Solar Cells – Let's Brighten The World

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Ever thought of lighting a bulb without paying electricity bill!!! Though it seems to be a dream, it can come true if we utilize renewable sources of energy that nature has blessed us with. With the increasing demand for energy and declining non-renewable sources, the cost of energy production is increasing day by day.Moreover, the carbon emission due to combustion of fossil fuels contribute to global warming which results in the increase of earth's temperature. This calls for the need for alternative energy resources and sun being one of the ultimate sources of energy on earth, it provides a ray of hope. The solar energy is seen as one of the most importantsources for clean and renewable energy to avoid the energy crisis. Since the sunlight falling on earth is a blessing to us and do not require any payment, solar energy requires only initial installation cost.

The key element in obtaining energy from the sun is a solar cell. Solar cells convert energy obtained from the sun into electrical energy. The performance of solar cells is measured by using efficiency as one of the parameters. The efficiency of a solar cell is defined as the ratio of electrical power to the optical power, generated by light falling on it. Thefavourable properties of silicon, like robustness, reliability and ease of availability among others,makes it a dominating material in the market of solar cells. Conventional silicon solar cells are based on junction formation technology that requireshigh-temperature processing. The high-temperature processing increases the cost of the solar cell, called "thermal budget", and also reduces its efficiency by degrading the silicon material. This depreciates the advantage of using solar energy by increasing the initial installation

* Ms. Astha Tyagi, Ph.D. Scholar from Indian Institute of Technology, Mumbai, is pursuing her research on "Design and Development of Passivated Carrier Selective Contact (CSC) based Silicon Solar Cells." Her popular science story entitled "Solar Cells – Let's Brighten the World" has been selected for AWSAR Award.

cost. Therefore, a low-cost solution for the development of solar cells is the need of the hour.

Our research focuses on the development of solar cells that do not require high thermal budget and result in improved efficiency. We started looking for an alternative design for solar cells that could solve our purpose and help us in contributing to society. Junction-less solar cells that utilize thin layers for separating charge carriers and, hence, produce electric energy seemed to be a good substitute. Now the next challenge was to find the materials that can act as charge separating layers with silicon in these carrier selective contact (CSC) solar cells. After exploring various options, we found titanium dioxide combined with molybdenum oxide or nickel oxide layers, popularly known as transition metal oxides (TMOs),on either side of silicon as possible suitable options. The validation of the idea was required. In order to understand the performance of CSC solar cells, we first chose to modelthese cells using software to minimize the wastage of hardware resources. The modelling of the working of CSC solar cells showed that under ideal conditions, these cells have the potential to reach efficiency higher than the reported efficiencies till now in silicon solar cells.

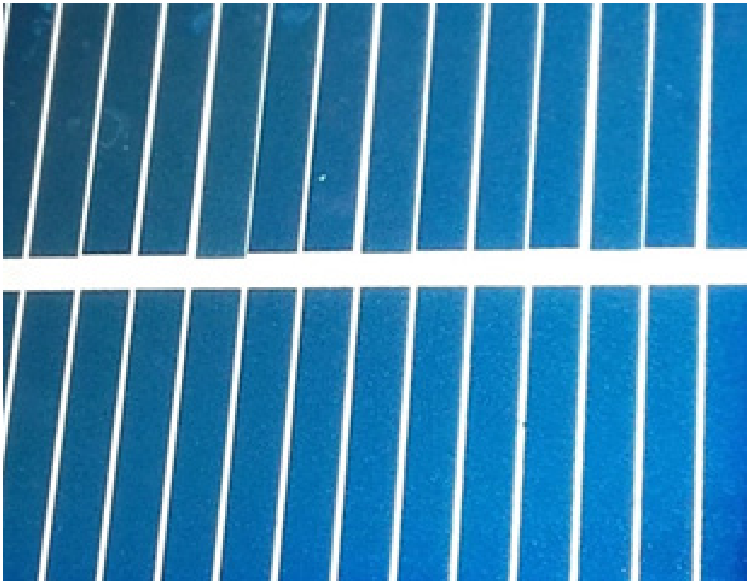
The literature helped us to understand that the practical realization of CSC solar cells with TMO layers over silicon result in highly non-ideal surfaceand, hence, poor performance. In order to overcome the issue of the non-ideal surface of silicon and TMO, we incorporated a passivation layer using amorphous silicon (a-Si) to achieve better surface quality. We went ahead to understand the surface quality using a-Si by practically depositing the TMO layers and incorporating a-Si layer in between silicon and TMO surface. When we did the minority carrier lifetime measurement to understand the quality of the surface, we found that surface quality had improved more than 30 times by inserting the a-Si layer. This verified that we are on the right path and increased our curiosity level even more to see these solar cells working in real life.

But still, the satisfaction level was missing because there were still absorption losses in the thin layers that were obstructing the conversion of optical energy to electrical energy and, hence, hampering the performance of CSC solar cell. To eliminate these absorption losses, we came up with the idea to use these thin layers at the rear of the solar cells. This type of solar cell is proposed to absorb most of the light and convert it into electrical energy. Since this was a novel idea, we termed this type of design as carrier selective back contact (CSBC) solar cells. Modelling of CSBC solar cells showed that they can achieve efficiency close to maximum achievable efficiency in silicon solar cells.

The promising results for CSC and CSBC solar cells boosted our confidence and we went ahead to understand the physics underlying the working of CSC and CSBC solar cells. Best way to explain the working of these solar cells is through the development of mathematical equations. Hence, we first developed mathematical equations for these solar cells andthen decided the parameters to be obtained practically.

A screenshot of a solar cell

Now the next challenge started, getting each layer optimized to get the desired results. We started with the development of TMO layers and adjusted the deposition conditions to achieve favourable



properties for the transport of charge carriers and, hence, improveefficiency. The development of the a-Si layer for surface passivation was successfully integrated into the device design. After a combination of these layers was successfully implemented, weconducted contacts to flow the electric current into the external circuit. In other words, the generated charge should be collected across the load for its utilization.

We are currently working on the development of indium tin oxide (ITO) and silver stack above molybdenum oxide for extraction of charge. This way we would be able to realize the CSC solar cells in the real world. For the realization of CSBC solar cells, we need further optimizations at the rear contacts for better efficiency. Through this work, we hope to contribute to the ambitious project of the Indian government titled *Jawaharlal Nehru National Solar Mission (JNNSM)* that aims to achieve a target of 100 GW solar energy production in India up to 2022.

The research team constitutes AsthaTyagi (IIT Bombay), Prof. KunalGhosh (IIT Mandi), Prof. Anil Kottantharayil (IIT Bombay), and Prof. SaurabhLodha (IIT Bombay). We have published a research paper titled "Performance Evaluation of Passivated Silicon Carrier Selective Contact Solar Cell", in IEEE Transactions on Electron Devices (IEEE TED) in January 2018 issue (Vol 65, 1) and the work has also been presented in IEEE Photovoltaic Specialists Conference (IEEE PVSC) 2017 under title "Carrier Selective Back Contact (CSBC) Solar Cell using Transition Metal Oxides".The novel structure of CSBC has also been filed for Indian patent titled "Solar cell and structure thereof" under application number 201721004570 on February 2018.