The SDS process for silicon ribbon growth

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Abstract

A lot of research has been done to try to reduce the costs of solar cells by developing ribbon growth techniques that bypass the ingot/wafering step. The SDS-Silicon on Dust Substrate process, here described, is a technique to produce ribbons directly from the gas phase. Test solar cells were fabricated on SDS ribbons as a demonstration of concept of this new technique.

Keywords: Photovoltaics; Solar Cells; Ribbons

1. Introduction

A lot of effort has gone into reducing the costs of solar cells by bypassing the ingot/wafering process, which is currently the dominant industrial process. Early on it was realised that such a wasteful process could be avoided by the direct preparation of silicon sheet by ribbon growth techniques [1][2]. The SDS-Silicon on Dust Substrate process, described here, is a new method for the growth of silicon ribbons for photovoltaic applications.

2. Process description and experimental setup

In the SDS process (see flow diagram in Fig. 1) a bed of silicon dust, obtained from high purity gaseous feedstock, is prepared, acting both as a cheap substrate and as a “sacrificial detachment layer”. A thick film is then deposited on this bedding layer by fast CVD, at low temperature and atmospheric pressure. Finally, the detached free standing ribbon is recrystallised by a floating molten zone (ZMR - Zone Melting Recrystallization) technique.

The advantages of the SDS process are: (i) no substrate and therefore no associated cost and no contamination; (ii) low energy and thermal budget by use of atmospheric pressures and low temperature CVD; (iii) high quality, free standing, crystalline silicon sheet by float zone crystallisation, with no contact with foreign materials.

The SDS process is well suited for operation in a continuous mode. For example, at a 20 µm/min deposition rate (achievable with silane at ~900ºC), 10 minutes are required to achieve a 200 µm thick pre-ribbon. This deposition rate is such that, during the recrystallization step, with a constant advance speed of 10mm/min, only a 100 mm long high temperature (900ºC) zone is required.

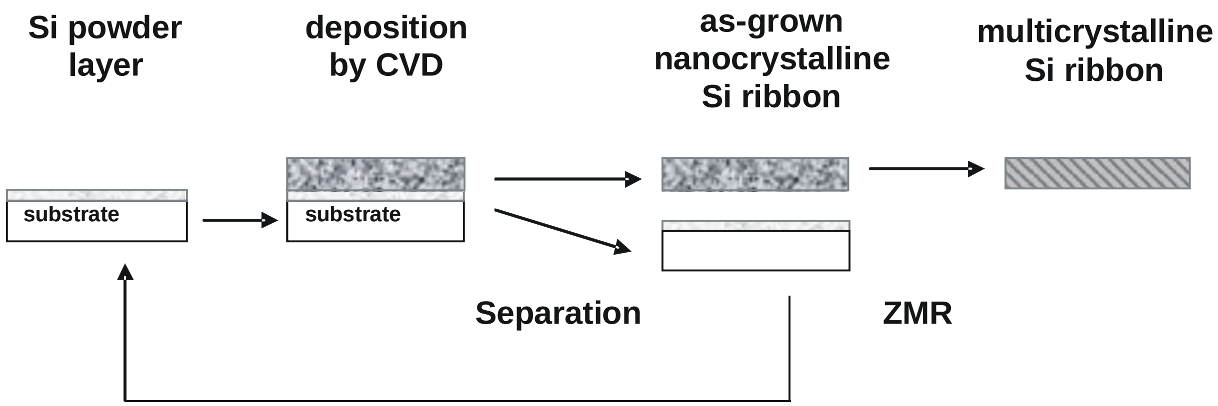

Fig. 1. SDS process flowchart.

2.1. Experimental setup

Silicon is deposited by CVD on a layer of silicon powder. The deposited layer is easily separated from the quartz substrate owing to the presence of the powder layer and constitutes a self supported pre-ribbon. By ZMR processing this pre-ribbon is converted into a multicrystalline ribbon that can be used as substrate for solar cells.

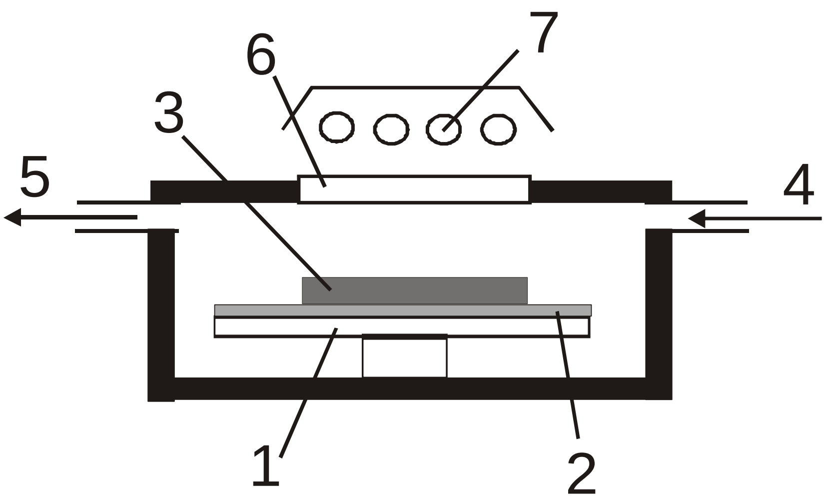

Fig. 2. Experimental setup for the CVD deposition step.

The CVD deposition step was tested so far in a specially designed batch mode furnace (see Fig.2). The substrate (1) is a single plate of quartz covered by a layer of silicon powder (2). It remains stationary in the central stage below the quartz window (6). The powder layer is heated by the radiation from halogen lamps (7); silane gas flows (4) through the furnace and thermally decomposes depositing silicon on top of the powder layer. Conditions in the furnace are set to ensure an approximately uniform growth of the deposited section of silicon (3) ribbon on top of the flattened powder layer (2).

3. Results

Several runs were performed to optimize CVD deposition conditions. It was observed that film porosities below ~50% allowed reproducible ZMR [3].

The SDS pre-ribbons produced during the CVD step are intrinsic. To be used as base material for solar cells they must be doped. We used a spray doping technique [4] to do the p-doping and ZMR in one step.

The recrystallized ribbons were 300 µm thick, with a crystalline structure consisting of grains of a few centimetres long and a few millimetres wide, p-doped, with resistivities of 1.5 Ωcm.

Fig.3. Top view of a SDS ribbon after the final ZMR step. The ribbon is 3 cm wide and the thickness is 300 µm.

We prepared very simple (no passivation nor anti reflection coatings) solar cells on this new material to assess the overall potentiality of the whole process.

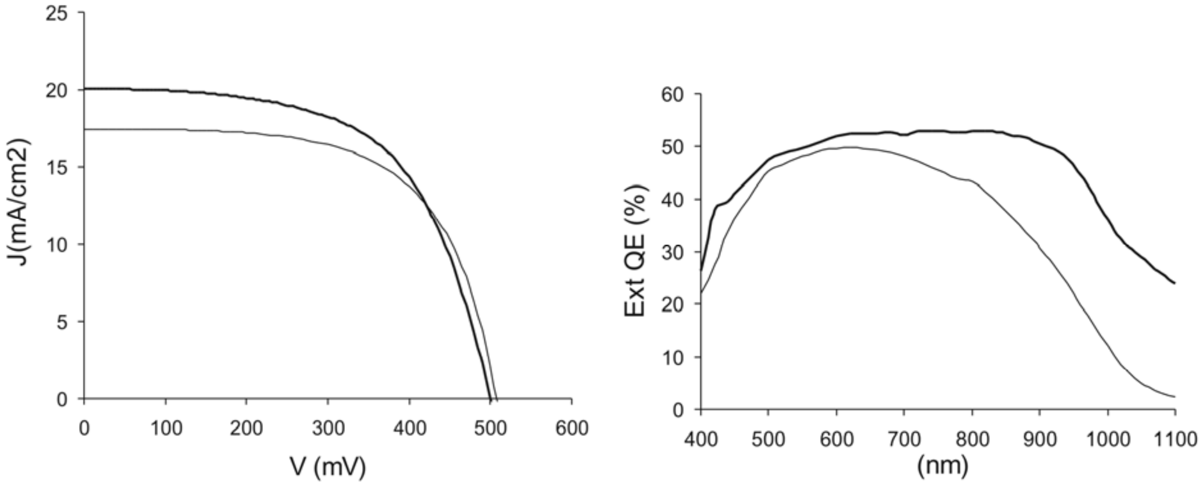

Fig. 4 – I-V and Spectral Response results for a control cell (bold line) and for the best SDS cell in this study.

The lower values of the short-circuit current in SDS samples when compared to the control samples are in agreement with the lower quantum efficiency values in the infrared region of the spectrum in the Spectral Response measurements.

Nevertheless, the results on these first SDS solar cells, namely the obtained value for the diffusion length in the best SDS (70 µm) clearly demonstrate the ability to achieve high efficiencies.

4. Conclusion

The SDS-Silicon Dust Sheet method for the formation of silicon ribbons based on a gaseous feedstock was described, and the feasibility demonstrated by the preparation of full working photovoltaic cells on a SDS ribbon silicon. The advantages of the SDS process are (i) no substrate is required, thus reducing sources of impurity and cost; (ii) low energy budget because CVD is performed under atmospheric pressures and at low temperatures; (iii) high quality, free standing, crystalline silicon sheets are made possible by the non-contact float-zone crystallisation with in-situ doping.

5. References

[1] Wald F., *Crystals: Growth, properties and applications 5,* Springer: New York, 1981, 147-198

[2] Ciszek T., *Silicon Processing for Photovoltaics I,* North-Holland, 1987; 131-166

[3] Pinto C.R., Serra J.M., Brito M.C., Gamboa R., Maia Alves J., Vallêra A.M., *Proceedings of 21st European Photovoltaic Solar Energy Conference and Exhibition,* Dresden, 2006, 1099-1101

[4] Silva J.A., Brito M.C., Costa I., Maia Alves J., Serra J.M. and Vallêra A.M., *Solar Energy Materials and Solar Cells* 2007; doi:10.1016/j.solmat.2007.08 .002