A Recycling Focus for Sustainable Metal Production

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Silicon wafer-based solar cells today account for more than 90% of the global solar cell market. Annually, a total of approximately 100,000 tons of high-purity solar-grade silicon is produced for use in solar cells. With current technology, the energy payback time for photovoltaic (PV) modules is on the order of 18 months. With an estimated life-time for PV installations of more than 30 years, many years of CO₂-free energy can be delivered to the grid. Hence, we can truly claim that solar silicon is a sustainable metal from an energy point of view.

In some countries the price for solar electricity is comparable to the grid, so-called “grid parity.” This is the case for Italy and parts of California today, and is expected to happen soon for Japan, Spain, Germany, Australia, and the Netherlands.

In a world that can not get enough electrical power, solar cells are the preferred source of clean, renewable energy. The solar cell industry has experienced a more than 40% average annual increase from 1998 to 2008, thus creating a historical demand for solar silicon. The silicon industry has responded to this unprecedented challenge. Today, around ten companies are taking part in the race for the purest and lowest-cost process route for producing silicon feedstock, and this “sun rush” has lead to new processes and green field plants.

However, as for the gold rush, the speed and focus of the “sun rush” has a downside. The focus in the solar

cell industry has been on methods and higher production, with less interest in the new waste streams and end-of-life products. In 2002, Sarti and Einhaus¹ estimated silicon losses within a vertically integrated multi-crystalline solar cell production to be 68%, and this has not changed substantially since then. Silicon wafer sawing accounts for a considerable part of the silicon losses. Half of the silicon ingot is permanently lost as swarf, since the diameter of the sawing wire is approximately the same as the wafer thickness. Moreover, this high-value silicon does not re-enter the production line. With current silicon prices in the range of \$54 to \$72 per kg, it is evident that the value of silicon could be saved if some of the swarf was reclaimed. Other solar silicon recycling issues that need to be addressed are recycling of solar cell panels and re-melting of ingot cut offs.

For the first time in decades, we are experiencing the growth of a new metallurgical industry. For us as a research and development community, it could not be better: to experience an industry in its childhood, learning the hard way, needing guidance from experience, and making progress and quantum leaps in the face of a variety of challenges. We are very fortunate to take part in the growth of the solar cell industry and to help it become established and mature.

To that end, this issue of *JOM* features a topic on solar cell silicon production and recycling, with a thorough review of the leading solar cell producers. David Lynch has investigated the most prominent production methods and made a qualified analysis of future trends. His paper “Winning the

Global Race for Solar Silicon” begins on page 41.

For the silicon solar cell to operate efficiently, a major challenge is to meet purity requirements. In modeling efficiencies and removal of impurities, diffusivity data of various elements are needed. Kai Tang et al. have given a critical assessment of solid and liquid state diffusivities, based on the available experimental data. The paper “Critical Assessment of the Impurity Diffusivities in Solid and Liquid Silicon” begins on page 49.

Dissolved elements affect silicon solar cell efficiencies, but solid inclusions like SiC and Si₃N₄ particles also decrease cell performance. Arjan Ciftja et al. have investigated the removal of inclusions from silicon by settling and filtration and gives a brief research summary of this work. The paper “Removal of Inclusions from Silicon” can be found on page 56.

Hopefully these papers will make you even more interested in the solar cell silicon theme. In 2009 TMS arranged the first symposium on Solar Cell Silicon: Production and Recycling. It was a success and consequently, you are all hereby invited to join the follow-up symposium at the TMS 2010 Annual Meeting. At the end of the session there will be a plenary discussion on the recycling needs in the solar cell silicon industry, led by Gregory Hildeman of Solar Power Industries. Welcome!

References

1. D. Sarti and R. Einhaus, *Solar Energy Materials and Solar Cells*, 72 (2002), pp. 27–40.

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