NCPRE NEWS

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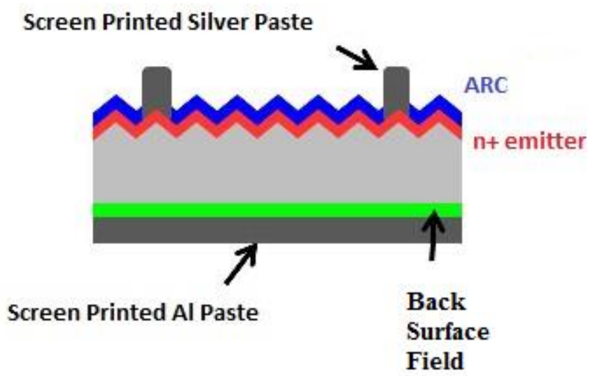
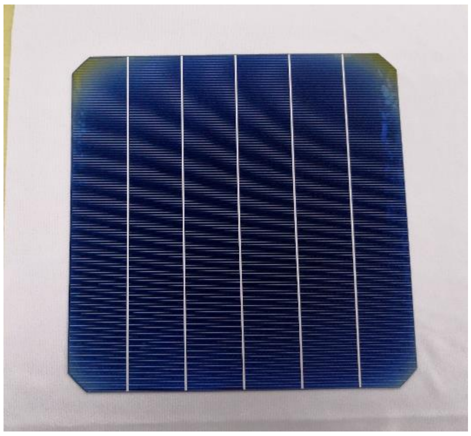
A Project of the Ministry of New and Renewable Energy at IIT Bombay

Si Solar Cell Activities at NCPRE

NCPRE's c-Si Solar cell Group headed by Prof. Anil Kottantharayil is working towards achieving high efficiency low cost silicon solar cells. At our cell fabrication facility in IIT Bombay campus, we have established a baseline for standard Aluminum Back Surface Field (Al-BSF) process. The team is actively engaged in optimizing the existing unit processes used in cell fabrication for improving the power conversion efficiency. At the same time, we are also developing novel low cost processes that have the potential to replace the existing technology in industrial environment. Our baseline process has already demonstrated 19% efficient Al-BSF mono-crystalline Si solar cells fabricated using low foot print laboratory tools.



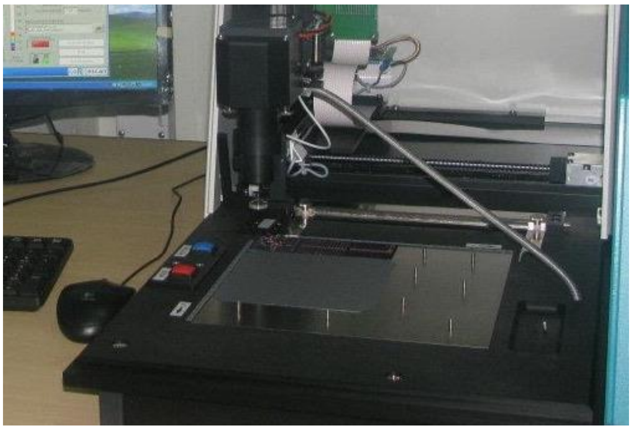
Structure of Al – BSF Si Cell

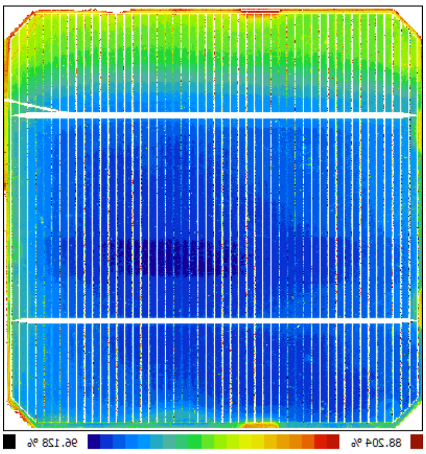


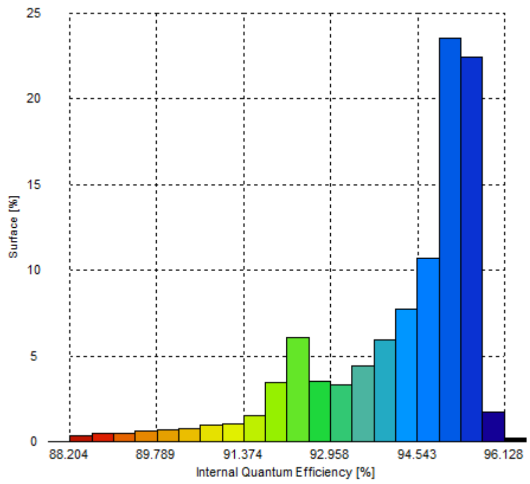
Top side of Typical Si Cell

Solar cell efficiency can be enhanced by reducing the various losses such as optical, electrical, and recombination losses in the solar cell. Optical losses are reduced using advanced Texturization techniques and anti-reflection coating (ARC). The electrical loss is reduced using better metallization techniques and contact formation that reduces the series resistance and contact resistance. Shading loss is completely eliminated in Interdigitated Back Contact (IBC) solar cell structure. Recombination loss is one of the major loss in solar cells which is due to bulk recombination, junction recombination, and surface recombination. Bulk recombination is reduced effectively using high-quality lifetime wafers. Junction recombination is eliminated in junction-less (no diffused junction) solar cell structure like a carrier-selective solar cell or a Heterojunction with Intrinsic Thin layer (HIT) solar cell. Surface recombination is reduced using different passivation techniques and layers.

The efficiency of Si solar cells can be improved through texturing process which improves the light trapping properties, or by employing shallow $POCl_3$ diffusion for obtaining improved blue spectral response, or by ARC which can further reduce the optical losses. An industrially viable alkaline based texturing process is already established for mono-crystalline Diamond Wire Saw (DWS) wafers. Our team has also developed an additive free texturing process for multi-crystalline DWS wafers which his being validated by our industry partners. We are also working on a low-cost single chemical based passivation process to improve the conversion efficiency over the existing conventional passivation schemes used in industry. Our existing baseline process is being optimized for different metallization combinations with busbar and finger dimensions to find the best contact pattern and its compatibility for the existing process. Our team is not only working in establishing routes for achieving high efficiency low cost Si solar cells but also developing several analytical tools that can quantitatively and qualitatively diagnose the losses and issues associated with the fabricated cells. Many of our Industry Partners are using these these capabilities for diagnosing problems associated in setting up their Al-BSF and Passivated Emitter Rear Contact (PERC) facility. Using our capabilities such as Photoluminescence (PL) Image and Light Beam Induced Current (LBIC) measurements we can quantitatively map the initial wafer quality used prior to processing, front surface recombination velocity, bulk diffusion length and back surface recombination on entire cell area.







Post Cell Characterization – Light Beam Induced Current Measurements

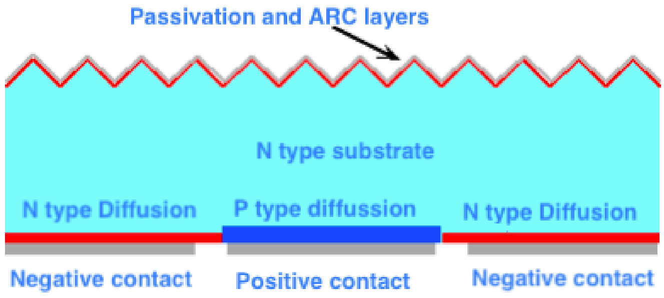
Chemical Passivation for Improving Cell Efficiency

One of our Ph.D. Student, Tarun Yadav is developing a low-cost chemical passivation process for silicon solar cells. Lately, crystalline silicon solar cell record efficiency has been reported to be 26.63% on 180 cm^2 area. Higher efficiency helps to reduce the levelized cost of electricity. Researchers all over the world are trying to enhance the efficiency and reduce fabrication cost of cells. This is done with new solar cell architecture or low-cost and low-temperature industrial fabrication processes. One of the ways of increasing cell efficiency is by reducing it's recombination losses. In order to reduce the surface recombination losses, many passivation techniques and layers are tested. Silicon oxide is one of the best known passivation layer used for silicon solar cells. However, the thermal oxide passivation used for Al-BSF process has couple of problems - high cost and degradation of lifetime due to activation of grain boundary defects. Chemical oxide is expected to be a good passivation layer for high efficiency solar cells. Tarun's work focuses on developing a new low-cost and low-temperature chemical passivation technique which will increase cell efficiency and can be included in industrial production without any major change in existing process line.

During his PhD, Tarun completed a 10 month internship at IMEC, Belgium as an international scholar. IMEC is an international R&D and innovation hub, active in the fields of nanoelectronics and digital technologies. During internship, his focus was to investigate factors that are impacting the fill-factor and improve the fill-factor HIT-IBC solar cells. HIT-IBC solar cell is the same architecture that has been achieved the world record efficiency. Fill-factor is affected by various factors, surface passivation is one of them which was the focus of his work. Regarding his experience at IMEC Tarun says," Working at IMEC with top researchers from around the world is quite fascinating for me. I have learned a lot of things from them like working style, finding a solution of a practical problem etc. People were very helpful and cooperative. The work culture was very enthusiastic and I had been provided with all the tools and training that was required for my research. There was no time constraint for working, cleanrooms were accessible 24 hours. I had a chance to interact with many people working in different areas during my stay that gave me more insight about the latest advancement happening in other field. I also got the opportunity to attend several workshops and courses organized at IMEC on various advanced topics such as Artificial Intelligence, Machine learning, Python etc. It helped me to learn a lot of new things which will help in my future research."

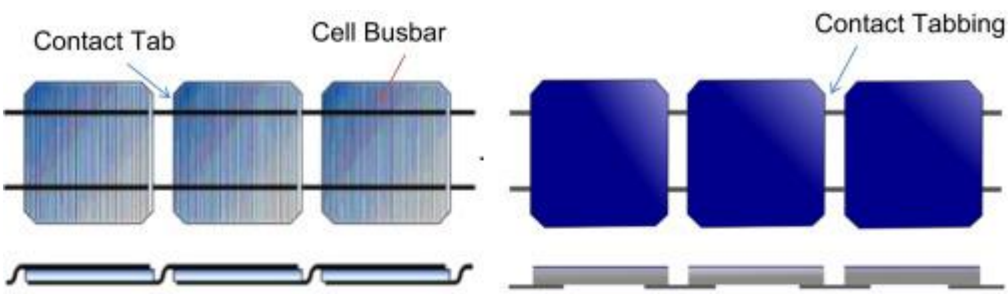
Interdigitated Back Contact (IBC) Solar Cells

One way of achieving high efficiency solar cells is by eliminating the shading losses. Rear contact cells are formed by moving all or part of the front contact grids to the rear of the device. The electron-hole pairs generated by light that is absorbed at the front surface is collected at the rear of the cell thus by reducing the shading loss cells can reach higher efficiency.



Schematic of IBC solar cell *Top Side of Typical IBC solar cell*

Interdigitated back contact solar cells thus have high efficiency due to absence of shadowing and also have a uniform attractive appearance. Other advantages of IBC cells includes lower resistive losses and improvement in short circuit current. Also unlike the Al BSF cells the interconnection of IBC cells is simpler and gives higher packaging density.



Interconnection of standard Al BSF solar cells and all rear contact cells

In spite of these advantages, this structure has not been adopted widely as the cost and complexity of the fabrication processes hinder the large scale implementation.

At NCPRE, we are developing a simplified process for IBC solar cell fabrication. The screen printing, a technology widely used for contact metallization can be adapted to create interdigitated junction patterns on the rear side. The team has shown impressive results of independent optimization of screen printed phosphorus and boron dopant paste diffusion. Further work will lead us to a promising fabrication process for IBC solar cells which can be eventually commercialized.