Solar-grade silicon at low cost

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Edge of silicon ingot. Credit: BT Usdin on flickr

(Phys.org) -- A new process developed by scientists at the University of Cambridge has the potential to drive down the cost of manufacturing solar-grade silicon and could increase the use of photovoltaic devices for capturing the sun's energy.

In less than the time it takes to read this paragraph, the sun will have provided as much energy to Earth as used by all of human civilization in one day. Yet, despite the huge opportunities solar power affords as a renewable source of energy, it still represents a small fraction of our current capacity to generate power.

One factor holding back the growth of the photovoltaic (PV) industry, which provides the modules that make up a solar panel, is the high cost of the solar-grade silicon on which it currently depends. Now, scientists from the University of Cambridge are developing and up-scaling a new process for making solar-grade silicon that they estimate will be 80% more efficient in terms of energy consumption and cost and generate 90% less CO2.

Based on a procedure known as the FFC Cambridge process developed by Professor Derek Fray and colleagues in Cambridge's Department of Materials Science and Metallurgy, the new modification pioneered by Dr Antony Cox has extended FFC to silicon for the first time and is now in its final research and development stages.

Silicon is the most commonly used material in PV cells. Numerous attempts have tried to find a new process for producing solar-grade silicon but, as Cox explained: "All are energy intensive, with a myriad of complex stages, and none have become a commercial process."

Moreover, the manufacturing methods commonly used to make crude silicon produce some 10 tons of CO2 for every ton of silicon produced, and the refinement stage (the Siemens process) produces a further 45 tons of CO2 as well as toxic gases.

"It's somewhat ironic that such an environmentally destructive process supplies 95% of the silicon required by the PV industry to harness a clean and sustainable energy source," said Cox. "In fact, a solar cell fabricated with the Siemens process would need to be operating for up to six years to match the same energy required to make it."

For PV cells to work there must be no impurities in the silicon that could hamper the movement of electron charge carriers within the material. When photons of sunlight strike the PV cell, their energy is absorbed by the semiconducting silicon, exciting electrons into a higher energy state and creating an electric current.

The two-stage process Cox has been developing uses white sand and calcium chloride (a product used commonly in the food industry) as raw materials. First, tablets of compressed sand are immersed into the calcium chloride electrolyte and heated to 900°C. The silicon in sand is present as an oxide and, during the FFC process, the oxygen atoms are ionised, migrate to the anode and are discharged as oxygen, which is the only by-product of the reaction. Sand is not easy to reduce to silicon and Cox has spent the past four years solving this fundamental challenge and up-scaling the first stage of the process.

In the second stage, an electrorefining process within the same cell takes silicon from 99.99% purity to the Holy Grail of 99.9999% purity. "Preliminary investigations were very encouraging and we are now developing the second stage," said Cox, whose research was funded by the Engineering and Physical Sciences Research Council.

"Crucially, this process requires minimal energy consumption, generates O2 rather than CO2 as a by-product, and is easily up-scalable because it involves fewer production stages," he added. "Many attempted scale-ups for other processes have been thwarted due to the sheer difference in scale between a pilot plant and a commercial plant where unforeseen problems are often revealed. In this process we plan to use many independent smaller cells allowing more control, rather than one huge plant. This should facilitate the transition to a commercial 'process'." Based on the results of an independent economic survey, he believes that the process will drive down the cost of manufacturing solar-grade silicon from around the current $40–200/kg to a maximum of $8/kg, making solar power a more affordable option to generate power.

Provided by University of Cambridge