A VERY BRIGHT FUTURE FOR DEPLOYABLE POWER

By Rich Kapusta

Recent advances in technology have created a thirst for power like never before. Access to energy when and where you need it is one of today's biggest challenges. The idea of harvesting energy from the world around us is one that holds great promise, but has yet to be completely realized. The good news is that recent advances in solar technology are making big strides in bridging this gap and enabling a multitude of new applications on the battlefield, at work, and at play.

Solar technologies have been around for decades, and the use of solar power by the defense and intelligence communities is on a very steep adoption curve. The primary driver is to reduce reliance on diesel fuel, and to diminish the massive effort required to re-supply fuel to military installations around the globe.

Today's glass-mounted solar panels work marginally well when you are powering a large military base in a fixed location with plenty of area for the panels to be deployed. But the future of deployable power comes in an entirely different form factor: thin, flexible, and extremely efficient sheets of solar fabric designed to be carried, worn, or embedded into an array of other materials and electronic systems. This film-like material has already demonstrated efficiency of over 30 percent, with a roadmap to continue well beyond that, and is made from minute amounts of high purity single crystalline gallium arsenide (GaAs). This is two to three times the energy density of all other solar thin films. The possibilities that emerge from having access to a material that can be made into any size or shape, can generate more than 250W of electricity per square meter of surface area, and has a power to weight ratio of 1 watt per gram are numerous.

UAVs

Let's start in the air. Our warfighters are relying more and more each day on small battery-powered unmanned aerial vehicles for communications and surveillance in the field. Thousands of these aircraft provide critical situational knowledge and can be the lifeline of a forward-operating soldier. These battery-powered electric aircraft are small, which means that their energy source must also be small. Most of these UAVs can stay in the air for about an hour, and then need to be retrieved, recharged, and re-launched. This constant cycle poses risks for damage to the aircraft, and more importantly, risks the lives of those retrieving them. But in the very near future, these aircraft will begin to incorporate a new solar technology, embedding a thin, flexible, and highly efficient material directly into the wing structure of the planes, allowing them to fly persistently as long as the sun is shining. The more power that can be generated from the fixed surface area of the wings, for the least amount of weight, the longer the planes will fly.

Alta Devices, the manufacturer of this new solar technology, is already working with a number of UAV manufacturers to incorporate this energy source. Enough power can now be generated from direct sunlight to keep the on-board battery fully charged during daytime flight. Instead of a small UAV flying for only an hour, it can be launched in the morning and retrieved after sunset. This changes the way UAVs will be utilized in the future and will reduce the human risks associated with these operations.

Figure 1 | Alta Devices' thin solar charging mats

Personal Power

A typical dismounted soldier carries about 100 pounds of gear. When speed and agility correlate directly to effectiveness and safety, every pound of excess pack weight matters. A large percentage of this weight is in batteries used to power all of the electronic gear used by today's soldier. And before the batteries are discharged, the soldier needs to return to base in order to get re-supplied, or supplies need to be brought to him or her. This limits the scope and duration of any mission. Solar charging solutions and rechargeable batteries offer potential alternatives, but if the solar material is too big or bulky and doesn't produce enough power, it doesn't solve the problem. However, thin, flexible, and highly efficient materials can significantly improve the effectiveness of our foot soldiers. With even a small amount of power available in a small, foldable, and lightweight package, tens of pounds of pack weight can be shed, and warfighter effectiveness increased significantly.

With the energy density of Alta Devices' GaAs-based material, it becomes feasible to carry hundreds of watts of personal power, enabling the availability of more powerful soldier electronics in the future. This technology multiplies the effectiveness of the dismounted soldier, and provides unlimited charge regardless of the duration of the mission, never having to worry about running out of power for critical pieces of equipment in the field. The flexible nature of the material itself allows it to be woven into fabrics of backpacks, integrated into helmets, and worn as clothing when necessary.

Transportable Power

If a small platoon of soldiers plans to set up a temporary camp in a remote location, a few kilowatts of power becomes necessary. The ability to quickly set up solar panels to power such a base is mission-critical. However, today's solutions are bulky, heavy, require multiple trucks to move from one location to another, and take time to mount and connect. Highly efficient, thin, and lightweight solar material will enable small battalions to relocate extremely efficiently. Solar arrays with multiple kilowatts of power can be transported in

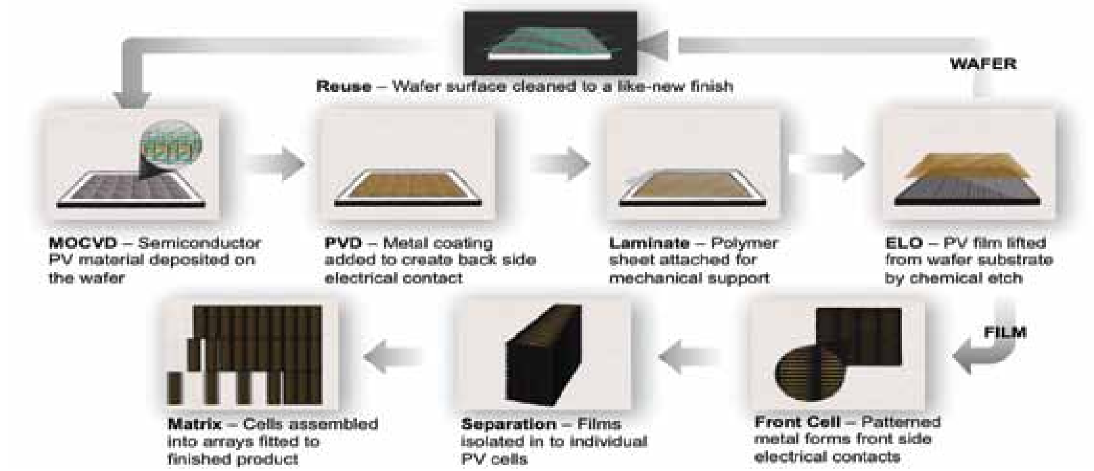

Figure 2 | Solar cell manufacturing process

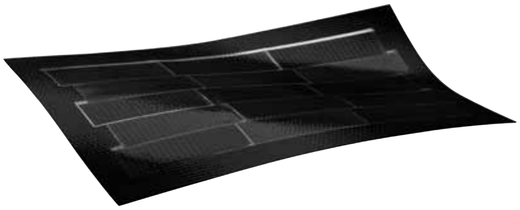

Figure 3 | Thin, flexible Alta Devices solar sheet

a densely packed form in a single vehicle and unfolded, mounted, and connected in minutes. Solar fabrics integrated into tents and tarps will also be a critical component of a forward-operating base power. At a power-to-weight ratio of 1,000 watts per kg, and with an energy density of over 250 watts per square meter, being able to deploy significant amounts of power on the fly will be a substantive advantage for our military.

Self-Powered Sensors

At the other end of the spectrum, there is a need for meaningful amounts of energy to be generated in tiny footprints. These would be used to power a multitude of wireless sensors deployed anywhere they are needed, without the need to ever replace the batteries. Accomplishing this requires a solar material with sufficient energy density that is thin enough to "disappear" into the device it needs to power. With the new generation of solar technology being commercialized, this is now possible. Wireless sensor applications include border patrol, pipeline management, security, and weather monitoring. Furthermore, this technology can also be embedded directly into the electronic gear used by soldiers. Imagine range finders with a small solar cell on top, or a sniper scope with a strip of solar cells on the side. Anything that is battery-powered can incorporate the cells directly into the device itself. Thin, flexible solar cells, providing nearly 30mW of power per square centimeter from the sun, become yet another critical tool in our arsenal of defense capabilities.

How Is It Done?

The concept is simple: start with GaAs, a material with notable solar properties that has been used to power spacecraft for decades, and create a manufacturing process using tiny amounts of the material, making it commercially viable and affordable for terrestrial applications. The fabrication process starts with a standard 4-inch square GaAs wafer. This reusable substrate is introduced into a metal-organic chemical vapor deposition (MOCVD) chamber. A buffer layer of GaAs material is grown first, followed by a thin release layer of aluminum arsenide, on top of which the photovoltaic device structure is grown. The solar absorber stack can be grown with one, two, or more junctions to tailor the device to its application. A back contact metal layer is then deposited and this metal-on-semiconductor stack is attached to a flexible handle using an adhesive.

The handle-metal-semiconductor stack is then introduced to a bath of aqueous acid. The acid etches the release layer, separating the wafer and leaving the remainder of the device intact. The etch leaves a semiconductor thin-film supported by the back metal composite and flexible handle ready for further processing. Front metallization is deposited using a plating process. An anti-reflective coating (ARC) is applied and the device is laser cut into cells to complete the process. The resulting cells are roughly $10cm^2$ in size and can be used individually or connected into sheets of custom sizes and shapes and assembled into mats, blankets, tarps, or integrated into any product that needs energy from light.

The energy density advantage is just one benefit of this technology. Due to the high voltage and small size of the cells, more voltage can be built in smaller areas, allowing the solar output voltage to quickly reach the bus voltage of the system and minimize demands on matching electronics. The use of shingling to electrically interconnect the cells minimizes the impact of partial shading without additional electrical circuitry. And, GaAs material has a significantly lower thermal coefficient than silicon (0.08 percent degradation/°C compared to 0.4 percent/°C for silicon), maintaining maximum output even under extremely high operating environments. Finally, the material is extremely sensitive to low light, making it well-suited for indoor as well as outdoor use.

With recent advances by Alta Devices, solar technology is not just for bulky, rigid, glass-based panels anymore. The future of deployable power lies in embedding high efficiency, thin, and flexible solar material into everything that has a battery, and being able to carry and transport large amounts of solar energy generation quickly and easily. We are on the verge of being able to deploy solar power everywhere it is needed, diminishing our dependence on diesel fuel, and ultimately saving money, supporting the environment, and protecting lives. Q

Rich Kapusta *is the Vice President of Marketing for Alta Devices. Kapusta has over 20 years of experience in the semiconductor and solar industries, ranging from large public companies to startups. He has six patents and holds a computer engineering degree from the University of Illinois, Urbana-Champaign.*