DARPA pushes for 50% efficient photovoltaics to power soldiers’ small tools

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DARPA’s Very High Efficiency Solar Cells program aims to develop rechargers efficient enough to build into flashlights, radios, etc. and cut more than half of soldiers’ backup battery weight.

Today’s typical soldier is outfitted with many tools to make him an effective fighter: night vision goggles, flashlights, laptops, and radios, for instance. All of these tools are powered by batteries, because they provide easily portable power. Unfortunately, the backup batteries soldiers are required to carry generally add 7–10 pounds or more to their basic load, and the logistics necessary to supply the troops with sufficient numbers of replacement batteries is costly. A tool-sized portable renewable power supply, integrated directly into equipment, would dramatically reduce the burden on both the soldiers in the field and the logistics system that supplies them.

Photovoltaic solar cells already provide the armed forces with portable power supplies. But with their present low efficiency, a 60W laptop recharger would require more than 0.37m$^2$ of solar cells. That is too big to fit on the laptop, and the soldier carrying it wouldn’t perceive it as a significant advantage. By contrast, solar cells approximately 50% efficient would allow the soldier to carry a set of tools with integral solar rechargers: on the handle of a flashlight, the top side of a laptop, or the face of a radio. Such a system would constitute a renewable field-portable power supply at the soldier level, and would cut out more than half of the battery weight the soldier must now carry.

In response to the objective of equipping soldiers’ small tools with integral solar rechargers, the Defense Advanced Research Projects Agency (DARPA) launched the Very High Efficiency Solar Cells (VHESC) program to develop and demonstrate 1,000 prototype 10cm$^2$ devices that are, at minimum, 50% efficient. DARPA’s investment in new discoveries in power generation and storage is one part of the agency’s core technology thrust to push new materials opportunities and discoveries that might change how the military operates.\(^1\) Besides VHESC, other such DARPA programs include the Direct Thermal to Electric Conversion program, to convert thermal energy to a high efficiency energy supply;\(^2\) the Palm Power program, to develop fuel cell and energy conversion technologies;\(^3\) the Mobile Integrated Sustainable Energy Recovery program, to convert packaging and waste created on the battlefield to a fuel source;\(^4\) and the Micro Power Generation program, to generate power at the micro scale to run stand-alone microsensors and micro-actuators equipped with wireless communication.\(^5\) DARPA will continue to pursue opportunities and new ideas to develop breakthrough technologies for the core technology of portable and sustainable power, which is of strategic interest.

The potential to achieve the aggressive objectives of the VHESC program is a result of rapid advancements in at least three areas: biosynthetic materials processing, non-imaging optics, and solar cell architectures. The most important of these fast-developing areas is the ability to leverage our understanding of biological materials synthesis and structure assembly processes so that we can engineer analogous synthetic processes to fabricate devices of technological interest: in this case materials and structures with the optoelectronic properties desired for making photovoltaic cells. A hallmark of this ‘bio-fabrication’ processing is that three dimensional structures are built from their molecular components with angstrom-level precision over all particle sizes and shapes.

One significant advantage of this approach is its simplicity: all of the process steps take place at moderate temperature and pressure. Bio-fabrication processes are also highly efficient. They may be capable of yields greater than 50% of the starting feedstock, when only 0.1–1% yields are commonly achieved in metal-organic chemical-vapor deposition (MOCVD) processes with the same optoelectronic materials. While bio-fabrication is the highest risk element of the VHESC program, if successful it will radically reduce the cost of the materials and structures used to make

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high-efficiency solar cells. Further, it may make possible new design architectures with even higher-efficiency performance.

The second major development area that is central to the VH-ESC objective is the practical and cost-effective application of non-imaging optics. Researchers have discussed their potential application to solar cells for several years, but solar cells incorporating non-imaging optics have been relatively large and inappropriate for soldier portable electronics. Furthermore, the efficiency of the resulting devices has never exceeded the efficiency of state-of-the-art vertically integrated tandem-stacked solar cells. While simple optics of this type have been incorporated into automotive headlights for over a decade, the tools and processes to design and cost-effectively fabricate small-feature, complex, broad-spectrum, non-imaging optics are a recent development.

The third major area of rapid change taking place is the development of new solar-cell architectures that significantly leverage the first two breakthroughs to arrive at a design space that was previously inaccessible because of materials or process constraints. While it may sound trivial, this last change is the most important to achieve, because the other breakthroughs offer a meager harvest if they are only considered in the context of existing architectural paradigms.

In order to cut more than half of the backup battery weight soldiers in the field now have to carry, DARPA’s VHESC program aims to develop 50% efficient solar rechargers that can be built into small tools soldiers use. This aggressive goal is now potentially achievable because of rapid advancements in biosynthetic materials processing, non-imaging optics, and solar cell architectures. Although bio-fabrication is the riskiest element in this project, if successful it will radically reduce the cost of high-efficiency solar cells, and it may make possible new architectures yielding even higher-efficiency performance.

The VHESC program is being executed by a large team employing both multiple approaches and the flexibility to swap parts and processes to optimally design and develop a minimum 50% efficient solar cell. Together, team members possess the broad range of interdisciplinary talents necessary to take on this challenging problem of truly national importance. Led by the University of Delaware, the team includes Corning, Encore, BP Solar, DuPont, Blue Square Energy, the Massachusetts Institute of Technology, the University of California at Santa Barbara, the University of Rochester, and the National Renewable Energy Laboratory.

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**References**