SunPower Discovers the "Surface Polarization" Effect in High Efficiency Solar Cells

Introduction

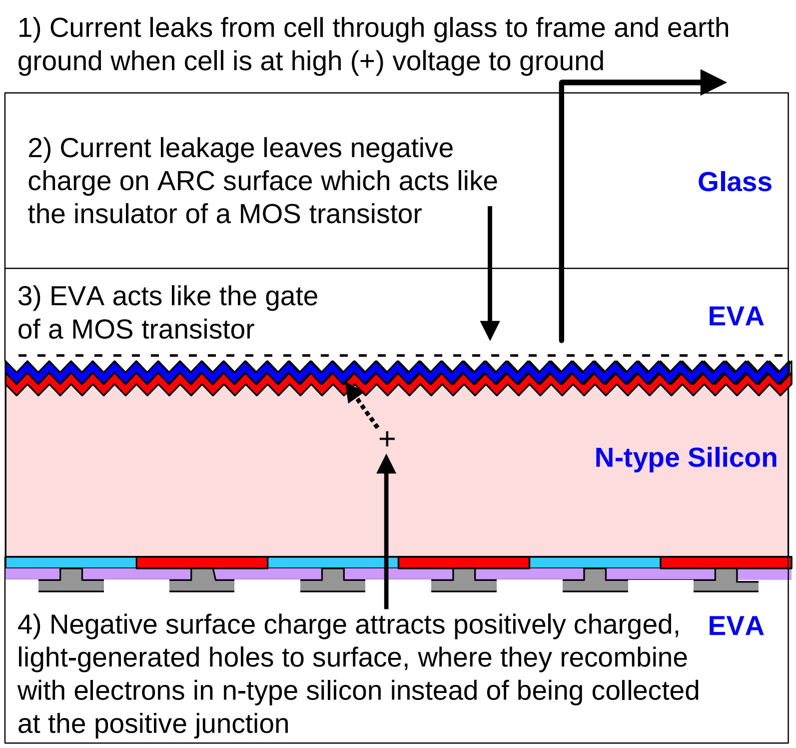
In August, 2005 SunPower announced the discovery of a new performance effect observed in high efficiency silicon solar cells. This new effect, called "surface polarization," creates the non-destructive and reversible accumulation of static charge on the surface of high-efficiency solar cells such as the company's all back contact A-300.

The high efficiency of SunPower's A-300 solar cell is obtained in part by covering its front surface with a proprietary coating which prevents the loss of the charge carriers generated by sunlight. This layer performs much like a transistor that is turned off, preventing current flow. If a large enough voltage is applied to the front of the cell, the "transistor" effectively turns on, allowing charge carriers to recombine at the front surface. When this happens, surface polarization reduces the output current of the cell. Also, like a transistor this effect can be fully reversed and current returned to the original level.

How Surface Polarization Occurs

Surface polarization can occur when a module is put into operation at high positive voltages. If the module is operated at a positive voltage with respect to the earth ground, then minute leakage current will flow from the cells to ground. As a result, over time a negative charge is left on the front surface of a cell. This negative charge turns on the surface transistor, attracting positive charge carries to the front surface where they recombine with electrons and are lost. This sequence of events is illustrated in Figure 1.

Figure 1: Cross-section of an A-300 solar cell embedded in a module with surface polarization.



Reversing Surface Polarization

When a module is operated at negative voltage with respect to ground, the surface polarization reverses. In this case the performance of the module is not affected; in fact, it can improve slightly because the front now repels light generated holes, guiding them to the back collecting junction. Figure 2 shows the situation at negative voltage.

Figure 2: Reversing surface polarization by operating an A-300 solar cell at negative voltage with respect to ground.

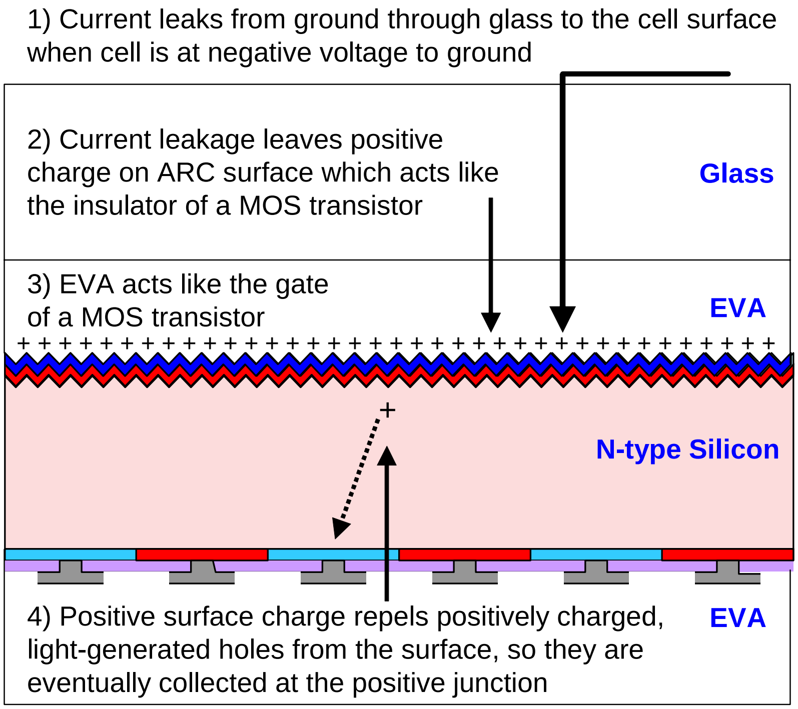
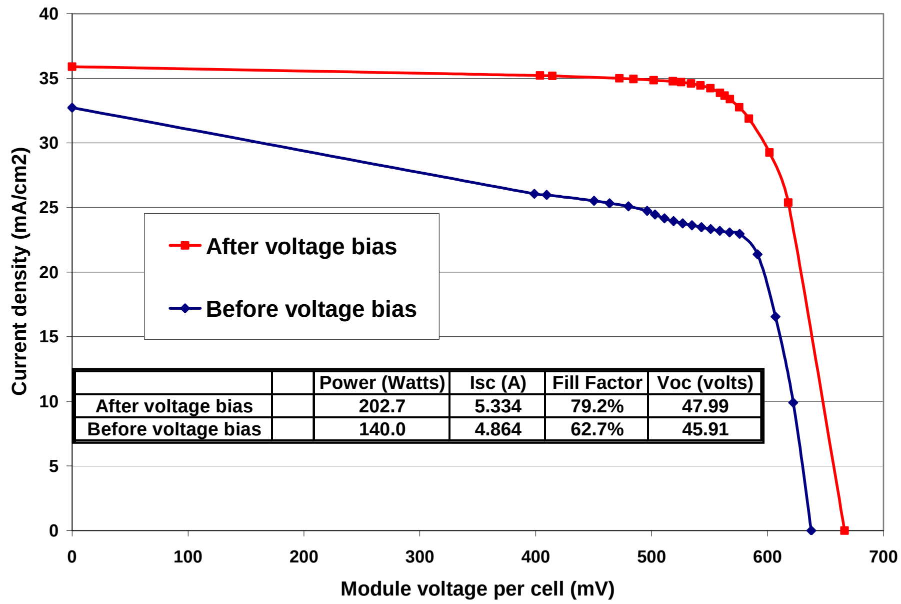


Figure 3 shows the current-voltage characteristic of a module that has undergone surface polarization after operating in the field at a positive voltage of 160 V. The blue line labeled "before voltage bias" shows that with surface polarization, the module output has declined to 140 W from its initial 200 W rating. After biasing the module at a minus 1000 V for one hour to reverse the surface polarization, the negative surface charge has been bled off and the module completely recovered, as illustrated by the red line labeled "after voltage bias." The surface polarization effect is completely reversible, with no lingering effect.

Figure 3: Module performance during and after reversing surface polarization with voltage bias.



	Power (Watts)	Isc (A)	Fill Factor	Voc (volts)
After voltage bias	202.7	5.334	79.2%	47.99
Before voltage bias	140.0	4.864	62.7%	45.91

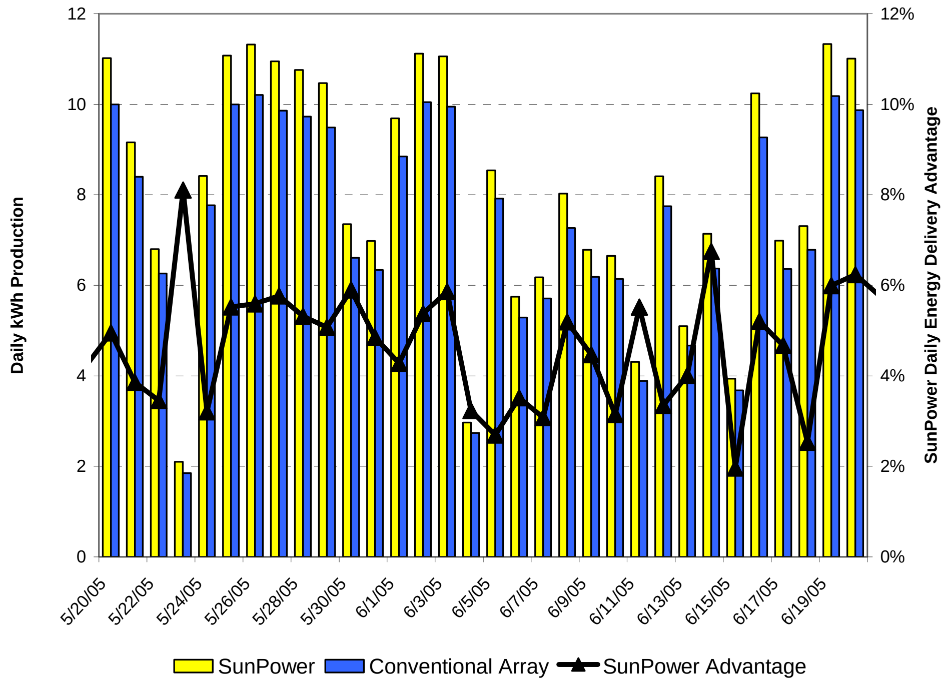
The polarization effect can be easily avoided by designing systems with proper grounding so that modules only see negative voltage. All of SunPower's system integration partners have developed grounding procedures that prevent module operation at positive voltage. In Europe, SunPower worked closely with its exclusive distribution partner, SunTechnics, to characterize the polarization effect and to develop system configurations that prevent the effect. SunTechnics also developed a range of system solutions and electronic devices to optimize SunPower system performance and meet European security standards. For European tracker systems, SunPower worked with Solon to characterize and develop system configurations to prevent the polarization effect. In North America, SunPower modules are exclusively installed with SunPower positive-ground inverters which eliminate surface polarization.

If a system is mistakenly installed with the incorrect grounding, modules will temporarily lose power, but no lingering effect remains after surface polarization is reversed. Because the surface polarization effect is completely reversible, once the grounding problem is corrected, modules will quickly recover to their initial performance without any further intervention.

SunPower Systems Field Performance

SunPower has installed systems around the world that have been operating since early 2005. These systems have confirmed that the use of proper system grounding can eliminate the surface polarization effect. For example, two side-by-side arrays have been operating in Germany since February, 2005 and have been continuously monitored in partnership with SunTechnics. An array of ten 160 W conventional multi-crystalline modules compared with an array of eight 210 W SunPower modules allows for an accurate comparison. Recent data from SunTechnics for these two arrays is plotted in Figure 4. The left bar at each date is the energy delivery of the SunPower array and the right bar the energy delivery of the multi-crystalline array. The black triangles give the ratio of kWh/kW rated for the two arrays. The SunPower array consistently out-performs the multi-crystalline array by the amount displayed on the right axis scale. The SunPower array delivers about 4% more energy delivery on a kWh/kW rated basis, due in part to the excellent low light performance and low temperature coefficient of efficiency of SunPower modules.

Figure 4: Energy delivery comparison of SunPower and conventional solar arrays in Bavaria.



Source: SunTechnics SunReader