INFORMATION SHEET
RENEWABLE DEVELOPMENT FUND

Investing in Renewable Energy

EMBEDDED NANOCRYSTAL SILICON FILMS: A NEW PARADIGM FOR IMPROVING THE STABILITY OF THIN-FILM SILICON

Executive Summary

A new and radically different technique was explored to control the microstructure of hydrogenated amorphous silicon and to improve the grain size of microcrystalline silicon (Si) thin films. Thin-film technology can reduce manufacturing costs of photovoltaic (PV) devices but this saving is negated by the lower efficiencies and poor stability of thin-film Si cells. The University of Minnesota (U of M) studied gains in efficiency and stability for amorphous Si thin-film cells by controlling the micro-structure of the amorphous hydrogenated silicon. In addition the microcrystalline large grain sizes rivaled wafer-based single-crystal silicon produced through conventional manufacturing.

Project Description

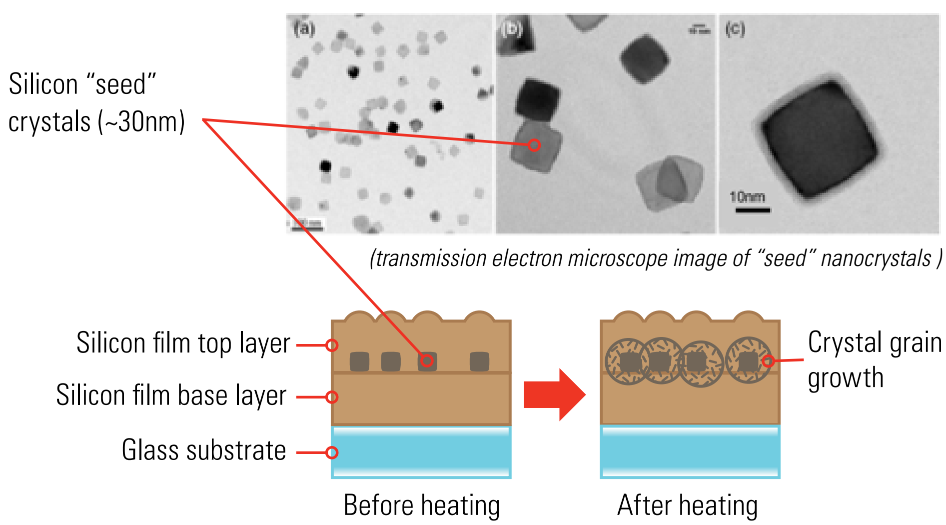
The project researched two methods for increasing the efficiency and lowering the cost of thin film silicon solar cells. The first approach was to produce silicon nanocrystals in a low-pressure plasma-based synthesis reactor and embed nanocrystals in amorphous silicon films. This deposition process provides the ability to independently control properties of the amorphous matrix and crystalline phase, which improves the electronic quality of amorphous silicon. In the second approach the U of M researchers embedded nanocrystals as nuclei for seed-induced re-crystallization of amorphous silicon films.

Methodology

Embedded nanocrystals reduce the degradation and efficiency of PV membrane caused by light. Large-grain recyrstalized Si speeds up the growth of crystals.

Embedded nanocrystals were used as nuclei for seed-induced recrystallization of amorphous silicon films. Seed concentrations were controlled to enable faster growth of microcrystalline silicon films with granular sizes larger than produced by other deposition approaches. Amorphous silicon films with embedded nanocrystals were studied to understand whether the inclusion of nanocrystals may improve stability with respect to light-induced degradation, leading to improvements in the conversion efficiency of amorphous silicon PV cells.

“Seeding” films to grow large crystal grains



(transmission electron microscope image of “seed” nanocrystals)

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RDF Mission: To increase renewable energy market penetration, assist renewable energy projects and companies, and support emerging renewable energy technology through research and development.

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Benefits

The outcomes of this research project may have significant benefits for the manufacture of thin film silicon solar cells.

- Increased stability may lead to solar cells that can maintain higher efficiency after prolonged solar irradiation
- Good optical absorption allows the films to remain relatively thin
- Reduction of manufacturing cost of amorphous silicon solar cells by about 30 percent
- Elimination of the incubation time by seeding of the films
- Reduced time needed for crystallization during film production and capital

Lessons Learned

- Inclusion of a small fraction of silicon nanocrystals into the amorphous silicon matrix led to films with improved electrical conductivities and reduced susceptibility to light inducted defect creation
- Seeding of amorphous silicon with nanocrystal seeds enabled faster production of microcrystalline silicon through thermal treatment of the seeded amorphous silicon films
- Inclusion of nanocrystal seeds eliminated the incubation time for the seed formation and yielded better control
- Doping by inclusion of Si nanocrystals may yield superior materials for all solar cell applications

Outcomes

This research has shown that the co-deposition of Si nanocrystals into amorphous silicon opens up two attractive routes towards producing more efficient, cost-effective PV cells:

- The inclusion of Si nanocrystals into amorphous silicon leads to a mixed phase material that is more resistive to light-induced defect creation than standard amorphous silicon
- The recrystallization of amorphous silicon seeded with nanocrystal grains enables to control the crystallization kinetics and electronic properties of the microcrystalline Si material produced
- Silicon based technologies face none of the toxicity and limited raw materials associated with conventional PV manufacturing

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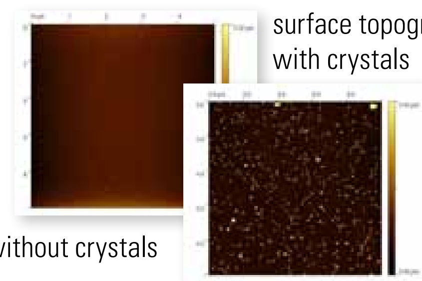
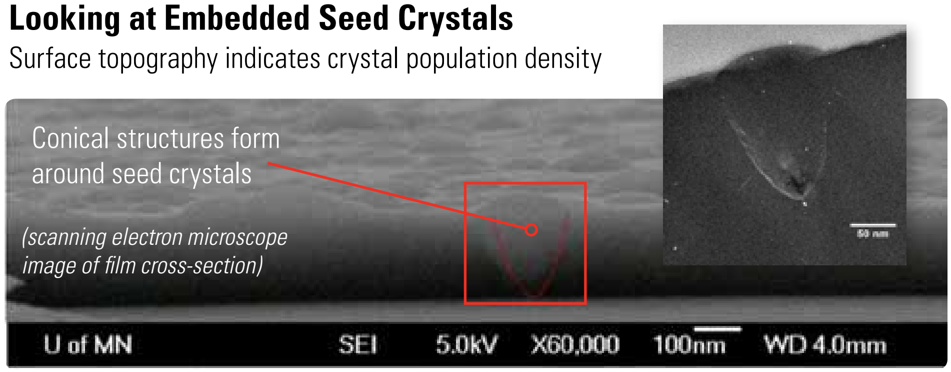


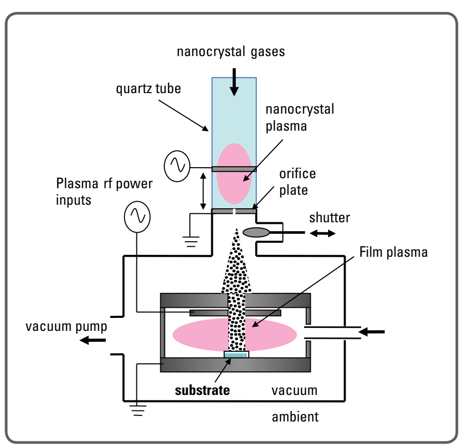
surface topography with crystals

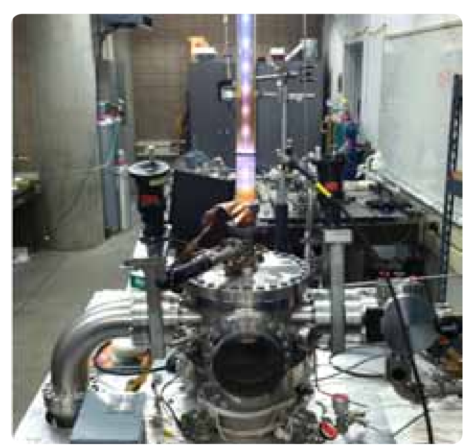
without crystals

Looking at Embedded Seed Crystals

Surface topography indicates crystal population density







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