

Project Summary

Nanoimprinted Diffraction Gratings for Light Trapping in Crystal-Silicon Film Photovoltaics

Name of applicant: Washington Technology Center, Seattle

Topic 1: Proof of Concept/Feasibility Assessment

Focus Area 1: PV Module – Light Trapping

Principal Investigator: Dr. Dirk Weiss (Washington Technology Center)

Silicon is in many respects an ideal semiconductor for photovoltaics: it is abundant and non-toxic, and a vast wealth of technical knowledge exists for this material. Over 90% of the solar photovoltaic capacity installed last year was wafer-silicon technology. Unfortunately, wafer fabrication is expensive and uses large amounts of energy. Worldwide research and development efforts are therefore focusing on directly growing crystalline silicon films, 100 times thinner than the wafers currently used, on cheap, large-area substrates, such as float glass. Unfortunately the efficiencies of these “film crystal-silicon” cells are currently lower than those of wafer cells. A key challenge to obtaining higher efficiencies is the inherently poor absorption of red and infrared light in silicon. This spectral range contains more than a third of “useful,” or “harvestable,” photons in sunlight: photons, the smallest energy units in light, must have energies higher than the so-called bandgap energy in order to be absorbed and to contribute to the energy output of a solar cell.

In this 12-month proof-of-concept project Washington Technology Center will fabricate a device that “traps” a significant portion of the photons that would otherwise be lost. The project, led by Dr. Dirk Weiss at the Washington Technology Center, will employ nanoimprint lithography and a new solution-based ceramic material to directly fabricate an optical grating structure on the backside of a film silicon cell. Nanoimprint lithography is a mechanical pattern-transfer technique similar to embossing, in which a three-dimensional mold with small features is replicated by pressing this mold into a deformable material. Alternative fabrication techniques that had been previously suggested in the literature – photolithography, electron-beam lithography and dry etching – are too slow and not cost effective in comparison with nanoimprinting. The material, a titanium-dioxide precursor, was developed by Dr. Douglas Keszler at Oregon State University, a subcontractor on the project. Film crystal-silicon cells will be provided by project collaborator Dr. Howard Branz at the National Renewable Energy Laboratory. Dr. Branz is considered one of the world leaders in crystal-silicon growth technologies. This project will furthermore employ silicon manufacturing for imprinting molds, metal deposition and optical device testing through reflectance measurements.

Washington Technology Center’s model calculations predict that the number of photons absorbed will increase by a factor of 1.8 due to light trapping. We predict that through further improvements of this technology, film crystal-silicon cells will have an efficiency of 13% at a cost of \$0.77/W by 2016. This represents a 30% cost reduction compared to the same technology without light trapping. If successful, film crystal-silicon technology will have an enormous impact on the price and availability of photovoltaic systems for residential, industrial and utility customers.