steps and order