Silicon Solar Consortium (SiSoC)

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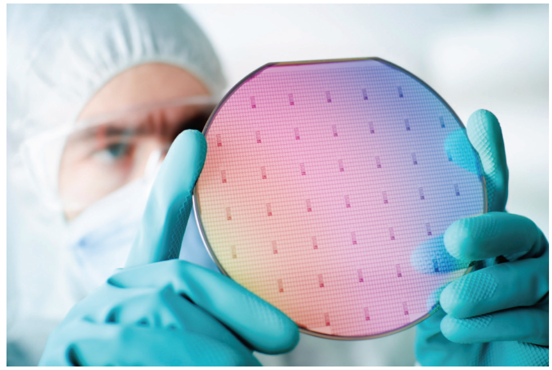
New Silicon Growth Techniques Lowers Costs of Solar Photovoltaics

Crystalline silicon continues to dominate the photovoltaics (PV) industry in the renewable energy market. Within silicon based solar, cast multicrystalline (mc-Si) and Czochralski (Cz) grown material account for the majority (~80%) of PV devices made. Each type has advantages and disadvantages when considering the total cost of production.

Traditionally much of the performance disadvantage incurred in mc-Si materials is a derivative of the growth methodology. Due to the nature of the solidification of the Si melt, the crystal segregates into smaller randomly oriented crystals and suffers from many planar dislocations. These regions serve as sinks for impurities, along with crystallographic stress defects which reduce photo-diode quality. This limitation of traditional as-grown mc-Si can only be overcome through advanced gettering techniques and supplemental processing which are currently not conducive to commercial application.

SiSoC researchers at the Georgia Institute of Technology (GIT) along with commercial partners have also produced >18% conventional cells through study of growth methodology and commercial process optimization. Collaborations with researchers at multiple companies have explored new growth techniques that seed the mc-Si casting crucible with a (100)-oriented Si crystal. With careful growth rate and temperature control they are able to grow a nearly single crystalline material over a large vertical and horizontal area of a casting which maintains the seed orientation. This material is called quasi-mono, cast-mono, or mono-cast (mcast-Si). Due to the crystal orientation of mcast-Si, anisotropic texturing methods normally used for Cz-Si can be applied to the wafers during cell processing. The net result is a >1% absolute boost in efficiency over isotropically textured mc-Si wafers (non-encapsulated). This type of material when commercially processed has obtained >18% efficiency which is on par with Cz-Si material.

However, much work remains to optimize the growth process. One issue is that a limited percentage of a mcast-Si ingot is capable of achieving maximum efficiency. The same lifetime and contamination distributions found in traditional mc-Si remain in the mcast-Si ingots. In addition, material near the edge and corner regions of the cast reverts to mc-Si and its traditional material and efficiency limitations.



If processes can be optimized to increase the area of monocrystalline material and if the material quality can be maintained with reduced costs, then the advantages of the mcast-Si material would be multi-facetted. One advantage would be the packing factor for wafers in a module. Mcast-Si wafers are 6x6 inches (~244 cm^2) square like mc-Si wafers. Cz-Si wafers are 6x6 inches (~239 cm^2) pseudo square in most cases with rounded corners due to growth constraints. A module can hold the same amount of mcast-Si cells as Cz-Si cells. Hence the mcast-Si material provides additional power due to maximizing the active area of the PV module. A second advantage is that the material retains the flexibility of Cz-Si for advanced cell structures needed to make the PV industry more competitive. Under application of one of GIT's more advanced structures, mcast-Si material has achieved >19% conversion efficiency on a full 244 cm2 substrate. This is a significant efficiency for full-scale cells based on materials grown using a casting methodology.

Economic Impact: A key cost of production metric for the PV industry is the total cost of production in terms of the power produced ($/Watt). If module efficiency is fixed at 16% and the wafer cost considered, mc-Si material is significantly cheaper to produce (~0.35¢/Watt) when compared to Cz-Si (~0.50¢/Watt). The potential impact of this collaboratively developed mcast-Si material on the PV industry is clear. If its cost can be driven down to near mc-Si levels while maintaining performance levels, on par with Cz based cells, then mcast-Si would provide a significant $/Watt cost advantages in the PV market.

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