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Novel concepts in thin film solar cells

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According to simulations [1,2] silicon/germanium (Si/Ge) alloys incorporated into the base of Si solar cells should enhance the efficiency. The attractive feature of this technique is that the fabrication technology of the solar cells do not need to be changed. Here we have deposited Ge-islands on standard, p-type (10Ωcm) Si substrates by MBE in the 3-dimensional Stranski-Krastanow growth mode [3] at elevated temperatures (700°C). The Ge-island layers form the base of the solar cell. We employed antimony (Sb) as surfactant to achieve rather high island densities (>10^{11} cm^{-2}, typical lateral width 20nm and heights 3nm) and we have stacked up to 75 Ge-island layers on top of each other with 8 monolayers (ML) each of which are separated by 9nm of an undoped Si buffer layer. On top of it we deposited a 200nm undoped Si layer on top of which we performed an n^+ emitter diffusion such that all the Ge-island layers are situated within the depletion zone of the pn junction (W~1μ). Non-optimized solar cells have been fabricated using a standard metal grid with TiPdAg contacts on the front side and a whole area metal contact (AlTiPdAg) on the backside of the wafer. The layer structure of the Ge-dot solar cell is shown in Fig. 1. AFM and TEM microscopy were used to characterize the growth of Ge-islands under various growth conditions and post-thermal treatment. Photocurrent measurements exhibit a higher response of the fabricated solar cells in the infrared regime compared to standard Si-cells (Fig. 2). However, the due to the low bandgap of Ge reduced open circuit voltage compensates the surplus in photocurrent with

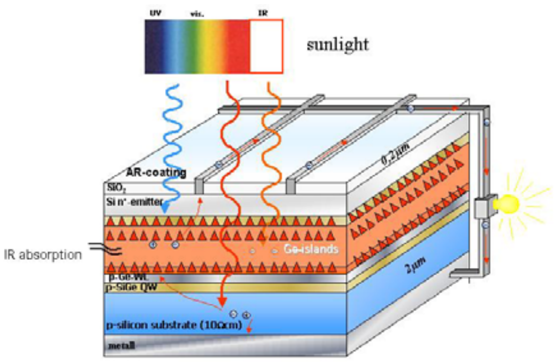

Fig. 1 : Ge- Qdot solar cell with the 3-dim. Ge-islands incorporated in the base of the Si solar cell. The Ge-dots primarily absorb in the infrared part of the spectrum where Si solar cells are transparent.

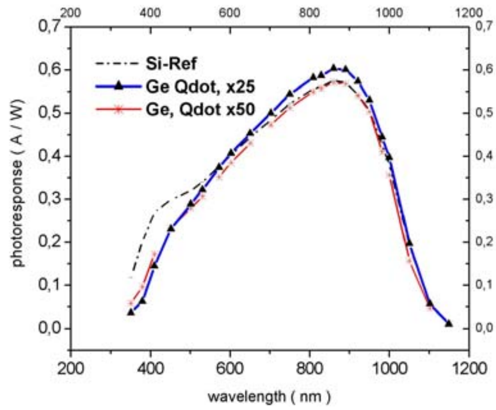

Fig. 2 : Photocurrent spectrum of Ge-dot solar cells compared with a Si reference cell

no net improvement of the overall conversion efficiency for a standard Si solar cell (thickness >200μ). Another intrinsic problem of these stacked Ge-layer structures is the recombination of the from Ge-wells excited carriers in the upper part of the sample. This can be clearly seen in the spectrum of Fig. 2 where the 75 Ge-layer structure shows a lower photocurrent compared to the 50-Ge layer structure. Therefore we suggest a technology which provides a lateral p-contact to all Ge-quantum dots by etching holes into the Si solar cell via plasma etching (∅~10-15μ). Subsequently a p^+ diffusion is done on the backside and in the holes which provides a p-contact on flat backside as well as in the etched holes of the wafer. By a further lithography and etching step the emitter is etched away around the holes on the front side which isolates the emitter from the p-contact. By implementing an additional SiGe quantum well layer during growth to which the carriers will be transferred from the Ge-dots the photoexcited carriers will be very effectively transported to the p-contact which should boost the efficiency of the Ge- Qdot solar cell. We therefore suggest to use a combined Ge island and SiGe QW structure to improve the efficiency of thin film Si solar cells for space applications.

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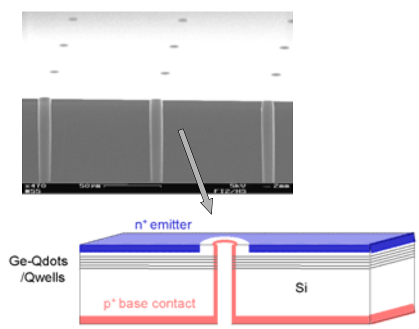
Fig. 3 Concept of lateral p-contact of Ge-Qdot solar cell using etched holes with a p-contact diffusion



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