**How to Improve Efficiency of solar Energy and**

**Re-considering the Accepted Theoretical Maximum Efficiency of Solar Cells**

***Electrical Power and Systems Machinery***

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**Sunlight to Electricity and Power to the People**

There is no doubt; solar energy is the most ancient of all forms of energy. Humans, plants and animals have been using solar energy for almost all of history in its raw form. Not until the turn of the 20th Century was first silicon solar cell made entirely by accident by Russell Ohl, a researcher at Bell Telephone Laboratories in New Jersey. Techniques for preparing silicon material coupled with those of making p-n junctions in a controlled way promised a bright future in solar energy during the 1950s. By the end of the decade, solar cells could convert about 14% of the available sunlight into electricity (Green). We have not gone far since then. What is holding us back? And what are the techniques to improve?

In solar cells construction, instead of the top contacts lying across the surface and blocking sunlight, the cells contacts can be buried into grooves down the surface. These grooves can be made by using a laser to blast on to the surface of the silicon wafers (Green). Since the exposed area is a function of efficiency, the overall efficiency of the cell is improved. Since the same quality of silicon wafer is used, there is no extra cost incurred. This cell will produce 20-30% extra power boosting the efficiency to the range of 16-18% (Green).

In silicon wafer construction, a cylindrical ingot of silicon is made and is then sliced into wafers. This is clearly not the best way to produce large areas of silicon needed to produce substantial power. One way to improve this is to use ribbon substances. In this technique, molten silicon rises up between rectangular faces of a carbon die. This will again result in construction of improved silicon wafers in a more economical way.

There is a tendency, in solar cells construction, to hold onto the ideas of self-supporting solar cells instead of depositing the cells straight on to a stronger supporting layer. It is better to deposit the thin layer of the photoactive material on to a supporting layer such as glass. This will reduce the amount of the semi-conductor used and will make possible the construction of a cell well over a hundred times larger in area. One drawback to this technique is that the supporting layer (glass for example) might be too expensive for small scale production. In large scale production, the costs of manufacturing thin-film cells will approach those of the materials used.

A mixture of silicon and germanium can be used to convert the blue, green and the red wavelengths of sunlight. This is exactly what is done in amorphous cells. In this build up, stacks of cells, each targeting a particular wavelength of light is constructed. Combinations of transition metals and elements in group III and IV of the periodic table of elements appear to provide astonishing results. One of such promising mixture is the mixture of cadmium and tellurium to form cadmium telluride (CdTe). However, CdTe is toxic and hence have limitations in terms of environmental concern. Other considerable mixtures are CuInSe2, TiO2 among others.

Last but not the least in the construction improvement is sun tracking. The southern and especially the southwestern part of the United States called the ‘sunbelt’ hold the most promise for cost effective solar energy utilization. Collectors that track the sun intercept about 80% more energy over a year and 150% more during the winter.

Having looked at ways to improve the efficiency of existing solar energy, let’s look at the theoretical maximum of solar energy and analyze why we can or cannot improve it.

Presently, the theoretical maximum efficiency of solar energy is 29%. What happens to the other 71%? Using our understanding of p-n junction semi-conductors, we will better understand what is going on.

The sunlight striking the earth’s atmosphere carries about 1.35 KW of energy per square meter. By the time this light reaches the surface of the earth, it carries about 1 kW/m2. The photons which make up this light have a range of different energies. The majority of the lost is caused by the energy of the photons being spread out (Buresch).

The perfect photon would have an energy exactly equal to the band gap of silicon. A photon with less than this amount of energy will not be able to nock out valence electron all the way to the conduction band. These photons pass straight through the silicon crystal with no effect wasting 24% of the solar energy in the process (Buresch).

If a photon has an energy larger than the band gap, the excess energy is not used. The unused energy makes the crystal hot. This causes an additional loss of 32% of the solar energy. The above mentioned losses are inherent in nature and as long as we used only silicon, there not much we can do about it (Buresch).

However, instead of using only silicon, using stochastic processes, we can design a system where silicon and other semi-conductive materials are randomly placed next to each other. In this system with favorable probabilistic occurrence, more of the photons that are too small for silicon will fall on a semi-conductive material with smaller band gap than those with higher band gap. Its valence electron will be kicked to conduction instead of passing straight through as was the case when only silicon was used. In this system, at least 8% of the 24% can be regained and thereby increasing the theoretical maximum.

Even more, more of the photons that are too large for silicon will fall on the semi-conductive material with larger band-gap. The excess energy that will have been wasted on silicon is now utilized. The overall result is much more efficient system.

Other factors affecting maximum theoretical efficiency are reflection and impurities. Reflection means photons bouncing off the crystal instead of going into the crystal. Better coating of the surface of the cells can increase the efficiency by 3%.

Impurities hinder the motion of the mobile electrons and holes generated in the depletion region. These mobile electrons and holes have only a limited lifetime before they run into another hole or electron and get absorbed. These carriers are not safe until they have reached their respective n or p region. If the time these particles need to move out of the depletion region is increased by bumping into impurities, the efficiency of the cell is greatly reduced. But purer crystal means more expensive crystal. Hence, a purer crystal with a better trade off between cost and efficiency should be used.

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