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Factors Affecting the Efficiency of Solar Panel Installed at Elevated Location

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A B S T R A C T

Silicon remains the material of choice for photovoltaic because of its abundance, non-toxicity, high and stable cell efficiencies, the maturity of production infrastructure and the deep and widespread level of skill available in relation to silicon devices. Rapidly decreasing module prices mean that area-related balance of systems costs are an increasing proportion of photovoltaic systems price. This places a premium on efficient cells. In recent years there have been large improvements in mass production of high quality wafers, the ability to handle thin wafers, maintenance of high minority carrier lifetimes, surface passivation, and minimisation of optical losses, device characterisation and in other areas. Many of these improvements are viable in mass production. The upper limit of silicon solar cell efficiency is 29%, which is substantially higher than the best laboratory (25%) and large-area commercial (24%) cells. Cell efficiencies above 25% appear to be feasible in both a laboratory and commercial environment. Such a cell will have minimal bulk recombination due to a combination of a thin substrate with a very high minority carrier lifetime; superb surface passivation; small-area electrical contacts consistent with low contact recombination, free carrier absorption and contact resistance; excellent optical control through the use of texturing, antireflection coatings and rear surface reflectors; low edge recombination assisted by the use of thinner wafers, larger cells and edge passivation; and sufficient metal coverage to minimise resistive losses. This paper will survey current work in high performance.

Keywords: Solar Radiations, High-Efficiency; Back-Contact, Solar Panel

1. Introduction

The dominant photovoltaic material is crystalline silicon. Crystalline silicon is abundant, non-toxic, low-cost, allows the fabrication of cells with high and stable conversion efficiency, is the most maturephotovoltaic material, and is the long-term market leader. There is very widespread and deep skill and infrastructure available in crystalline silicon technology, both within the photovoltaic and integrated circuit industries. Thousands of researchers and companies work in the area of crystalline silicon, feeding their capabilities into the manufacture of crystalline silicon materials, cells and modules. Problems and opportunities that arise rapidly come to the attention of many skilled people and companies, leading to commercial solutions. Companies innovate rapidly, creating machines that can implement in a commercial setting improvements obtained in laboratories. Crystalline silicon photovoltaic modules that meet certification requirements are widely trusted to perform as expected for decades. Their failure modes are well understood and

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avoidable. Crystalline silicon modules have substantially higher efficiency than any non-concentrating modules on the market, which reduces the cost of the area-related balance of systems components. As the cost of the modules declines, the latter becomes a dominant cost of photovoltaic electricity. These attributes are not shared to the same degree by competing materials. In difficult to change in the case where the dominant technology has many favourable attributes, as is thecase with crystalline silicon. Many analysts expect the past and present domination of the photovoltaic market by crystalline silicon technology to continue into the indefinite future.The theoretical limiting efficiency of the crystalline silicon solar cell under non-concentrating sunlightis about 29% [4]. This is not far below the theoretical limit for any single junction solar cell. The calculation of maximum efficiency assumes zero reflective losses, Lambertian light trapping, zero resistive losses, zero surface recombination, and volume recombination arising only from Auger and Radiative modes. Much higher efficiencies are possible with tandem solar cells and other theoretical concepts. The best III-V tandem cells reach 44% (Solar Junction, as reported by NREL) under concentrated sunlight. However, costs per unit area are orders of magnitude higher than for crystalline silicon cells. The best laboratory and commercial silicon solar cells currently reach 24-25% efficiency under non-concentrated sunlight, which is about 85% of the theoretical limit.

The main commercial motivation for developing higher cell efficiency is reductions in the area-related costs. These include module materials (silicon, cell fabrication, cell interconnection, glass, pottants, back sheets, frames) and systems costs (transport, fencing, land preparation, support structures, modul mounting, cabling). Secondary motivations include to obtain larger power outputs from small areas such as the roofs of buildings, and to obtain the reduced temperature coefficients of efficiency that arise from high open circuit voltage cells. Given the attractive attributes of crystalline silicon summarised above, two prospective routes to higher efficiency are improved cell design and fabrication, and tandem cells
based on silicon.

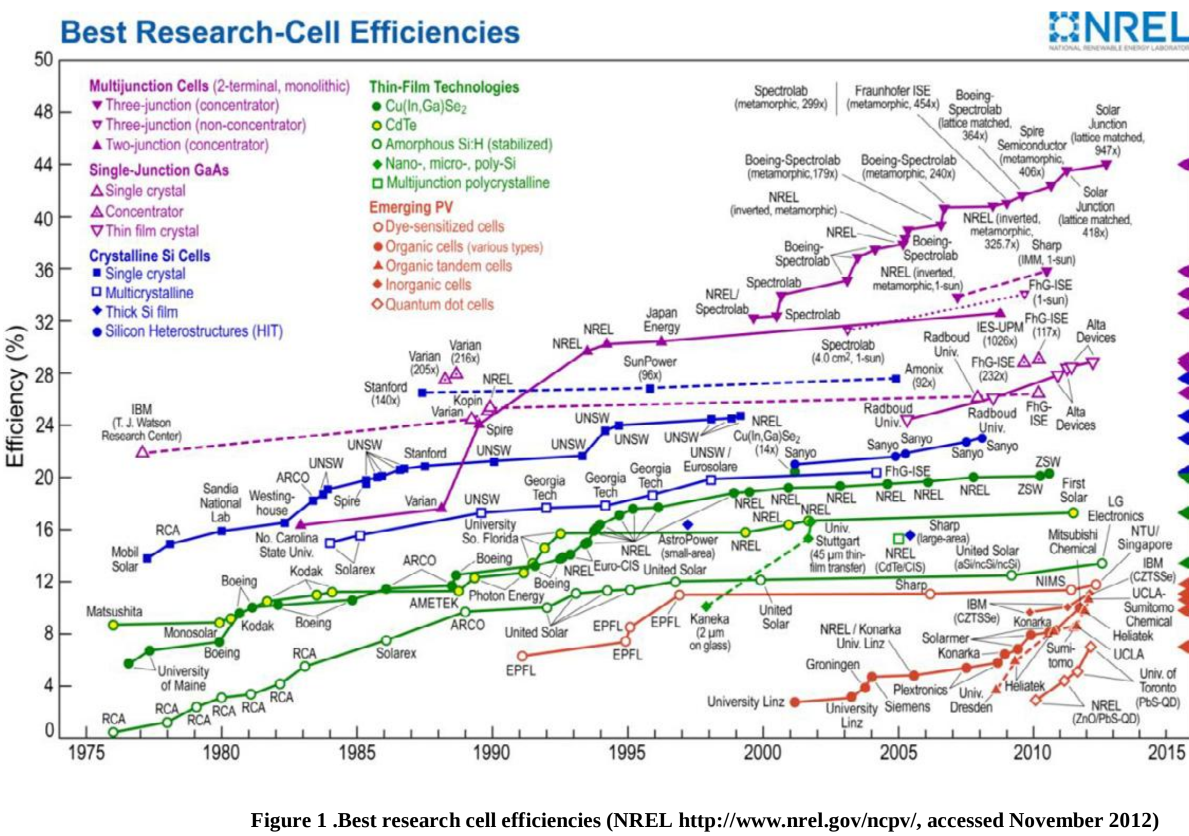
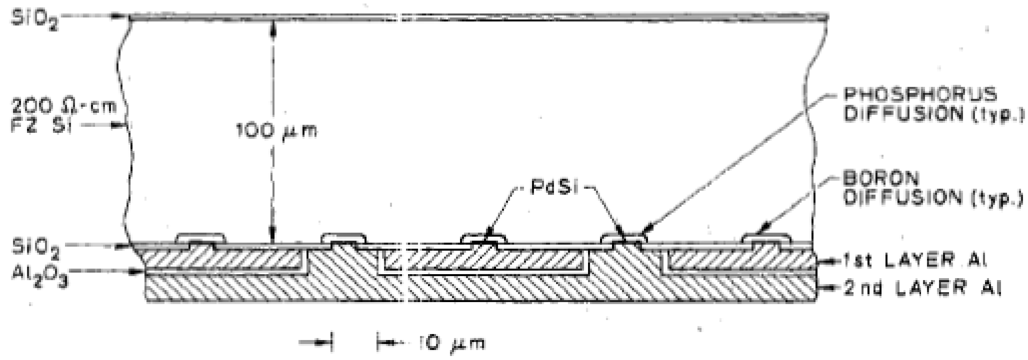


Figure 1 .Best research cell efficiencies (NREL http://www.nrel.gov/ncpv/, accessed November 2012)

The original reason for the development of back contact solar cells by the Stanford group was to obtain high-performance silicon concentrator cells. However, the development of III-V tandem solar cells with much higher efficiency potential than single junction silicon cells eliminated the concentrator market for silicon. SunPower Corporation grew out of the work of the Stanford group, and set out to simplify and improve back contact cells for large-scale one sun commercial applications. SunPower makes the best silicon solar cells presently on the market, with efficiencies of over 24% for the best large area (155 cm²) cells, and Voc of 720 mV, Jsc of 41 mA/cm2 and fill factor of 83% [2, 3].



2. Working of Solar Panel

Efficiency of solar cell is greatly affected by the amount of solar irradiance. It is one of the most dynamic factors which change the solar array performance [3]. It is measure of amount of solar radiation from the sun striking on specific surface. It is commonly expressed in watts per square meter (W/m2). Under ideal conditions a solar panel should receive an irradiance of 1000 W/m2 but unfortunately this is not true in most environments. Irradiance depends on geographical position, angle of sun to solar panel and amount of energy wasted by reflection from dust particles or from fog or clouds. Therefore change of irradiance means change of output performance of solar panel.

Solar Photovoltaic (PV): Historical development: Solar Photo-voltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. It is a device that directly converts solar energy into electricity by photovoltaic effect. Photoelectric effect was first time recognized in 1839 by F.C. Becquerel. In this Phenomenon the electrons are emitted from matter after absorption of energy from radiation. In 1883 – First solar cell was built by coating Selenium with extremely thin layer of gold. In 1958 – Bell laboratories found that Silicon (Si) doped with certain impurities was very sensitive to light. This finding resulted in the production of first practical solar cell with sunlight conversion efficiency ~6% made from materials that emit electrons when exposed to EM radiation. Mainstream materials presently used for photovoltaic include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Due to the increased demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years. The amount of power available from a solar cell depends on Type and area of material - Intensity of sunlight - Wavelength of sunlight Working principle: Sunlight is made out of tiny energy pockets called photons and that each individual solar cell is designed with a positive and negative layer thus being able to create an electric field (similar to the one in batteries). As photons are absorbed in the cell their energy causes electrons to get free, and they move to the bottom of the cell, and exit through the connecting wire which creates flow of electrons thus generate electricity. The bigger amount of the available sunlight the greater the flow of electrons and the more electricity gets produced in the process. It is a form of photoelectric cell (in that its electrical characteristics e.g. current, voltage, or resistance vary when light is incident upon it) which, when exposed to light, can generate and support an electric current without being attached to any external voltage source, but do require an external load for power consumption. Pure Si is a poor conductor of electricity. Doping – introducing impurities into an intrinsic (pure) semiconductor to change its electrical properties. Examples of n-type dopants – Phosphorus (Ph), Arsenic (As), Antimony (Sb). Examples of p-type dopants –Boron (B), Aluminium (Al). Doping provides with charge carriers (holes and electrons) that can carry electrical current. Electric field to force electrons to flow in a certain direction. This electric field is achieved by bringing together p-type and n-type semiconductors together to make a diode. Holes and electrons from p-region and n-region respectively recombine, creating a depletion region and an electric field. The movement of holes and electrons are represented below. Depletion region continues to grow till the electric field becomes large enough to prevent the flow of charge carriers from one side to the other. Now, if the diode is exposed to light, it frees the electrons in n-region and these electrons, repelled by the electric field, flow through the load to p-region. These electrons constitute current.

Individual solar cell, several cells are wired in series in the manufacture of a "laminate". The laminate is assembled into a protective weatherproof enclosure, thus making a photovoltaic module or solar panel. Modules may then be strung together into a photovoltaic array. Photovoltaic arrays: A photovoltaic array (or solar array) is a linked collection of solar panels. The power that one module can produce is seldom enough to meet requirements of a home or a business, so the modules are linked together to form an array. Most PV arrays use an inverter to convert the DC power produced by the modules into alternating current that can power lights, motors, and other loads. The modules in a PV array are usually first connected in series to obtain the desired voltage; the individual strings are then connected in parallel to allow the system to produce more current. The array rating consists of a summation of the panel ratings, in watts, kilowatts, or megawatts. Mounting systems: Modules are assembled into arrays on some kind of mounting system, which may be classified as ground mount, roof mount or pole mount. For solar parks a large rack is mounted on the ground, and the modules mounted on the rack. For buildings, many different racks have been devised for pitched roofs. For flat roofs, racks, bins and building integrated solutions are used. Solar panel racks mounted on top of poles can be stationary or moving. Side-of-pole mounts are suitable for situations where a pole has something else mounted at its top, such as a light fixture or an antenna. Pole mounting raises what would otherwise be a ground mounted array above weed shadows and livestock, and may satisfy electrical code requirements regarding inaccessibility of exposed wiring. Pole mounted panels are open to more cooling air on their underside, which increases performance. A multiplicity of pole top racks can be formed into a parking carport or other shade structure. A rack which does not follow the sun from left to right may allow seasonal adjustment up or down.

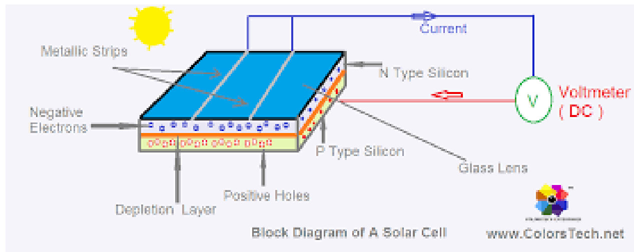


Figure 2 Solar Cell Working

Solar Thermal effect

i. High upfront and maintenance costs constitute significant barriers. This is particularly relevant for poorer potential customers.

ii. The lengthy payback periods and small revenue stream also raises creditworthiness risks of such systems.

iii. The bias against distributed energy technology platforms among conventional energy agencies and utilities

iv. In the case of solar thermal applications, diffusion can be hindered by gaps in technical and financial data needed for accurate planning and implementation of projects

3. Data Analysis

A. Without mirrors and without cooling

Though this method was practiced by most of the people from all over the world a few years ago but now a days this method is almost losing its value due to its low efficiency. The curve from fig.2 clearly shows that output power by using solar panel without mirrors and without cooling is not only far lessthan other two methods but also less than its rated power. Solar irradiance, most of the time in this case is also round about 750w/m^2.

B. With mirrors and without cooling

Efficiency of solar panel can be increased by increasing solar irradiation on solar panel. As we have seen from the graph that irradiance is continuously changing with respect to time so output power largely depends on irradiation. As earth has only one sun so reflecting mirrors can also be named as sun. So here in this case solar radiations from four suns are striking on solar panel and the results are also encouraging . This is because in these peakhours as irradiance received is at its maximum so temperature effect dominates in these hours of the day and power output decreases. Collisions between atoms and electrons are hindering the flow of current and thereby increasing resistance which eventually leads to increase in temperature and cause reduction of output power. It can also be verified from Fig.3 that efficiency of solar panel during these hours is less than the other hours of the day but at the same time its efficiency is better than using solar panel without mirrors and without cooling. Approximately, on average 32% efficiency was improved by position.

Technical Barriers

Solar PV issues

i. The efficiency constraint is one of the main barriers to widespread use. The thin-film and crystalline-silicon modules have efficiency ranges of 7% to 10% and 12% to 18% respectively. Even as PV technologies with significantly higher efficiencies are under development, the present efficiency ranges constitute a barrier.

ii. ii. Strong demand for PV outpaced the supply and partly stalled the growth of solar sector. However, the resulting surge in production combined with the present financial crisis has created an industry wide. iii. The performance limitations of balance of system components, of solar PV system such as batteries, inverters and other power-conditioning equipment are another area with considerable room for improvement.

iii. Lack of clarity regarding technical limits of exporting power to the grid and network grid protection requirements for PV systems to safely export power. v. In the case of stand-alone PV systems, storage is an important concern as is the shorter battery life compared to that of the module. Further, safe disposal of batteries becomes difficult in the absence of a structured disposal/recycling process.

iv. Lack of proper information about the utilization of solar electric systems, especially PV, For instance, incorrect charging techniques such as polarity reversal were seen as frequent problems that damaged the junction boxes of the PV panel. It was observed that cracks in the glass of the PV module, water intrusion during rainy season, dust and algal growth accumulating along the lower section of the panels also constituted some of the major problems of PV systems. When the PV systems are promoted, especially from government sponsored programs, very little care is given to the potential load of the prospective user, household. People have been found to install more bulbs than the specified number. In addition, in many cases it was found that the replacement for a fused CFL bulb was a cheaper incandescent one. This resulted in faster drainage of the battery. It has also been observed that in an effort to overcharge,, the battery, the charge controller is bypassed. Such practices reduce the battery life and require investment in a new battery.

4. Conclusion

The results of the experiment for improving efficiency of solar panel using mirrors and cooling were come out to be highly encouraging. Using mirrors plus cooling is better than the other two as efficiency is approximately 52% in this case. Output power from simple solar panel without using mirrors was 24 watts and from solar panel with mirrors and cooling was 37.709 watts which means instead of purchasing new solar panel one can obtain 52 percent more power from the same solar panel using this technique.

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