

Crack Initiation for Kerf-Loss-Free Wafering

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Abstract

To reduce the kerf-loss in producing thin silicon wafers from an ingot, a stress-induced lift-off method (SLIM-Cut) has been recently developed. To enforce the crack initiation for lift-off and to control the wafer thickness in this method, micro-EDM processes have been experimented to generate small notches on crystalline silicon substrates. While the die-sinking EDM remains challenging and to be tuned, small notches of less than 30 μm can be generated by the micro-EDM milling process.

1 Introduction

The solar cell market is currently dominated by crystalline silicon based solar cells which consist 91% of the market share worldwide. Although the new emerging technologies, including thin-film solar cells, are getting a momentum, crystalline silicon based solar cells are still predicted to be the dominant player with more than 80 percent market share by 2015 [1]. The wire-saw technique for producing thin wafers faces a major challenge to meet the needs of the solar cell industry: the kerf-loss consumes half of the ingot. The achievable reduction of the wafer thickness with wire-sawing is also limited. For many reasons including flexibility, highest efficiency potential and cost, the optimal thickness for the bulk silicon technology lies definitely below 100 μm . To date there is no cost effective method to produce such thin wafers. Therefore, there is an urgent need for a wafering method being able to produce 50 μm -thick wafers at low cost.

2 Stress-induced Lift-off Method (SLIM-Cut)

In order to tackle the increasing demand of thin wafers, a patent-pending new wafering technique named SLIM-cut (for Stress-induced Lift-off Method) for producing ultra-thin (<100 μm) crystalline silicon wafers has been developed at IMEC in Belgium[2]. As depicted in *Figure 1*, the SLIM-Cut process only requires the usage of a screen-printer and a belt furnace. During this SLIM-Cut process, a paste

layer with a mismatched CTE with respect to the substrate is first deposited on a thick substrate. Then the substrate goes through a belt baking furnace and is cooled down. During the cooling process, initiation and propagation of a crack parallel to the surface occurs due to a large stress field induced by differential contraction. So far free-standing wafers of more than 10 cm² have been obtained. And this process has been successfully applied on crystalline silicon with different orientations, as well as on multi-crystalline material.

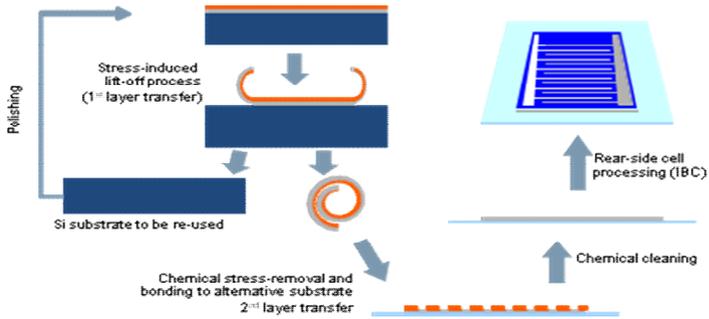


Figure 1: Schematic of SLIM-Cut process [2]

However, the controllability of the SLIM-Cut process needs further improvements since the lift-off of the thin wafer occurs quite randomly, which results in low process yield and the thickness of the wafer is not controlled. One solution to this problem is to provide some predefined micro notches on the substrate to enforce the crack initiation and control the wafer thickness in the same time.

3 Fabrication of micro-grooves on silicon with EDM technique

In the perspective of material properties of crystalline silicon and the small size of the notch compared to wafer thickness (50µm), micro-EDM is one of the favourite processes. Both die-sinking EDM and micro-EDM milling have been investigated.

3.1 Die-sinking EDM

3.1.1 Electrode preparation

At the first thought, the advantage of die-sinking EDM for engraving micro-notch is that the process can be straightforward to produce a notch in one step. However, the production of the electrode turns out to be quite challenging. To avoid metallic contamination, candidate materials for the electrode are limited. Here aerospace-

grade aluminium alloy 7075 is chosen and the electrode is produced on a Kern MMP micro-milling machine. It is possible to produce fin-shape Aluminium electrode with thickness thin to 12 μm , but the straightness of the electrode is poor due to the milling force. An optimized dimension is 25 μm in thickness and 250 μm in height (*Figure 2*).

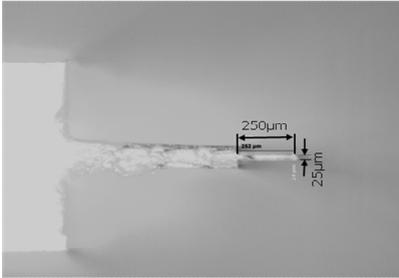


Figure 2: Side view of a 25 μm Aluminium electrode

3.1.2 Die-sinking of notch

Die-sinking EDM experiments have been carried out on an AGIE Compact machine with deionised water as dielectric. Experiment results show that the Aluminium electrode melts down quickly in the process and loses its original shape. Consequently, the notch produced by this process is too wide (~100 μm) with irregularities, so further process optimization and investigation are necessary.

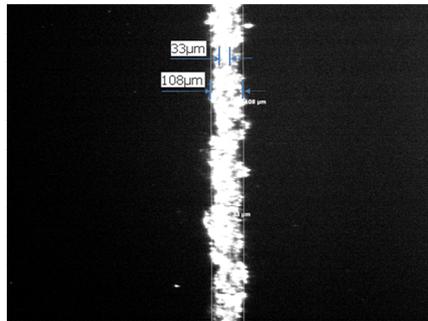
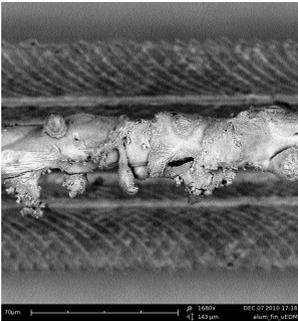


Figure 3: Electrode after micro-EDM (Left) and notch by die-sinking (Right)

3.2 Micro-EDM milling

The investigation of notch-making by micro-EDM milling was carried out on a SARIX machine with oil dielectric. An electrode of 20 μm (*Figure 4*, left) is produced with an on-machine wire-EDM grinding device. Then the electrode is applied to the process for making a notch on a silicon substrate.

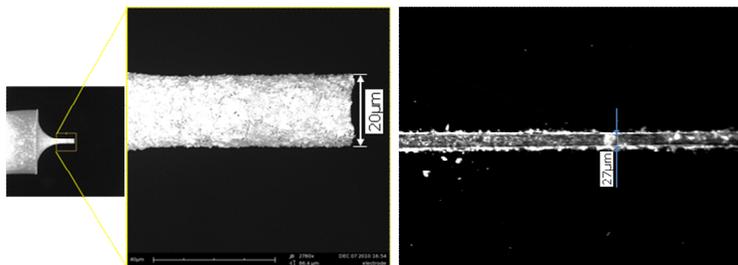


Figure 4: Micro-electrode($\varnothing 20\mu\text{m}$) (Left) and micro-EDMed $27\mu\text{m}$ notch (Right)

So far the micro-EDM process can be successfully applied on boron-doped crystalline silicon with an electrical resistivity of $0.02\Omega\cdot\text{cm}$. In principle, the electrical resistivity of the silicon material should be lower than $1\Omega\cdot\text{cm}$ in order to be easily machined by micro-EDM. For crystalline silicon substrates without dopants and possessing high electrical resistivity, a method using auxiliary conductive cement has been applied and a notch of $27\mu\text{m}$ has been made (*Figure 4*, right).

A shortcoming of this micro-EDM milling process is that it is not so convenient to generate a conical notch on a substrate. The effects of notch shape on the SLIM-Cut process will be further investigated in the future.

Conclusions

The die-sinking micro-EDM process remains challenging for engraving small notches. The micro-EDM milling process can generate notches of $30\mu\text{m}$ on crystalline silicon substrates, even on substrates with high electrical resistivity.

Acknowledgement

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