ZONE MELTING RECRYSTALLIZATION OF SELF SUPPORTED SILICON RIBBONS OBTAINED BY FAST CVD FROM SILANE

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ABSTRACT: In this paper we report our first results on zone melting recrystallization (ZMR) of self supported pre-ribbons obtained by fast CVD from silane.

Keywords: Silicon, Ribbon, Zone melting.

1 INTRODUCTION

It is recognized that solar cell production costs would be substantially reduced if high-quality crystals could be obtained by short-circuiting the ingot/wafering path, which is the dominant industrial process.

Already in the early days of solar cells it was realised that ingot growth followed by wafering was a very wasteful process, and that ribbon growth techniques should be the right way to pursue. Although easy to enunciate, this problem proved very difficult to solve. This is demonstrated by the fact that even today ~95% of the industrial production, while shifting from Czochralski single crystals to directionally solidified multicrystalline ingots, still relies on silicon crystallization in ingot form, followed by wafering. Out of many proposed and researched alternatives, only two processes of sheet growth (the EFG process and String Ribbon) have very recently reached significant industrial production, still accounting for only ~5% of production volume.

Silicon ribbons can be obtained by:

i) Direct growth of self supported silicon ribbon from the melt. That’s the case of EFG [1] and String Ribbon [2].

ii) Growth on a substrate, remaining attached to it. We mention here the research done at FhISE [3], IMEC [4] as examples of silicon growth on a low-cost silicon substrate.

iii) Growth on a substrate, later detached from it. RGS [5] and SSP [6] ribbons are two representative cases of this group.

All these techniques present different problems associated with impurity contamination related to the dies or substrates used. This is true even for processes that use Chemical Vapour Deposition (CVD) of silicon films on large area substrates. Despite numerous attempts, no foreign substrate process has proved outstandingly attractive so far. Also, for reasons still not understood, CVD on multicrystalline silicon substrates has systematically underperformed the expectations.

We are developing a two-step process aiming to produce high quality crystalline silicon sheet for photovoltaic application: (1) fast deposition by CVD of a self-supporting silicon sheet from the gas phase, a pre-ribbon of high purity but structurally unsuitable for solar cells, with high porosity and microcrystalline structure, followed by (2) zone melting recrystalization (ZMR) to produce large grain crystalline silicon sheet capable of yielding high efficiency solar cells.

This paper describes the experimental details and preliminary results of ZMR on these self supported pre-ribbons.

2 EXPERIMENTAL PROCEDURE

2.1 Samples

Pre-ribbons of high purity are prepared by fast CVD deposition. They are structurally unsuitable for solar cells because of their microcrystalline structure and high porosity. Over 100 pre-ribbons were prepared, with average sheet densities between 42 and 84 mg/cm^2, corresponding to solid silicon thicknesses between 180 and 360µm, with varying degrees of porosity and homogeneity. They were made of undoped silicon.

2.2 ZMR

At this stage of development of this process, our purpose was the evaluation of the pre-ribbons properties that could lead to successfull ZMR.

We are using an in-house developed ZMR furnace. It has two elliptical mirrors that concentrate the radiation of two 1000W halogen lamps as shown on Fig.1. In a typical run, the sample is moved downwards with a 3mm/min velocity and the atmosphere inside the furnace is renewed with a 1.1 l/min argon flux.

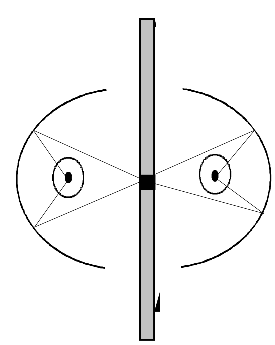

Figure 1: ZMR setup. Radiation from two halogen lamps is focused onto the sample surfaces creating a 2mm wide molten zone.

3 RESULTS

ZMR proved to be non trivial due to the peculiar characteristics of these pre-ribbons, which may vary widely according to deposition conditions.

In this preliminary work we used ZMR as an assessment tool of feedback to the CVD deposition step, that is, as a tool for searching for the conditions that bring about satisfactory recrystallization of the pre-ribbons.

We observed that we could obtain pre-ribbons with three different cross sections: plane-convex (that is, thinner at the edges), plane-concave (thicker at the edges) or plane-plane (uniform thickness). The first leads to ZMR disruption at the edges of the ribbon; the second to holes in the middle. The third is the one that allows successful ZMR provided the pre-ribbon has low enough porosity. We found out experimentally that successful ZMR only occurred for porosities $\leq 50\%$.

Finally, control of pre-ribbon inhomogeneity of mass distribution, and use of CVD growth conditions that produced appropriate porosities, led to reproducible crystallization with low failure rate.

The width of the molten zone during processing is of the order of 30mm and is limited by the capabilities of the ZMR furnace used.

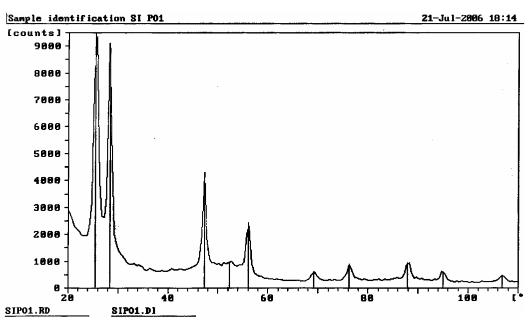

Figure 2: X-ray powder diffraction of the pre-ribbon before ZMR.

X-ray powder diffraction indicates that the pre-ribbon before ZMR is microcrystalline (Fig. 2). After ZMR the grain structure improves significantly as expected (see Fig.3). The successfully recrystallized ribbons have

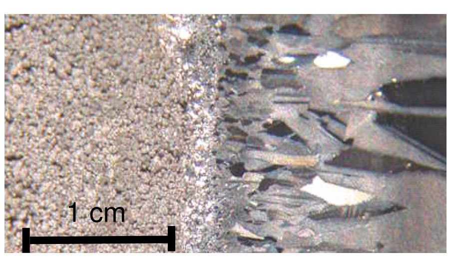

Figure 3: Close-up of the starting ZMR process showing the difference of the grain size after ZMR.

thicknesses around 200µm with a crystal structure consisting of grains which are a few centimeters long and a few millimeters wide as shown in Fig. 4.

Figure 4: Crystallographic structure of the ribbon after ZMR.

Impurity content in the ZMR processed ribbons should, in a continuous process, depend on the original impurities present in the pre-ribbon, since the ZMR process produces no contamination. We in fact observed strong impurity segregation, but this was expected since our ribbons were limited to a few centimeters in length. Also, infrared spectroscopy did not reveal any interstitial oxygen nor carbon. These are, however, preliminary results, since we have not yet done a more systematic study on the impurity content in these ribbons.

At this stage we did not try to make solar cells on these substrates because they are not doped. Among the various options to achieve a doped ribbon we point out the one presented by J. Silva et al. [7] at this conference, which is a simple method we intend to try in the near future.

4. CONCLUSIONS

ZMR was successfully applied to self supported pre-ribbons obtained by fast CVD deposition. We observed that control of pre-ribbon inhomogeneity of mass distribution and the use of CVD growth conditions that produced porosities below ~50%, are keys to reproducible recrystallization with low failure rate.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

[1] F.Wald, in “Crystals: Growth, properties and applications” **5** (1981) 149.
[2] T.Ciszek, in “Silicon Processing for Photovoltaics I”, Ed. North- Holland (1987) 131.
[3] W.Zimmermann et al, Proceedings of the 2nd World PVSEC (1998) 1790.
[4] F. Duerinckx et al, Progress in Photovoltaics, 13 (2005) 673.
[5] W.Koch, Proceedings of the 2nd World PVSEC (1998) 1254.
[6] A.Eyer et al, Proceedings of the 9th EC PVSEC, (1989) 17.
[7] J. Silva et al, at this conference