Renewable Energy Research Center

Progress towards sawing thinner Si wafers (~100 μm) using thinner diamond wires for PV use

Halubai Sekhar、福田 哲生、高遠 秀尚

産業技術総合研究所　再生可能エネルギー研究センター　太陽光チーム

Challenge to saw thinner wafers using thinner diamond wires

- The diamond wire should possess high qualities to saw thin silicon wafers with a high processing yield.
- The diamond particles should be uniformly sized and highly dispersed without agglomerations on the wire.
- We have developed two types (100d-M6/12 and 80d-M6/12) of diamond wires, where 100d and 80d are diameters of core wires, and M6/12 shows the range of diamond particle sizes. We obtained wafers with thicknesses of 200 and 120 μm in processing yields of 100 and 96%.

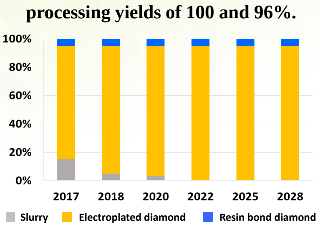

Figure 1. Road map for wafering technology for mono-Si, ITRPV-2018 9th edition.

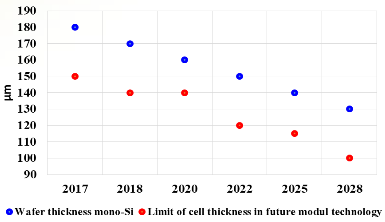

Figure 2. Road map for wafering thickness trend, ITRPV-2018 9th edition.

Multi diamond-wire sawing technology

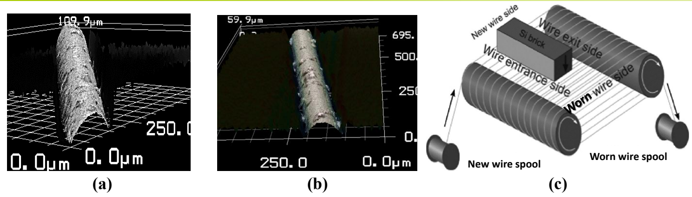

Figure 3. Diamond wire 100d-M6/12 (a), diamond wire 80d-M6/12 (b) and schematic of a multi-diamond wire saw (c).

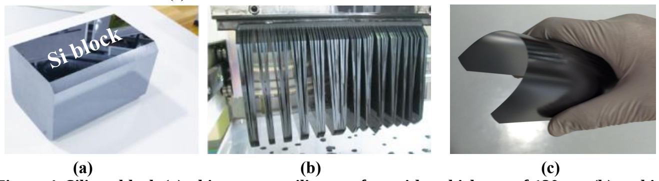

Figure 4. Silicon block (a), thin as-sawn silicon wafers with a thickness of 120 μm (b) and its high flexibility (c).

The impact of saw mark direction on the fracture strength of thin monocrystalline silicon wafers (120 μm)

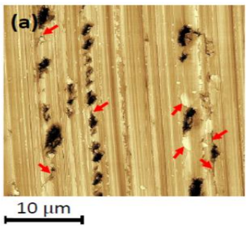

Figure 5. Laser microscope image of saw marks and elongated pits accompanied by cracks (shown in red arrows).

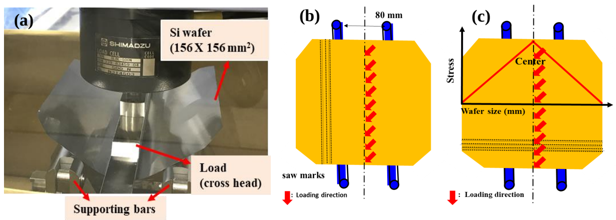

Figure 6. Three-line bending test (a), schematic of loading parallel to saw marks (b) and perpendicular to saw marks (c).

Fracture stress (FS)[1] : $\sigma_{frac} = \frac{3P_{frac}L}{2bh^2}$

P_{frac} : fracture load
L: the distance between two supporting bars (80 mm)
b: the width of a sample wafer (156 mm), and
h: the thickness of a sample wafer (120 μm)

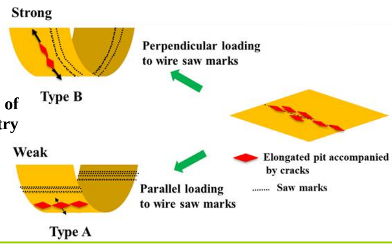

Figure 7. Mechanism of fracture strength asymmetry in bending wafers.[2]

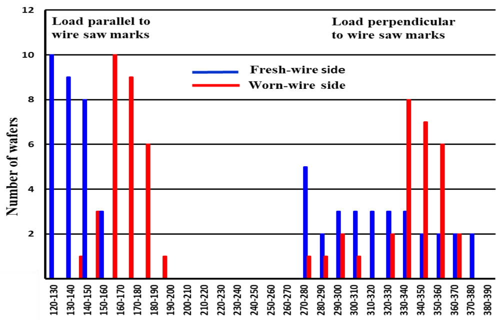

Figure 8. Results of bending test. The right group shows the results in perpendicular bending to saw marks and the left group in parallel bending to saw marks.[2] In parallel bending, the strength was divided into two groups, the lower strength group consisting of fresh-wire side wafers and the higher strength group of worn-out side wafers.

The impact of damage etching on fracture strength of diamond-wire sawn monocrystalline silicon wafers (200 μm)

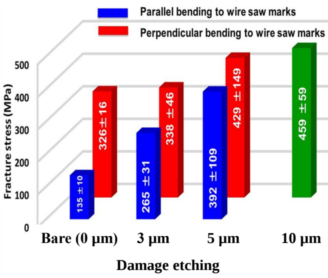

Figure 9. Fracture strength of bare, 3, 5, and 10 μm etched wafers.[3]

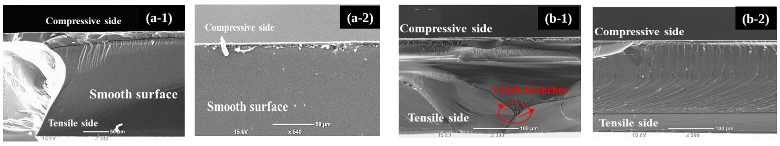

Figure 10. Fracture surfaces of bare wafers in parallel bending (a-1) and (a-2), and those in perpendicular bending (b-1) and (b-2). In parallel bending, the fracture surfaces are smooth or have a little perturbations. On the contrary, in perpendicular bending, the surfaces have complex paths of crack-propagation and clear perturbations described by Sherman's crack advance model.[4, 5]

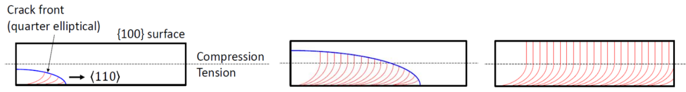

Figure 11. Sherman's crack advance model.[3, 4, 5]

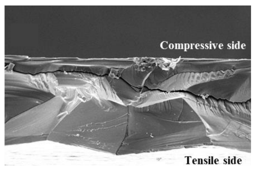

Figure 12. Fracture surface with complex paths of crack propagation (5 μm etched wafers).[3]

Conclusion and future issue

- To employ a thinner diamond wire (80d-M6/12) allows to saw thinner wafers (120 μm) with reduced silicon kerf (100 μm) per wafer.
- It needs to control the vibration of thin wafer and wires when sawing is in progress, which strongly impacts on the processing yields.
- To study the impact of wire vibrations on the damage of thinner wafers and their fracture strength.
- To supply thinner wafers for our cell processing group.

References

1. H. Sekhar, T. Fukuda, K. Tanahashi, K. Shirasawa, H. Takato, K. Ohkubo, H. Ono, Y. Sampei, and T. Kobayashi, Jpn. J. Appl. Phys. 57, 095501 (2018).
2. H. Sekhar, T. Fukuda, K. Tanahashi, K. Shirasawa, H. Takato, K. Ohkubo, H. Ono, Y. Sampei, and T. Kobayashi, Jpn. J. Appl. Phys. 57, 08RB08 (2018).
3. H. Sekhar, T. Fukuda, Y. Kida, K. Tanahashi, and H. Takato, Jpn. J. Appl. Phys. (2018) (to be published).
4. D. Sherman, J. Mater. Sci. 38, 783 (2003).
5. I. Beery, U. Lev, and D. Sherman, J. Appl. Phys. 93, 2429 (2003).