Component: NAVY
Topic #: N201-069
Title: Low-cost, High Efficiency, and Non-rigid, Perovskite-based Single-junction or Tandem Solar Cells
Technology Areas: Battlespace Materials / Processes
Acquisition Program: Ground Renewable Expeditionary Energy Network System (GREENS)

OBJECTIVE: Develop and demonstrate, on increasing scales, novel solar cell designs and manufacturing processes relevant to production of robust perovskite-based solar cell modules that outperform crystalline silicon solar cells in terms of cost, efficiency, and energy payback time and have a comparable expected lifetime. Target DoD applications include flexible solar cells mounted on lightweight semi-rigid substrates such as in the current Marine Corps GREENS expeditionary solar power system.

DESCRIPTION: Metal halide perovskites were researched in the 1990’s as easy to form semiconductors that formed and crystallize from solution and immediately had promising properties [Ref 1]. However, the poor stability in air (oxygen, moisture) and the presence of lead persisted as major hurdles for further development and commercialization. After a dormant phase, interest was resurrected when the perovskite materials showed excellent performance as absorbers for dye-sensitized solar cells and eventually as the active layer in thin-film solid-state solar cells [Ref 2]. Researchers quickly developed methods to grow films with large grain sizes and fabricate devices with interfacial layers that provided short-term protection from moisture and oxygen to allow facile characterization. Seemingly overnight, hundreds of labs entered this research area and the inherently high-performing semiconductor gave solar cells that increased in power conversion efficiency from below 10% to over 22% within five years [Ref 3], appearing to have the potential to challenge crystalline silicon as a commercial solar cell alternative.

The incredible thrill of research that yielded new record cells every few weeks is satisfyingly in the past (2010–2015). Further records in power conversion efficiency come more slowly and much of the research has moved towards improving inherent stability, removing lead, and developing stable and high-performing device stacks. Inherent stability has been improved by tuning the perovskite composition to tighten the crystal lattice without a large drop in performance. Longer-term research on two-dimensional (2D) lattices currently sacrifices efficiency for stability. Likewise, lead replacement reduces efficiency. Eventually these areas of research may lead to thin film lead-free perovskite devices with reasonable lifetimes and high efficiency that can be applied to flexible substrates with reduced packaging. In the short term, 3-dimensional metal halide perovskites in well crystallized layers, in an appropriately designed device stack, and robustly packaged form-factor promise to compete with silicon on a cost and efficiency basis.

In the perovskite solar cell community, academic institutions and small businesses have demonstrated power conversion efficiencies above 18%, but significantly fewer have investigated each specific layer of the stack for both optimal performance and stability under accelerated aging conditions. Even fewer have begun scaling deposition processes and carried out market analyses to identify device formats that will compete in a crowded, competitive market. This SBIR topic is a manufacturing technology project. The Navy is interested in companies with plans to commercialize perovskite-based solar cells who have progressed to the stage where they have demonstrated a viable device stack of >1 cm² area and >18% power conversion efficiency. The Phase I proposal should describe the company’s development of the device stack including how various layers were selected/developed, how they are currently deposited, and plans to scale processing. The proposal should include stability data for unpackaged devices under ambient conditions or other stability characterization. The proposal should include a cost analysis.

PHASE I: The entry point into this SBIR is for the performer to have developed and characterized a high-performing perovskite based solar cell that has achieved >18% power conversion efficiency and to have adequately described the packaged stack performance and stability in the initial proposal. At the start of Phase I, the performer will pursue certification of this device stack at the 1-cm² level if this has not been done, either with an independent laboratory or with the Navy. By the end of the 6-month Phase I effort, the performer should develop: (1) a mini-module with >18% power conversion efficiency, 50 cm² or larger, fully packaged device on flexible or rigid substrate, produced by any combination of deposition techniques; (2) a commercial module design; (3) detailed plans on how to develop the manufacturing technology to fabricate larger >18% efficiency modules on flexible substrates over the two-year Phase II including identification of key technical and cost barriers; and (4) an updated business plan/market evaluation with strong cost analysis. The fabrication and performance of the mini-module should be presented in the final report along with the other deliverables mentioned in the above paragraph. The mini-module performance should be verified by standard techniques and be available for independent evaluation.
PHASE II: Continuously mature device stack, processing, and packaging towards a >18% power conversion efficiency solar cell mini-module (>200 cm²), fully packaged on a flexible substrate with target 10 year lifetime, threshold 5 year lifetime. Include regular submission of packaged small multi-cell modules to an independent party for performance and stability characterization. Provide quarterly metrics and quarterly reporting. Deliverables include the module described above and a final report which details the progress towards a commercially viable product, remaining technical and cost hurdles, and an updated business plan.

PHASE III DUAL-USE APPLICATIONS: Scale to cost-effective production level. Work with DoD acquisition programs or current vendors to design and produce application specific solar cell modules for incorporation into products for military applications.

REFERENCES:

KEYWORDS: Perovskite; Solar Cells; Stability; Efficiency; Flexible Substrate; Mini-module