Technologies

Three key elements in a solar cell form the basis of its manufacturing technology. The first is the semiconductor, which absorbs light and converts it into electron-hole pairs. The second is the semiconductor junction, which separates the photo-generated carriers (electrons and holes), and the third is the contacts on the front and back of the cell that allow the current to flow to the external circuit. The two main categories of technology are defined by the choice of the semiconductor: either crystalline silicon in a wafer form or thin films of other materials.

Crystalline Silicon Solar Cells ? Market Share 80-90%

Historically, crystalline silicon (c-Si) has been used as the light-absorbing semiconductor in most solar cells, even though it is a relatively poor absorber of light and requires a considerable thickness (several hundred microns) of material. Nevertheless, it has proved convenient because it yields stable solar cells with good efficiencies (15-17%, half to two-thirds of the theoretical maximum) and uses process technology developed from the huge knowledge base of the microelectronics industry.

Two types of crystalline silicon are used in the industry. The first is monocrystalline, produced by slicing wafers (up to 150 mm diameter and 200 microns thick) from a high-purity single crystal boule. The second is multicrystalline silicon, made by sawing a cast block of silicon first into bars and then into wafers. The main trend in crystalline silicon cell manufacture involves a move toward multicrystalline technology.

For both mono and multicrystalline Si, a semiconductor junction is formed by diffusing phosphorus into the top surface of the silicon wafer. Screen-printed contacts are applied to the front and rear of the cell, with the front contact pattern specially designed to allow maximum light exposure of the Si material with minimum electrical losses in the cell.

Some companies are trying to bypass the inefficiencies of crystal growth/casting and wafer sawing processes by using new production technologies, even though these processes have issues involving lower growth/pulling rates, poorer uniformity, and surface roughness. One method grows a ribbon of silicon, either as a plain two-dimensional strip or as an octagonal column, by pulling it from a silicon melt. Another method melts silicon powder on an inexpensive conducting substrate.

Each c-Si cell generates about 0.5 volts. Cells are usually soldered together in a series to produce a module with higher output voltage. The cells are hermetically sealed under toughened, high transmission glass to produce highly reliable, weather resistant modules that may be warranted for up to 25 years. Modules are designed to meet rigorous certification tests set by international standards agencies. Click here [1] for more details on PV module certification.

Thin Film Solar Cells ? Market Share: 10-20%

The high cost of crystalline silicon wafers has led the industry to look at less expensive materials to make solar cells. The selected materials have all been strong light absorbers. They also only need to be about 1 micron thick, so materials costs can be significantly reduced.

The most common materials used are amorphous silicon (a-Si), or the polycrystalline materials: cadmium telluride (CdTe), copper indium (gallium), and diselenide (CIS or CIGS). Each of these materials can be deposited over a large area onto substrates of about 1 meter, and hence can be used for high volume manufacturing. The thin film semiconductor layers are deposited onto either coated glass or a stainless steel sheet. A transparent conducting oxide layer forms the front electrical contact of the cell, and a metal layer forms the rear contact.

Amorphous silicon is the most developed of the complex thin film technologies. In its simplest form, the cell structure has a single sequence of p-i-n layers. Such cells suffer from significant degradation in their power output (in the range of 15-35%) when exposed to the sun. Thinner layers can be used to increase the electric field strength across the material and to provide better stability. However, the use of thinner layers reduces light absorption, and hence cell efficiency.

The industry has developed tandem and even triple layer devices that contain p-i-n cells, stacked one on top of the other. In the cell, at the base of the structure, the a-Si is sometimes alloyed with germanium to reduce its band gap and to further improve light absorption. This added complexity has a downside though; the processes are more complicated, and process yields are likely to be lower.

Thin film cells are laminated to produce a weather-resistant and environmentally-robust module. Although they are less efficient, thin films are potentially cheaper than c-Si because of their lower materials costs and larger substrate.

One interesting avenue for further development of amorphous silicon is the use of microcrystalline silicon, which seeks to combine the stable high efficiencies of c-Si technology with the simpler and cheaper large-area deposition technology of a-Si.

Emerging thin film technologies are starting to make significant progress in grid-connect markets, but crystalline technologies continue to dominate. Thin films have long held a niche position in low power (<50W) and consumer electronics applications. Thin film may offer particular design options for building integrated applications.

Developing Technologies: Concentrators

Solar cells usually operate more efficiently under concentrated light. This has led to the development of a range of approaches using mirrors or lenses to focus light onto specially designed cells. Heat sinks, or active cooling of the cells, have also been used to dissipate the large amount of generated heat. Unlike conventional flat plate PV arrays, concentrator systems require direct sunlight, and will not operate under cloudy conditions. They generally follow the sun's path through the sky during the day by use of a tracking mechanism.

Concentrators have not yet achieved widespread application in photovoltaics, but solar concentration has been widely used in solar thermal electricity generation technology. For example, generated heat has been used to power a turbine.

Batteries

Rechargeable batteries are the most effective storage mechanism available. Remaining capacity can be used up by the electrochemical conversion process of the battery. Battery storage capacity is rated in ampere hours, which is the current delivered by the battery over a set number of hours, at a normal voltage, and at a temperature of 25ºC.

Most PV systems use lead acid batteries or conventional flooded batteries. Nickel cadmium batteries are usually the best option when very high reliability is required.

Charge Controllers

A charge controller is used to prevent over- and under-charging of the battery. A charge controller is typically necessary if the peak charging rate of the solar module is more than 1.5% of the battery ampere hour capacity. The quality of the regulator is a key factor in the reliability of the overall system because it aligns the depth of discharge with the battery temperature and the rate of discharge. Blocking diodes perform the role of preventing reverse discharge of the battery through the modules at times of low to no sunlight. This prevents damage to the modules and reduces energy loss.

Monitoring current and voltage throughout the system is important for safety and overall system performance. A voltmeter will monitor the performance of the battery, while an ammeter monitors the output of the solar modules.
