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Lightweight Thin-film Solar Cell with Periodic Optical Nanostructures

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Report developed under SBIR contract for topic A17-074. AmberWave, Inc. has previously developed a method to electrically and mechanically integrate an ultra-thin monocrystalline Si layer to a conductive and fracture-resistant supporting layer such as a steel alloy foil. This Ultra-Thin Silicon (UTSi) approach has been used to demonstrate flexible solar cells with over 17% efficiency at under 20 microns silicon thickness. For this Phase II effort, working with our partner NRL we improved upon key elements of the UTSi solar cell develop under our Phase I program, and continued to explore integrating periodic optical nanostructures with the UTSi solar cell to boost rear internal reflectance and increase solar cell effective optical thickness. Key achievements of this program were demonstration of UTSi solar cells with combined area of over 1 ft2 and output power density ≥ 7.6 W/ft2 (up to 11.9 W/ft2) and specific output power ≥ 35 W/lb (up to 106 W/lb). All of these values exceed the Phase II targets for this topic. In addition, we developed a cost model showing how this technology can be scaled up to enable large-area lightweight portable solar panels at an estimated $5/watt price, 50% lower than the Phase II topic target.

15. SUBJECT TERMS

Thin silicon solar cell; high efficiency solar cell; flexible solar cell; nanostructures

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AmberWave, Inc.
Phase II Non-Proprietary Summary Report under contract #W911QY19C0013

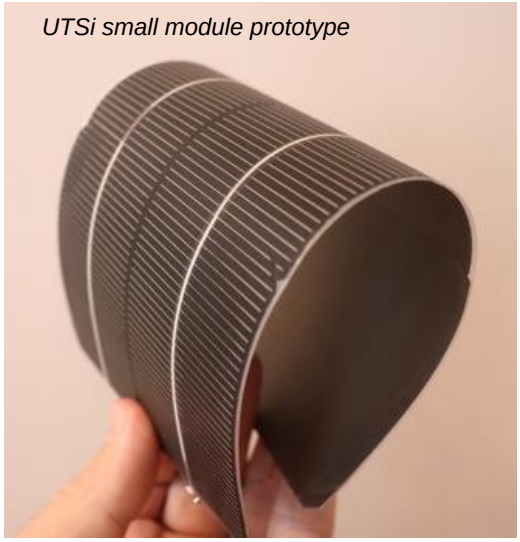
Title: Lightweight Thin-film Solar Cell with Periodic Optical Nanostructure

AmberWave, Inc. has previously developed the Ultra-Thin Silicon (UTSi) technology, where an ultra-thin (~20 micron) mono-crystalline Si layer is mechanically, electrically and optically integrated with a supporting thin metal foil. Mainstream Si solar cells, ~130-150 microns thick, are quite brittle and sensitive to cracking under flexure or impact, necessitating robust and heavy protective packaging layers. However, Si below about 40 microns is highly flexible, and AmberWave's supporting foil layer protects this thin layer and enables high-throughput automated handling during manufacturing. Unlike previous thin crystalline Si approaches, the UTSi approach is compatible with the leading high-volume Si solar cell and module manufacturing tools for front and rear surface processing. Thus, at sufficient manufacturing volume UTSi modules can be cost competitive with mainstream Si PV technology, for the first time bringing the efficiency, reliability and economics of Si PV to a lightweight, robust flexible format. We have used this approach to demonstrate flexible solar cells with over 17% efficiency at under 20 microns silicon thickness.

For this Phase II effort, working with our partner NRL we improved upon key elements of the UTSi solar cell developed under our Phase I program, and continued to explore integrating periodic optical nanostructures with the UTSi solar cell to boost rear internal reflectance and increase solar cell effective optical thickness.

Anticipated military uses are for soldier-portable power for battery recharging, remote deployable power, and incorporation into temporary shelters. We expect that this solar cell will enable lightweight flexible modules with power per unit weight about 3X greater than portable PV modules in use by the military today, at a cost expected to be $5/watt or less. With this advantage and the Army as a first customer for this product, and with leading portable PV module suppliers as partners, we will then expand to commercial portable charging.

In parallel, we are pursuing UTSi-based building-integrated photovoltaics (BIPV) product development with a focus on commercial and industrial (C&I) metal rooftops, which are largely unserved by standard Si PV modules due to weight limitations. This is a 4 gigawatt/year opportunity in North America alone. In addition to the weight advantage, factory-integration of the PV module with metal roofing panels will enable up to 30% lower total PV system cost, due to reduction in installation hardware and labor costs. We intend to partner with metal building industry incumbents for the development and marketing of these products.


UTSi small module prototype

AmberWave is in the planning stages for establishing multi-megawatt production capacity, in collaboration with a US manufacturing partner. This line will be used to produce portable power products as well as early sales of the integrated PV-roofing module product. The same UTSi solar cell design serves both applications.