Solar cells grow thinner, but glow brighter

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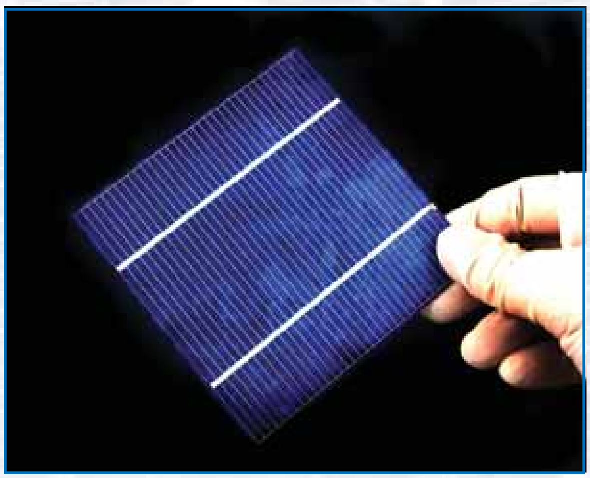
There is growing awareness and deliberations on environmental issues as is evident from international summits on environmental issues. A conference on environment was held in 1972 in Stockholm, the capital city of Sweden. The representatives from different countries thought of sustained development without degrading the natural environment. There were also similar discussions in the UN General Conference in 1972. After 20 years, in June 1992 an 'Earth Summit' was held at Rio de Janeiro (Brazil). Representatives from 178 countries discussed environmental issues. Subsequently, at the UN Conference on Global Climate Change, held in Kyoto, Japan on 11 December 1997, delegates from 159 countries signed an agreement on global warming that continued the process begun at the 1992 Earth Summit under clean development mechanism. The agreement known as Kyoto Protocol has come into force from 15 February 2005. Developed nations are to reduce emissions of greenhouse gases by 5.2% below 1990 levels by 2012.



In December 2007, nearly 200 nations agreed at the UN-led talks at Bali, Indonesia. The new pact of Bali summit to combat global warming will replace Kyoto Protocol after three years. According to a report from UK Hadley Centre, global greenhouse gas emissions should be near zero by 2060 in order to restrict average global temperature rise to within 2 °C above pre-industrial level. Therefore, all nations must show leadership by insisting on an equitable framework with clear emission reduction targets. They have no option but carbon-free technologies in order to reach zero emission of greenhouse gases. Solar power is treated as the best option in this regard.

Solar energy

About 5 × 10^9 years of perpetual radiation by the sun is possible due to nuclear fusion, a process in which the lighter nuclei like hydrogen combine into heavier nucleus of helium and release tremendous amount of energy. The interior temperature of the sun is more than 20 000 000 °C and that of the surface is about 5500 °C. A small portion of total solar radiation reaches our upper atmosphere at the rate of 1.36 kW per square metre (known as solar constant). The atmosphere and its clouds absorb or scatter as much as 53% of this radiation and the remaining 47% radiation that reaches the ground consists of nearly 50% visible light, 45% infrared radiation, and smaller amounts of ultraviolet light and other forms of electromagnetic radiation. Unbelievably, solar energy reaching the earth in one hour is equal to the total energy used by the world's population in one year. The radiations from the sun can be converted into electrical energy using devices like solar cells.

Solar cells

The device that can directly convert solar energy into usable electrical energy is known as solar cell or photovoltaic cell. The voltage generated from a single photovoltaic cell is typically only a fraction of a volt. By connecting large numbers of individual cells together, more than one kilowatt of electric power can be generated. A group of solar cells connected in series to produce a desired amount of electricity is called a solar panel. Solar cells are widely used in calculators, watches, toys, satellites, space probes, and so on. Nowadays, scientists are trying to increase the efficiency of solar panel to have easily feasible solar vehicles.

Structure of solar cells

A solar cell contains six layers stacked up one on another. They are (i) front electrical contact layer, (ii) antireflection layer, (iii) top junction layer, (iv) absorption layer, (v) back junction layer, and (vi) back electrical contact layer. The two electrical contact layers are present in some widely spaced grid pattern and is composed of a good conductor such as a metal. The back electrical contact layer simply acts like an electrical contact and thus covers the entire back surface of the cell structure. It is always made of metal to ensure good electrical conduction. Materials such as silicon oxide or titanium dioxide are employed as the antireflection layer in solar cells.

The three important layers called energy conversion layers, namely the junction and absorption layers below the antireflection layer, belong to semiconductor materials such as silicon, gallium arsenide, indium phosphide, and copper indium selenide. Semiconductors can absorb the visible light of sunlight by producing excited free electrons. In a solar cell, the sunlight enters the device through the antireflection layer. The layer traps the light incident and transmits this light into the three energy conversion layers below. The middle absorber layer in the structure is the core of the device. The two electrical contact layers allow electric current to flow out of and into the cell.

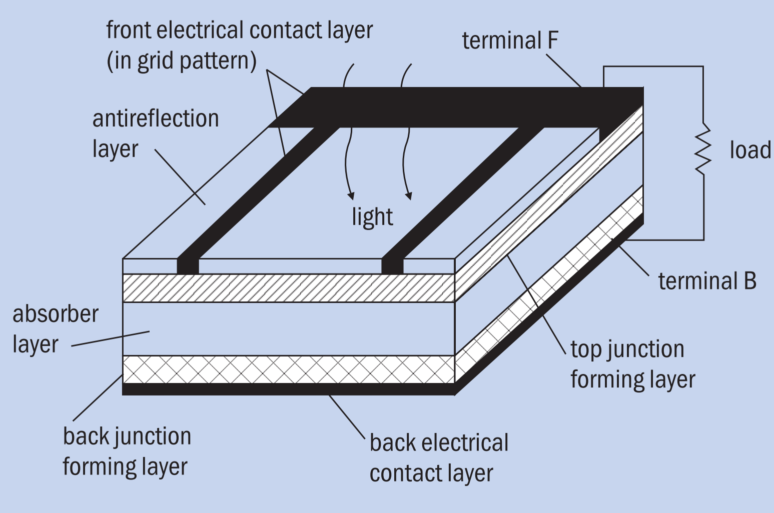


Figure 1 Structure of a solar cell

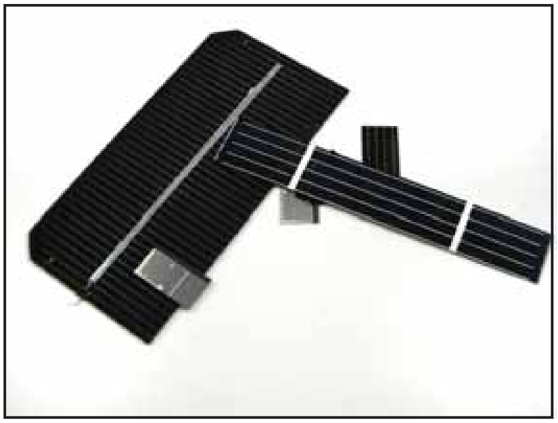
Principle of operation in solar cells

The process which causes the cell to convert light directly into electrical energy is called photovoltaic effect. When different types of thin semiconductors are joined together by special fabrication technique to form solar cell, an electrical field is automatically set up at the interface between these materials. The role of the junction layers is to establish this electric field. But electrons are attached to specific atoms and not free to move in a direction dictated by the electric field in order to constitute an electric current. Light striking the cell provides the energy needed to free some electrons from their bound condition. Free electrons cross the junction between two dissimilar semiconductors more easily in one direction than in the other. It leads to accumulation of electrons on one side of the junction.

These energetic electrons are collected by the electrical contact layers for use in an external circuit where they can do useful work. A negative voltage is created with respect to the other side, just as one electrode of a battery has a negative voltage with respect to the other. This is known as open circuit voltage or photovoltaic emf. It is of the order of 0.5 volt for silicon cell and 0.1 volt for a germanium cell. The photovoltaic battery can continue to provide voltage and a direct current as long as light continues to fall on the two materials.

Development of solar cells

The solar cell we use today has taken about 170 years to get its present form. In 1839, the French physicist Antoine-César Becquerel, while experimenting, observed that voltage developed when light fell upon a solid electrode in an electrolyte solution. The development of solar cell technology stemmed from this discovery of the photovoltaic effect. But it took another 50 years for the first true solar cell using junctions to be made. Charles Fritts for the first time constructed a solar cell using junctions formed by coating the semiconductors selenium with a very thin layer of gold. No doubt, the device was able to transform less than 1% of the absorbed light energy into electrical energy. But it motivated other researchers to opt for clean power. Another metal–semiconductor junction solar cell made of copper and copper oxide was demonstrated in 1927. Both the selenium cell and the copper oxide cell were being employed in light-sensitive devices, such as photometers, by 1930. All these early solar cells had conversion efficiencies within 1%.



The main aim of the researchers was to enhance the energy conversion efficiency of the cell beyond 1%. The first solar cell with greater efficiency came in 1941 with a silicon solar cell developed by Russell Ohl. In 1954, three American researchers – G L Pearson, Daryl Chapin, and Calvin Fuller – demonstrated a silicon solar cell capable of a 6% efficiency when used in direct sunlight. Solar cells made of gallium arsenide having more than 20% efficiency were fabricated in 1980s. in 1989, the efficiency could be hiked to 37% through convergence of sunlight onto the cell surface by means of lenses. In general, solar cells of widely varying efficiencies and cost are now available.

Recent developments

Research by Walukiewicz and Yu

Researchers like Wladek Walukiewicz and Kin Man Yu at the Materials Science Division of Lawrence Berkley National Laboratory in USA have developed solar cells with energy conversion efficiency above 40%. They have created a new type of semiconductor material. In conventional single conductor solar cells, the efficiency achieved is only 25%. In this case, the electrons absorb solar energy to jump from a bound state (called valence band) to a free state (called conduction band) to a free state (called conduction band). The incident sunray carried photon with energy, E = hf, where 'h' is a constant known as Planck's constant and 'f' is the frequency of light. Electrons only use those photons/sunrays having more energy than wide energy gap (called forbidden gap) to jump from valence band to conduction band.

About half of the solar spectrum with the photons having lower energy pass right through the material and are not used in the production of electricity. The newly developed semiconductor material can capture these low-energy photons to produce electricity and hence increase the efficiency, according to www.technologyreview.com.

As shown in Figure 2 (a), the usual semiconductors possess two bands, namely, valence and conduction bands. But the new and more efficient semiconductors have three energy bands instead of the usual two. A third band is created below the conduction band, effectively splitting the energy gap into two smaller parts (Figure 2 [b]). The splitting up of conduction band was possible by introducing a few atoms of oxygen into a sinc–magnesium–teleurium alloy. Similar splitting is also possible by adding nitrogen to a semiconductor such as gallium–arsenide–phosphide to get multi-band semiconductor. The third band acts like a stepping-stone for the electron. Thus, a low-energy photon may excite an electron to the intermediate band and then up to conduction band using another low-energy photon. A high-energy photon is represented by H in Figure 2 (a) whereas, two low-energy photons are represented by L1 and L2 in Figure 2 (b).

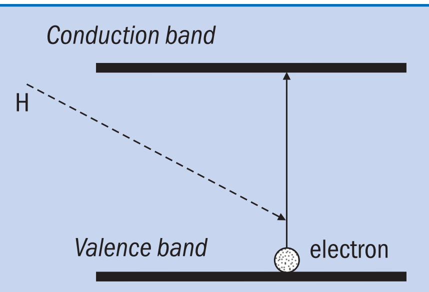


Figure 2(a) Bands in semi conductor

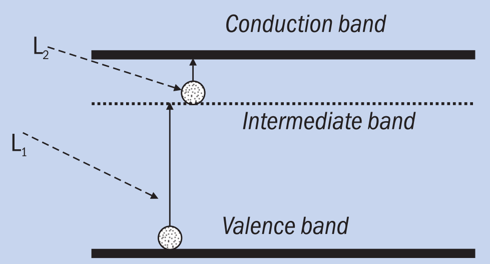


Figure 2(b) New type of semiconductor with three bands

Research by Barnett and Honsberg

According to www.renewableenergyaccess.com, a consortium led by University of Delaware has achieved solar cell efficiency of 42.8% breaking the previous record of 40.7% attained in December 2006. The research was led by Allen Barnett and Christina Honsberg who direct the University's High Performance Solar Power Programme. With a goal of 50% efficiency they have worked for 21 months before presentation. The previous best of 40.7% was achieved with a high concentration device that requires sophisticated tracking optics and features a concentrating lens the size of a table and more than 1 foot thick. In contrast, the consortium's devices are potentially far thinner at less than 1 cm. The cell uses a novel lateral optical concentrating system. It splits the solar light into 3 different energy silos of high, medium, and low. Thus, the whole solar spectrum is used by the cell with various light sensitive materials.

Solar cells thinner than a hair strand

Scientists have developed thin solar cells that will power the nanoscale gadgetry of tomorrow. The cells are 20 000 times as thin as human air. Charles Leiber and colleagues at the Harvard University have devised this silicon nanowire that can convert sunlight into electrical energy. A single strand of such wire virtually invisible to the naked eye can crank out up to 200 billionth of a watt, that is, 200 picowatt. At nanoscale, this power is enough to provide a steady output of electricity to run ultra-low power electronics. It is so thin that it can be worn on or fitted inside the body. It is no doubt clean, highly efficient, and renewable.

Future research

With the introduction of a third band below the conduction band of the semiconductor, the problem is partly solved, but not over. Researchers are trying to introduce more and more intermediate levels to absorb the whole solar spectrum for its 100% conversion into electricity. Regarding the size, people are trying to make thinner and lighter solar cells in order to power the nano-gadgets in future. No doubt, the research in this field sounds promising.