20 years crystal growth of solar silicon: my serendipity journey

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The past two decades have been the most significant period in the crystal growth of solar silicon. The market growth was over 500 times, and the accumulated installation of silicon solar panels was near one TW, which shared 95% of the solar photovoltaic (PV) market. Hence it is fair to say that solar silicon was the key engine pushing global PV growth, and the advancements of its crystal growth technology were much faster than ever. We have been very lucky to get involved in this field starting from 2001, which was still in the early stage of this PV boom.

We started from the hot-zone development of n-type Czochralski (Cz) solar silicon for high pulling speeds, lower power consumption, and multiple charges [1]. Besides the bigger sizes and considering double crucibles, the later Cz developments in recent years were quite the same. Then very soon we moved to silicon casting in 2005 to grow bigger and better ingots. In 2011, small-grain high-performance multi-crystalline silicon, the so-called HPM, was proposed [2-4]. Because of the much better ingot quality and growth yield, it became the mainstream of solar silicon until 2018. Its market share reached its highest peak at more than 70% in 2017, but then slid down quickly due to the emergence of diamond wire slicing. The Cz silicon was much easier to cut and its kerf loss was much less. Since then, the Cz ingot diameter started to increase quickly. The wafer size increased from 156 mm x 156 mm (M0) to 217 mm x 217 mm (M12+) in a few years; the increase in wafer area was almost doubled. Now a day, the market share of Cz silicon is over 80%. Although mono-like silicon could hope for casting, some challenges remain [4-6]. In this presentation, I will share my experiences and views on these developments. Some fundamental and practical aspects of crystal growth technology of solar silicon will be discussed [7-8].

References

[1] L.Y. Huang, P.C. Lee, C.K. Hsieh, W.C. Hsu, C.W. Lan, On the hot-zone design of Czochralski silicon growth for photovoltaic applications, J. Cryst. Growth. 2004;261:433-443.
[2] Y.M. Yang, A. Yu, B. Hsu, W.C. Hsu, A. Yang, C.W. Lan, Development of high-performance multi-crystalline silicon for photovoltaic industry, Prog. Photovoltaics. 2015;23:340-351.
[3] C.W. Lan, A. Lan, C.F. Yang, H.P. Hsu, M. Yang, A. Yu, B. Hsu, W.C. Hsu, A. Yang, The emergence of high-performance multi-crystalline silicon in photovoltaics, J. Cryst. Growth. 2017; 468:17-23.
[4] C.W. Lan, Y.F. Yang, H.K. Lin, H.P. Hsu, B. Hsu, C. Hsu, Engineering silicon crystals for photovoltaics, CrystEngComm. 2016; 18:1474-1485.
[5] Y. C. Wu, A. Lan, C. F. Yang, C. W. Hsu, C. M. Lu, A. Yang, and C. W. Lan, Effect of seed arrangements on the quality of n-type mono-like silicon grown by directional solidification, Cryst. Growth Des. 2016; 16:66416647.
[6] C.Y. Lan, Y.C. Wu, A. Lan, C.F. Yang, C. Hsu, C.M. Lu, A. Yang, C.W. Lan, Control of ingot quality and solar cell appearance of cast mono-like silicon by using seed partitions, J. Cryst. Growth. 2017;475: 136-143.
[7] C.W. Lan, "Solar silicon " in Single crystals of electronic materials: growth and properties, R. Fornari, ed.(Elsevier Ltd. 2019).
[8] T. Jain, H.K. Lin, C.W. Lan, Twinning mechanism at three-grain tri-junction during directional solidification of multi-crystalline silicon, Acta Materialia. 2018;144: 41-50.