NCPRE

NewsLetter

August 2020 Edition

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NCPRE *Profile*

The National Centre for Photovoltaic Research and Education (NCPRE) at IIT Bombay is one of the leading PV research center in the country. It was launched in 2010 with funding from the Ministry of New & Renewable Energy (MNRE) of the Government of India, soon after the launch of India's National Solar Mission. The broad objectives of NCPRE are to provide R&D and education support for India's ambitious 100 GW solar mission. NCPRE has 29 faculty members and over 120 research staff and students across 9 Departments at IIT Bombay. State-of-the-art laboratory facilities, with over 200 equipment spread across 12 laboratories, have been set up which are accessible to all researchers and Industries. The Centre is involved in both basic and applied research activities.

These research activities include silicon solar cell fabrication and characterization, new materials for PV devices, energy storage and batteries for PV, development of power electronic interfaces for solar PV systems, and module characterization and reliability. NCPRE has a strong programme of industry outreach. It undertakes projects and consultancy in its areas of expertise. It also provides services for characterization and measurements. NCPRE periodically conducts workshops and hands-on training in the field of photovoltaics for industry as well as academia.

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Dinesh Kabra, Investigator

Electrochemical Energy Storage in Stationary Applications : *The Current Scenario*

With the installation of large-scale wind and solar power plants and to meet the growing demand for clean and energy-efficient storage systems, the installation and scaling up of Li-ion batteries in grids and PV systems has increased rapidly in the last decade. Li-ion batteries offer high energy and power capabilities and can be configured as per the desired application requirements with varying parameters such as power, energy, and voltage ratings. Lithium-ion batteries are not only emerging as the best choice for EVs but also emerging as efficient energy storage solutions for stationary applications. Lithium-ion based UPS systems coupled with solar PVs, such as Tesla's Powerwall are replacing the VRLA based battery systems.

Along with the stationary energy storage at home, Li-ion batteries can provide and maintain energy power backup in the telecom sector as well where uninterrupted power supply is essential at all times. Telecom companies are likely to implement PV modules on their towers to maintain energy sufficiency, which will further increase the demand for Li-ion batteries as efficient energy storage solutions.

New-generation UPS systems utilizing li-ion batteries provide a longer operational cycle life, high energy density, power, and are environment-friendly. Moreover, they are inexpensive and are increasingly emerging as a desirable product for energy storing commercial and residential applications. Furthermore, Government agencies in developed countries are encouraging the residential sector to become self-sustained and achieve zero-energy targets. Hence, there are significant chances of growth in regards to the demand for PV systems. Further increase in demand of li-ion batteries is driven by the PV system users who are interested in purchasing li-ion batteries for their residential energy storage solutions.

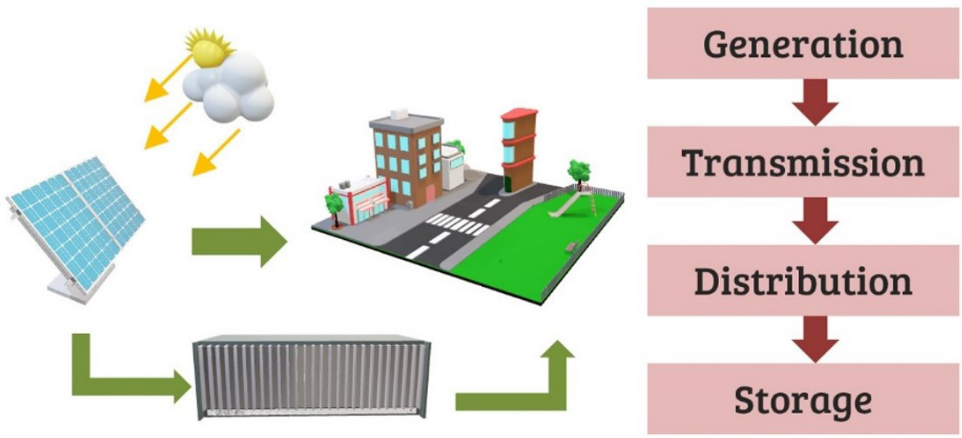


Figure - Sustainable energy development through renewable energy generation and storage

As energy storage plays a crucial role in the success of renewable energy technologies; Under the supervision of Prof. Sagar Mitra, NCPRE's Energy Storage group is focussing on various aspects of battery research; newly efficient, high performance materials and alternative chemistries such as Na-ion, Ca-ion, Mg-ion batteries. With an increase in the emergence of its multiple applicability of batteries, the activities of the group are focused on the development and optimization of prototype cells and tailoring their performance to meet solar applications. In addition to this, activities such as modelling and simulation of cell performance are being looked at to provide insights into further device development. The development of better materials for conventional Li-ion technology as well as upcoming technologies such as Na-ion is carried out. The ultimate objective of battery development activities at NCPRE is to fine-tune conventional technology, select the best possible alternatives, incorporate the results of the research components and integrate everything to provide solutions for different scales of solar energy storage systems.

Prof. Sagar Mitra

Aakash Ahuja

Sodium-ion Battery Technology: *Complimenting the Li-ion Battery*

Na-ion batteries are quickly emerging to be a complementary solution to fulfill the energy storage demands for the current scenario. Due to the high availability of sodium ion resources, inexpensiveness, excellent electrochemical features, Na-ion batteries are a propitious candidate for energy storage devices. The battery research team at NCPRE has been able to demonstrate a Na-ion full cell with doped ammonium vanadium oxide (NVO) cathode against hydrogenated sodium titanium oxide (NTO). The cell is capable of retaining 94% capacity after 400 cycles, has a high energy density of 467 Wh/kg at a very high rate of 0.2 A/g, a record over FARADION cells.

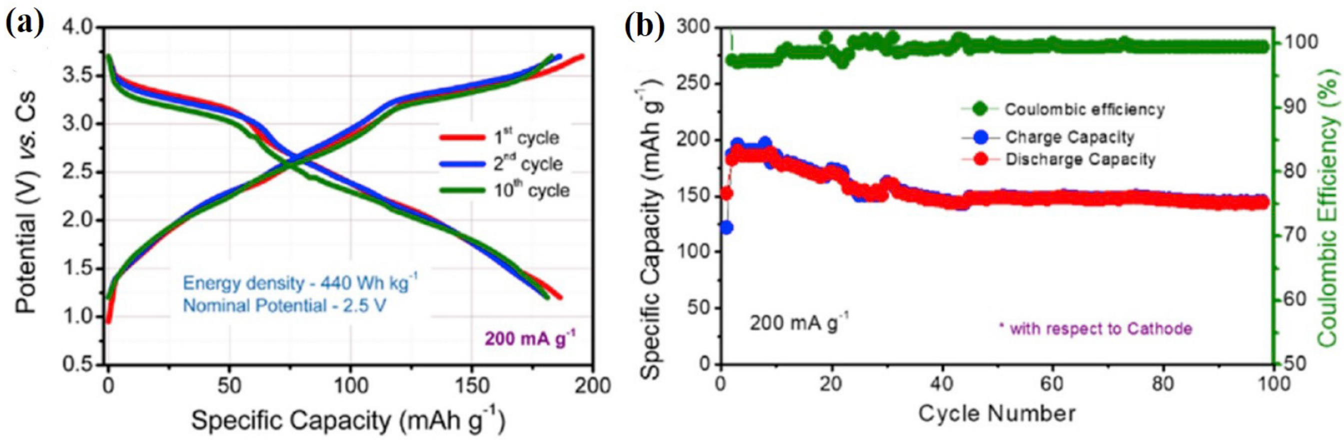


Figure - Na-ion battery full cell prototype (a) Charge discharge charcateristics (b) Cyclic performance

Various other chemistries such as novel layered transition metal oxide, sodium vanadium fluorophosphate cathode along with hard carbon anode are also being developed in order to achieve a high volumetric density cell for stationary storage application. Recently, the energy storage group at NCPRE has reported, for the first time an extremely high energy density (770 Wh kg^{-1}) and excellent electrochemical performance cathode. These findings can pave a way to produce a high-performance rechargeable sodium-ion battery full-cell using alternative cathode and anode with a comparable energy density of current lithium-ion technology. The team has also been working on scaling up of the tried and tested chemistries to the pouch and cylindrical cells with 2.5 Ah capacity in order to bridge the gap between research and commercial productivity.

Prof. Sagar Mitra

Abhinanda Sengupta

Silicon-Carbon (SiC) as Anode: *Next Generation Anode for Li-ion Batteries*

Silicon and silicon-based composite material have the potential as next-generation anode material for lithium-ion batteries due to its higher specific capacity (~ 4200 mAh/g, Li4.4Si), low cost, low working voltage, and environmental benignity than conventional graphite (~ 350 mAh/g). Hence, it can aid to achieve a driving range of 300 miles for electric vehicles. NCPRE battery research group has already synthesized Si from sand (SiO2) by microwave heating, which is a fast and energy-efficient approach (Figure). However, Si as anode has some limitations, such as first cycle capacity loss and very high-volume expansion (~ 300-400%) during continuous charging and discharging process. Si nanoparticle, nano-rods, and nanowire are the possible solutions to reduce volume expansion up to a specific limit, but nano-Si is highly reactive and can dissolute within electrolyte during cycling.

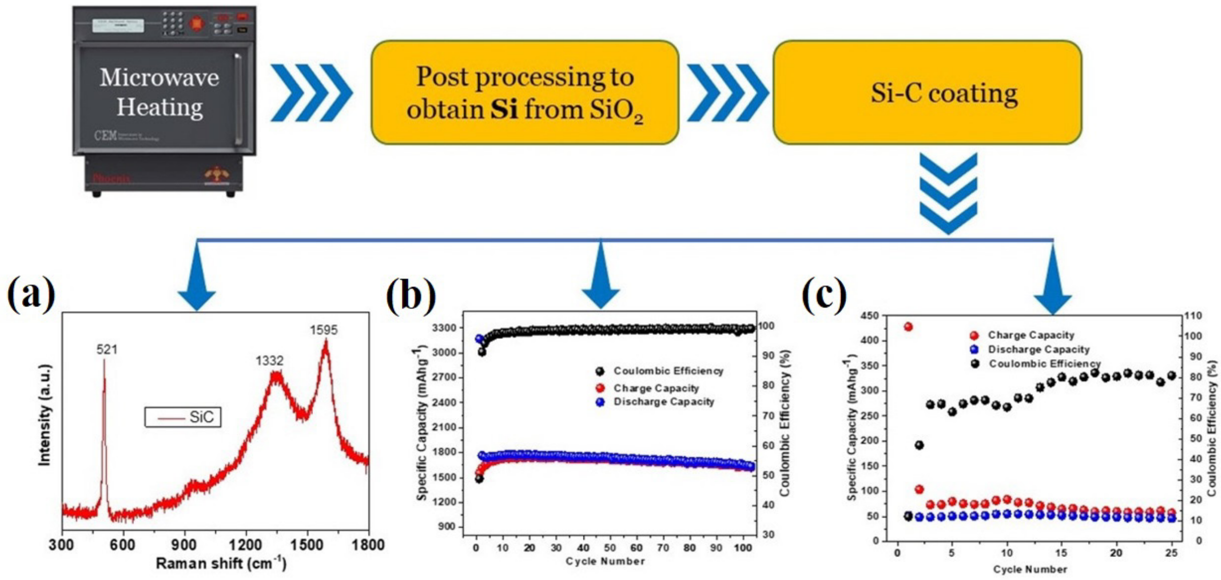


Figure - (a) Raman spectra for as synthesized SiC (b) Charge-discharge profile for SiC half-cell (c) Charge-discharge profile for SiC Li-NMC811 full-cell data (2016 coin cell)

Therefore, mixing of Si with carbon is another approach to reduce the volume expansion problem because carbon can accommodate the volume expansion and provides the electrical conductivity chain from bulk to current collector. The team is currently working on the development of SiC || Ni-rich Li-NMC811 full cell lithium-ion battery to achieve 300Wh/kg energy density at the cell level for electric vehicles. However, this chemistry has some challenges, such as first cycle capacity loss and capacity fading during cycling. The target (300Wh/kg) can be achieved with optimization in higher cut-off voltage (≥4.4V), active material loading (porosity), and cathode/anode modifications. The figure shows the synthesis process for SiC anode and characterization results for SiC half-cell and SiC||Li-NMC811 full cell. Figure (c) represents the capacity and cyclic performance of a full cell utilising Si-C anode and NMC811 cathode on a 2016-coin cell. The optimization to this material with currently available high-performance cathodes would result in a more efficient and high energy density battery.

Prof. Sagar Mitra

Manoj Gautam

Physics-based battery models in PV-battery hybrid power systems

Lithium-ion batteries (LiBs) are one of the promising technologies of choice for energy storage applications due to its high energy and power density. Under the guidance of Prof. Venkat R, the team is working on a power management control strategy for a standalone PV-Battery Energy Storage (BES) hybrid power system. The control algorithm tracks the Maximum Power Point of the solar-cells while avoiding overcharging of the LiBs under different solar radiation and load conditions.The framework (as shown in figure) also performs thermal management and proposes a strategy to minimize thermal degradation in the batteries. in a standalone solar-PV–BES hybrid power system. This is achieved using a physics-based electrochemical-thermal single particle model for simulating the battery. This model can capture the thermal aspects of degradation of the BES system. The BES system is better protected against thermally driven capacity fade using the proposed thermal management and control strategy that does not use any external cooling systems. Simulations for an entire year are performed using real-world solar insolation and household energy consumption data of a residential area in India to check the usefulness of this approach.

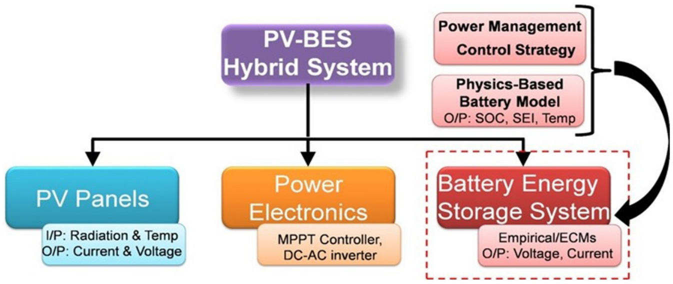


Figure - Schematic of proposed system integration of PV-BES systems [M. P. Bonkile, and V. Ramadesigan, J. Energy Storage, 23, 258-268, (2019)]

Prof. Venkat R

Mayur Bonkile

Vanadium Redox Flow Battery: *A Large-scale Energy Storage Device*

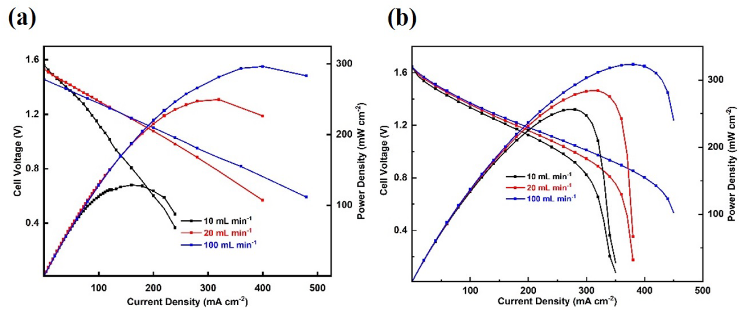


Figure - Performance curves of VRFB with (a) 3 mm and (b) 2.5 mm gasket thickness using a serpentine flow field. The electrode material is treated CF (acid medium) of 25 cm area.

Redox flow battery (RBF) is one of the most efficient energy storage devices to fulfil the storage requirements of renewable energy technologies. Vanadium redox flow battery (VRFB) is superior among RFBs because of its scalability, flexibility, energy-power decoupling, along with low environmental impact. The electrode materials play a critical role in the performance of VRFB. The porous nature of the electrodes offers large specific area and optimum pore size. Compression of the electrode reduces the thickness, which decreases the porosity and its interaction with the vanadium ions. For that reason, the performance of VRFB not only depends on the surface area but also on the thickness of the electrode. As a result, it may be prudent to express all the performance parameters in terms of per unit volume (cm^3), rather than the surface area (cm^2) of the electrode. The figure illustrates the conventional characteristic performance curves obtained with a VRFB of 3.2 mm thick carbon felt, treated in acid medium, with serpentine flow field using two different thickness (3 and 2.5 mm) of the silicone gasket with 25 cm^2 cell area. It has been observed that there is not much difference in the power density obtained at a flow rate of 100 mL min^{-1} with 3 mm and 2.5 mm thickness of the gasket. However, performance with 2.5 mm thick gasket is better than that with 3 mm thick gasket at a lower flow rate (10 and 20 mL min^{-1}). This observation suggests that 22 % compression of the 3.2 mm thick carbon felt electrode offers better performance than 6 % compression of the electrode. Under the guidance of Prof. Manoj Neergat, the future aim of the team is to develop a durable VRFB of optimum power output.

Prof. Manoj Neergat

Anand Tripathi

Uncovering the Quantum efficiency of a solar cell in a PV module

The solar electricity action works on the principle of the Photovoltaic effect. As we go deep into the photon level, we define Quantum Efficiency (QE) of a cell at a given wavelength as the short circuit current per incident photon from the solar cell. Ideally, each photon absorbed by a solar cell can produce a current flow of one electron if the terminals of the solar cell are shorted, which leads to 100% QE. Depending on the total number of photons absorbed by the solar cell, one gets the maximum current that a solar cell can produce under short circuit condition. In the case of real solar cells, the short circuit current is less than its maximum. That is because QE is less than 100% for photons of different wavelengths of the solar spectrum and depends on the cell design, material etc. For a single cell, the QE measurement is straightforward as per equation below:

$$QE_{cell} = \frac{I_{cell}}{I_{ref}} \times QE_{ref}$$

where I_{cell} and I_{ref} are the short circuit currents of the solar cell (I_{cell}) and reference solar cell (I_{ref}) (whose QE is known) at a particular wavelength. However, in a solar module, many cells are connected in series. Non-availability of direct access to a cell in the module makes it not an easy process to extract the QE of that cell. So, the challenge is how to measure the QE of a selected cell in a module without having access to theindividual solar cell terminals. It turns out that it is still possible to measure the QE of a selected cell if the test cell controls the current flow through the module terminals. This is done by illuminating the whole module with a white bias light except the test cell which is illuminated with a fraction of the same white light (by shading) as shown in the figure.

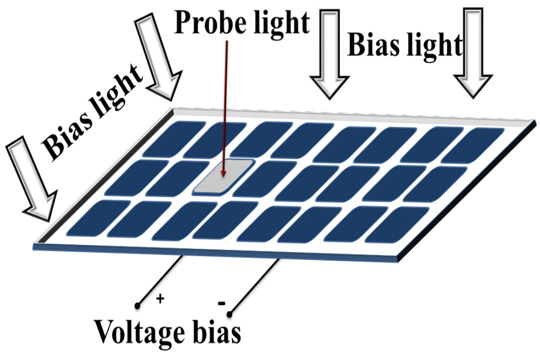


Figure: Schematic for QE measurement

Prototype -The technique employs LEDs with around 20 different wavelengths ranging from 300nm - 1100nm. The use of LEDs would eliminate the need for monochromator to help in making the system more robust by reducing the mechanical parts. The novel, custom 3-D printed LED holders were designed in IIT Bombay, and Fibre Optic cables were used to reduce coupling loss. The above-mentioned principle incorporated while developing the prototype as shown in the block diagram of the setup.

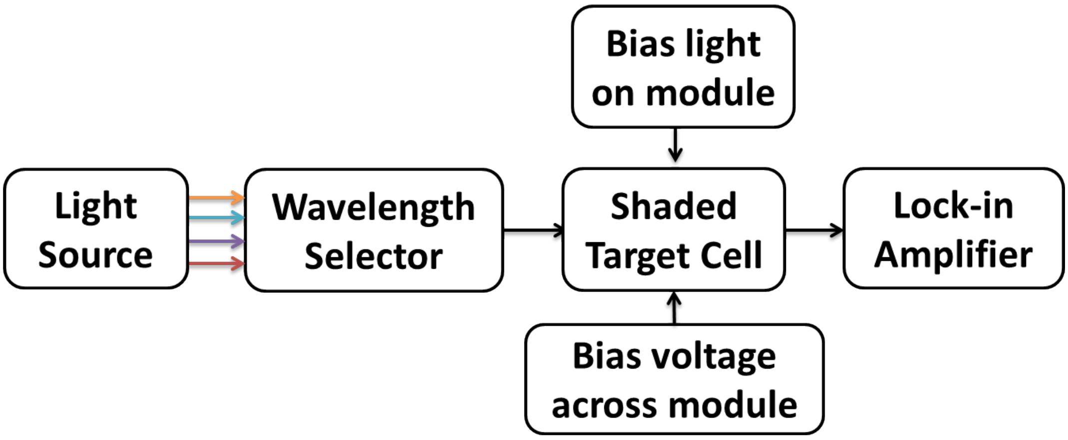


Figure: Block diagram for QE measurement setup

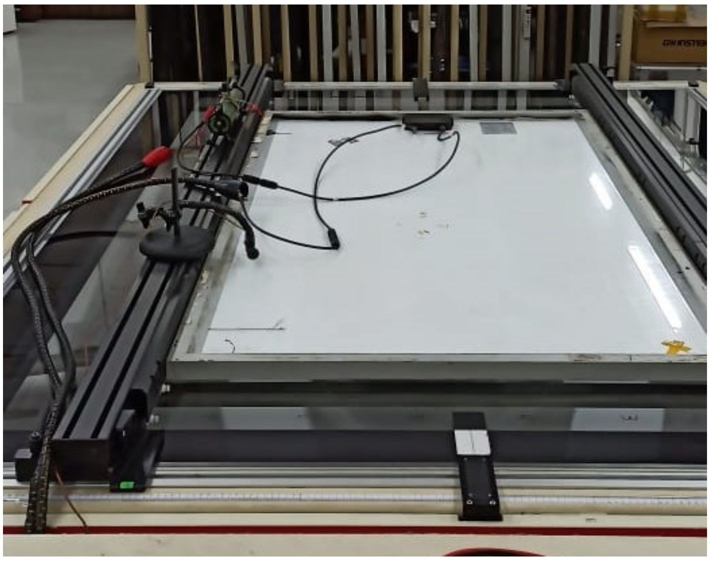


Figure: I-V measurement on SPIRE SLP-5600 simulator

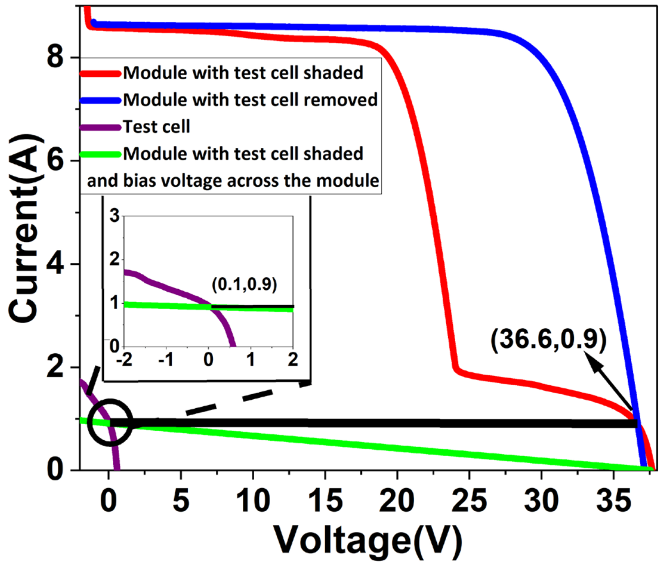
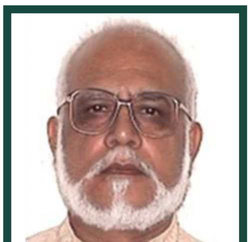


Figure: Verification of test cell short circuit conditions with the applied bias voltage

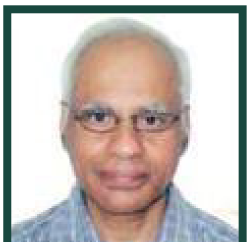
The prototype developed was tested for QE measurement of a cell in mini-modules and has shown fruitful results. This was further extended to understand the modifications required in the prototype for commercial modules (6-inch solar cell). Usually, a commercial module has additional components such as bypass diodes across a string of solar cells for protection against partial shading. This bypasses the test cell string making it difficult to measure the QE of the test cell. In order to verify if the method followed for mini-modules is valid for commercial modules with bypass diodes, we considered a 72 cell module. It has three bypass diodes for a string of 24 cells. The electrical terminals of the test cell were extracted from the backsheet and the I-V for the module and the test cell were measured on SPIRE SLP-5600 simulator as shown in the figure.

The short circuit condition of the test cell was observed by calculating and applying the required bias voltage across the module. The results proved that the bypass diodes didn't affect the test cell current limiting condition. Also, the applied bias voltage –36.6 V (blue and red curve intersection point) maintains the test cell at nearly short circuit condition i.e., 100 mV (green and violet curve intersection) as shown in the graph for voltage bias calculation.

K. Naga Bhavya Jyothi



Prof. Brij Mohan Arora



Prof. K.L.Narasimhan

Prof. Narendra Shiradkar

Optimization of front metal contact design of industrial Si solar cells by combining advanced characterization and predictive simulations

There is a continuous effort in optimizing the crystalline silicon (c-Si) photovoltaic (PV) manufacturing, which includes Si growth, wafer cutting, cell fabrication, and module production to increase the ultimate PV module power conversion efficiency along with the cost reduction. Considering the cost aspect, particularly in cell processing, silver (Ag) used for front metallization remains as the most expensive non-Si material. Nearly 100 mg of Ag per standard 6”x 6” Si solar cell is used and this has to be reduced down to 50 mg by 2029, as proposed by ITRPV 2020. Overall, it is essential to continue the efforts to lower the Ag consumption for further cost reduction. However, it is equally vital to optimize Ag consumption precisely, as it plays a crucial role in the power conversion efficiency of a solar cell. At NCPRE, we have developed a comprehensive methodology involving PL imaging and Suns-Voc measurement in the selection of front grid design for n+ diffused emitter silicon wafer solar cell. PL imaging under different bias condition provided a detailed understanding of the spatial distribution of recombination and resistive losses. This information can be then utilized in simulation packages like Griddler to optimize the Ag front contact design. Solar cell manufacturers are welcome to collaborate NCPRE to take advantage of this combination of characterization and predictive modelling for their process optimization.

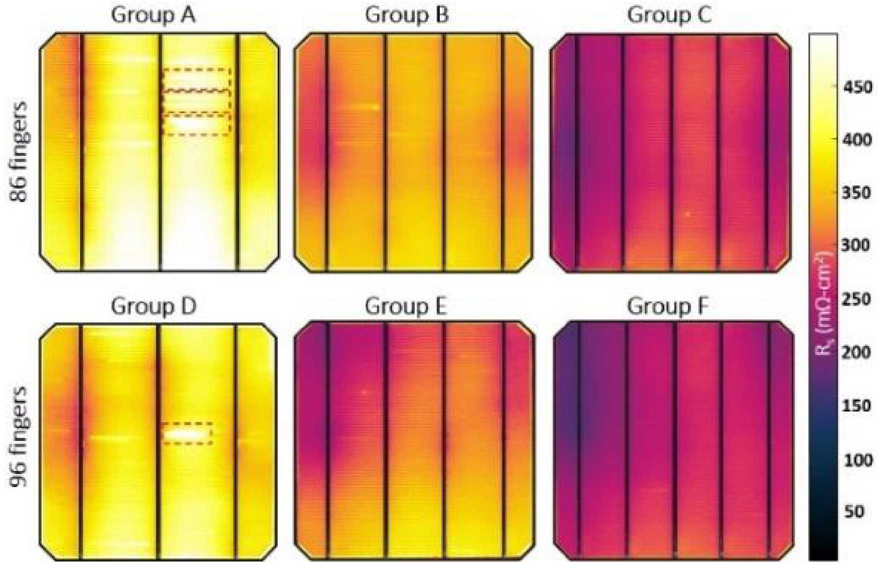


Figure : Mapping of series resistance on cell area using biased PL imaging

**Prof.
Anil Kottantharayil**

**Dr.
Ashok K Sharma**

**Dr.
Hemanta Ghosh**

Siddharth Behera

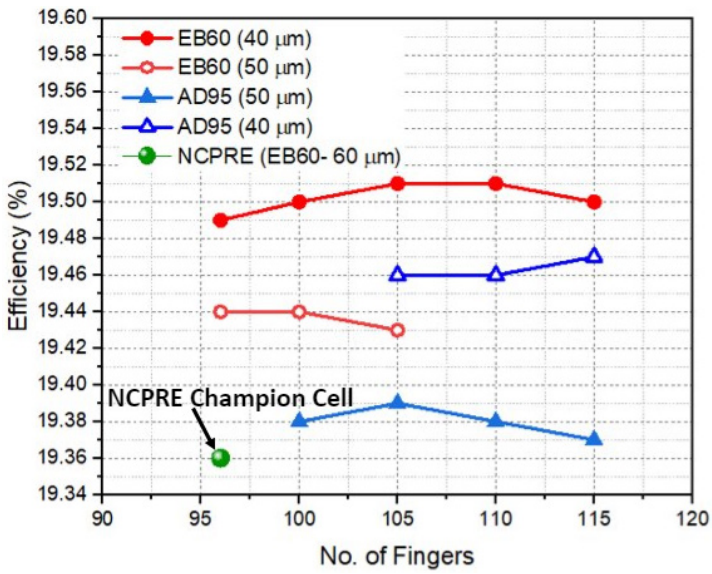


Figure : Griddler Simulation different sheet resistance and number of fingers

PERC solar cell: *A technology replacing Al-BSF*

According to the ITRPV (Eleventh Edition, April 2020) roadmap, Passivated Emitter Rear Contact (PERC) cell technology is expected to gain a market share > 70% in 2020 with Aluminium Back Surface Field (Al-BSF) cells technology trailing far behind at 20%. In September 2019, Canadian solar, one of the world's largest solar cell manufacturing company set a world record of 22.80% conversion efficiency for p-type large area (246.7 cm^2) multi-crystalline PERC solar cell.

Development of high efficiency PERC Cells is one of the most important activities of the silicon solar cell group of NCPRE. PERC technology uses a combination of dielectric surface passivation and reduced metal/semiconductor contact area to decrease the rear surface recombination. The reduced metal contact scheme increases the effective internal surface reflection at the rear side as an Al/Si interface reflects only 65% of the incident light compared to > 90% in case of dielectric/Si interface. But these advantages come at the cost of increased series resistance due to additional spreading resistance as a result of reduced metal contact area. Investigations indicate that the pitch and the size of the rear point contacts which define the metallization fraction along with the substrate resistivity are fundamental design parameters for PERC cells. figure below (a-c) shows the potential distribution simulated in COMSOL Multiphysics for three different contact geometries namely full area, line and circular contacts. The electric field lines shown in figure below (d-f) due to partial rear contact are crowded leading to the additional spreading resistance.

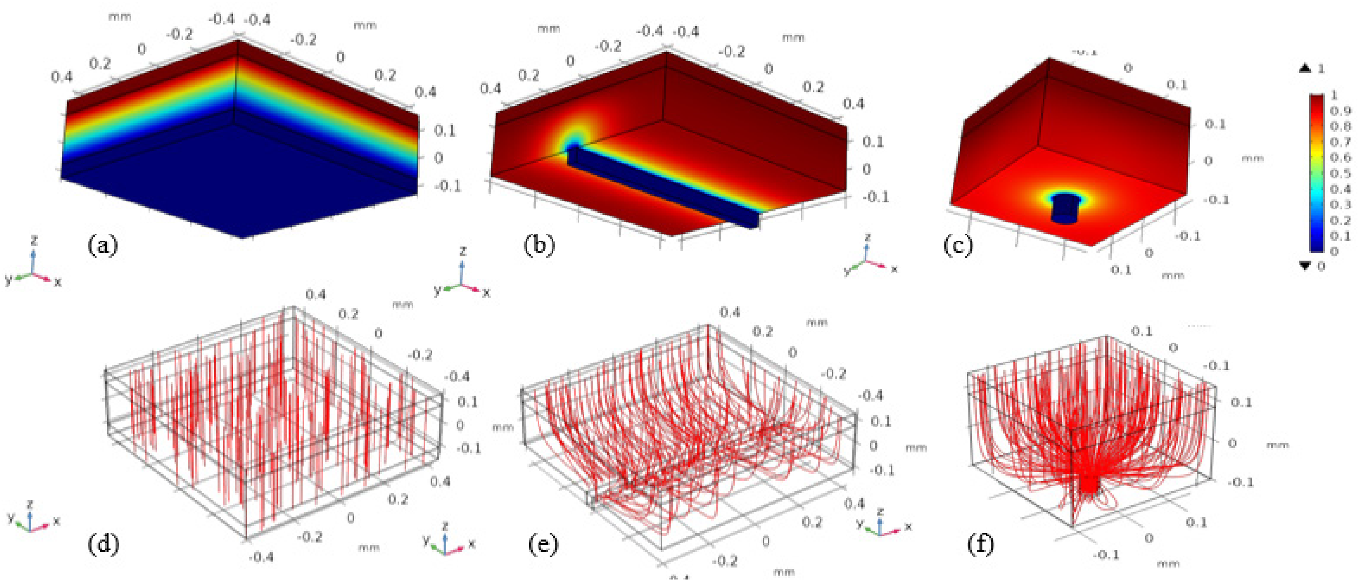


Figure : Distribution of electric field potential (a-c) and electric field lines (d-f) for full area, line and circular contact geometry at the rear side of a PERC Cell

Dr. Suchismita Mitra

Prof. Anil Kottantharayil

Contrasting temperature dependence of band gap in CH3NH3PbX3 (X=I, Br, Cl): *insight from lattice dilation and electron-phonon coupling*

Although hybrid halide perovskites ($MAPbX_3$, $MA=CH_3NH_3$, and X=I, Br, Cl) have been ubiquitously explored from the photovoltaic perspective, there are still few unanswered questions which require a more fundamental understanding. One such unsettled issue is the puzzling behavior of band gap. Unlike conventional semiconductors, $MAPbX_3$ (X=I, Br) is found to show a blue shift (increase) in the band gap (Eg) with increasing temperature (T), while $MAPbCl_3$ shows an unusual red shift (decrease). In order to understand this, we performed a detailed T-dependent study of electronic, optical and structural properties of $MAPbX_3$ combined with the state of the art first principles calculations. With increasing T, two dominant mechanisms which come into play are lattice dilation and electron phonon coupling (EPC). The former (later) is responsible for increase (decrease) in Eg. We found that lattice dilation effect dominates in $MAPbX_3$ (X=I, Br), causing an enhancement in Eg. EPC involves various contributions, of which the interaction of charge carriers with the longitudinal optical (LO) phonon mode via Frohlich interaction is the most dominant one at room T. We quantify this contribution using Frohlichs theory of large polarons and show that the Eg correction due to this effect in $MAPbCl_3$ is almost double as compared to $MAPbBr_3$ and thus explain the reduction in Eg for the former.

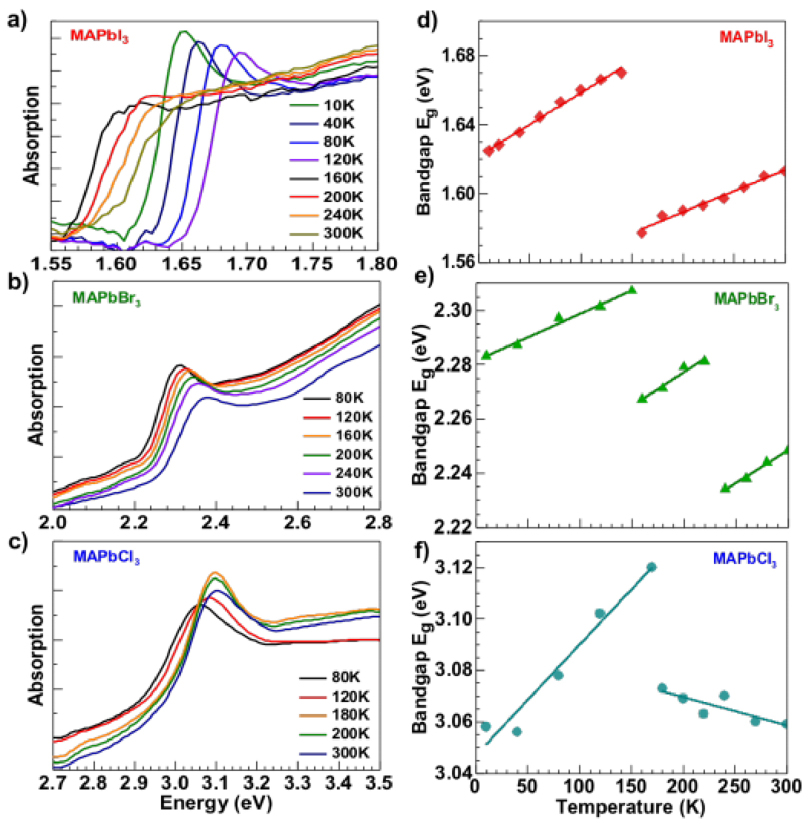


Figure Absorption spectra at different temperatures for (a) $MAPbI_3$, (b) $MAPbBr_3$ and (c) $MAPbCl_3$. Temperature dependence of electronic band gap for (d) $MAPbI_3$, (e) $MAPbBr_3$ and (f) $MAPbCl_3$. Solid lines are linear fit to the raw data to obtain band gap coefficients

Rishabh Saxena

Jiban Kangsabanik

Dr. Shivam Singh

Dr. Nakul Jain

Prof. Aftab Alam

Prof. Dinesh Kabra

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Aiding Effects of Interleaving to Improve Design Performances of a 50 Hz Zig-Zig Transformer Employed in a UACDC System

An integrated magnetic design approach is studied for design of a line-frequency zig-zag transformer, which is employed in a unified ac-dc (UACDC) system to integrate low voltage solar photovoltaics (PV) with three-phase ac grid. It is deduced that in case of the UACDC system, the interleaved winding strategy is the best suited for the zig-zag transformer design, where the primary (high-voltage) winding is placed between the zig and zag (low-voltage) winding sections. Benefits of interleaving are two-fold i.e. (a) It improves the integrated boost inductance, offered by zig-zag winding sections, which is beneficial for interfacing the low voltage PV with the common dc bus of the PWM converter. (b) It also keeps the eddy current effect minimal in the multi-layer winding sections, thereby reducing the copper loss and improving the transformer efficiency. To verify the effects of winding arrangements on the design performances of the zig-zag transformer, two winding systems are studied i.e. (a) normal winding, where the zig-zag (low-voltage) windings are placed near to the core and the primary (high-voltage) winding is placed outside. (b) interleaved winding, where the primary (high-voltage) winding is placed in between zig-zag (low-voltage) winding sections.

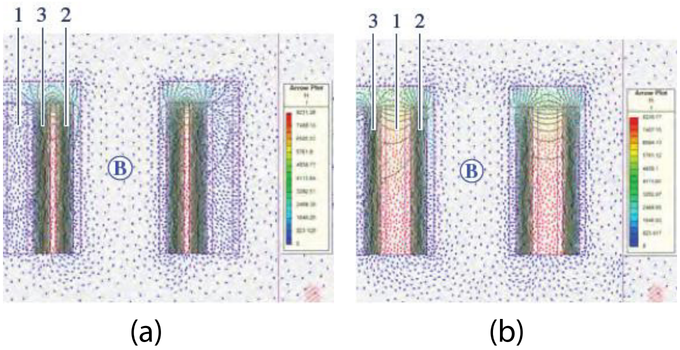


Figure : 2-D FEM results results show the effect of winding arrangements on the magnetic field intensity (H), when excited from the PV source. (a) In the normal winding,H(x) attains a maximum value of +8.14 A/mm but is confined in the zigzag windings only. (b) In the interleaved winding, H(x) attains a maximum value of +8.13 A/mm but the entire primary winding acts as an additional leakage layer, culminating into higher stored leakage energy. It thereby achieves a high value of integrated boost inductance(Lpv), offered by the zig-zag winding sections.

In the figure above 2-D finite element method (FEM) analysis shows that in case of the interleaved winding arrangement, the integrated boost inductance for zig-zag winding sections is significantly enhanced, which is beneficial to interface the low voltage photovoltaic (PV) with the high voltage dc bus of the PWM converter and keep current ripple within desired limits. Interleaving winding arrangement also keeps the proximity effect minimal in the multi-layer winding sections of zig-zag transformer; as the winding ac resistances are kept low, it reduces the fundamental and harmonic copper losses in the transformer windings and improves its efficiency. To corroborate these findings, an experimental prototype of a 1kW, 415/130 V, 50 Hz, zig-zag transformer is built and tested. The winding ac resistances of the zig-zag transformer are measured over a wide frequency range with the help of a programmable LCR bridge as shown in the figure below . The predicted and measured values agree well, indicating a good modelling accuracy and verifies the aiding effect of interleaving to minimize the ac effect in multi-layer winding sections.

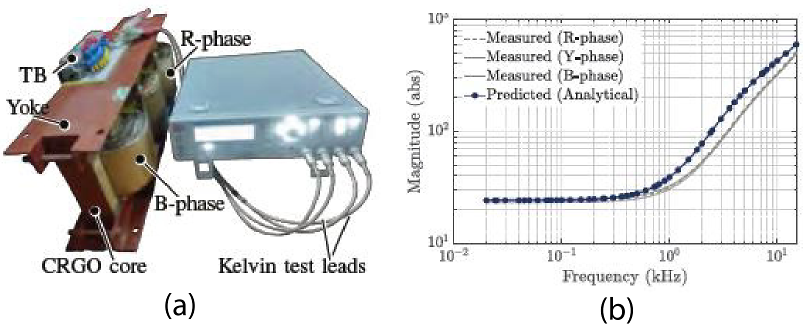


Figure : (a) Winding ac resistances of zig-zag transformer are measured between the frequency ranges of 20 Hz and 15 kHz using a programmable LCR bridg (HM8118). (b) Predicted and measured values of the winding ac resistances agree well indicating a good modelling accuracy.

Prof.
B. G. Fernandes

Annoy Kumar Das

Semi Automated Coating Machine (SACM)

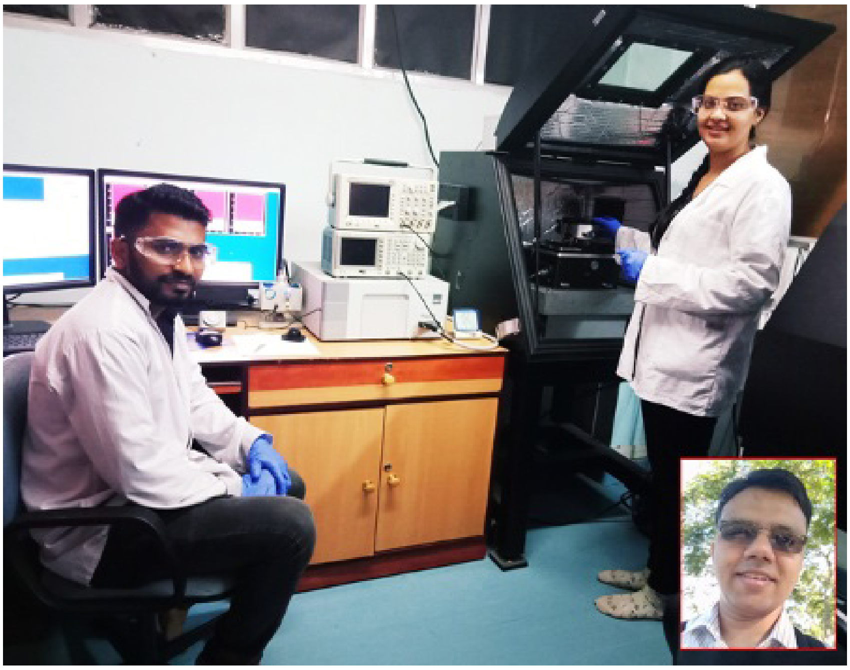
The coating machine which has been installed is of six meters long and can coat within two minutes on either Al or Cu foil. It's an indirect coating technique which makes it unique and the wet thickness can be maintained around 1mm. Extra added feature is we can maintain the tension of the foil also. Depending on the material we can change speed, time and heating zones to get dry active area. This coating machine is very useful for the commercialization of the batteries.

Specifications of the Coating Machine

Suitable material width	Al foil : 150-400mm Cu foil : 150-400mm
Suitable material thickness	Al foil : 8-30µm Cu foil : 8-30µm
Suitable material diameter	350mm
Coating thickness	Cathode:50µm-10mm Anode : 50µm-10mm
Coating gap length	5-400mm
Coating speed	1-7m/min(Depending on the drying condition)
Machine speed	7m/min
Coating accuracy	<±0.3mm

Perovskites perform well under pressure

Researchers manipulate new knowledge on perovskite ferroelectricity to enhance piezoelectric effect and create nanogenerators



Richa Pandey (right) and SB Gangadhar (left), who developed the $FASnI_3$ PENGs. Inset: Prof Dinesh Kabra, who supervised the research.

The reach of piezoelectric nanogenerators (PENGs) is limited by the high toxicity of lead-containing ceramics such as $Pb(Zr_xTi_1\text{-}x)O_3$ (PZT). But now that scientists at IIT Bombay in collaboration with Applied Materials Pvt Ltd, India, IISER Pune, IITD and JNCASR have unveiled the origin of ferroelectricity in lead-free hybrid perovskites, there may be a safer alternative. Indeed, PENGs made with their new technology could be perfect for powering self-sustainable devices such as pacemakers, health monitors and microsensors. After unravelling the ferroelectric mechanism in $FASnI_3$, the researchers set about enhancing the effect by incorporating the perovskite into a ferroelectric polymer and by carefully combining these two active components, they were able to further enhance the piezoelectric response to 73 pm/V. This unprecedented performance led the researchers to consider possible applications. "PENGs create electrical power by squeezing piezoelectric materials. As $FASnI_3$ produces one volt each time the lattice contracts by 73 pm, it is an ideal candidate for such an application," The researchers' hypothesis was confirmed by developing a device with the novel material and measuring the 23 V generated, an unprecedented high amongst existing lead-free PENGs.

Further details can be found in

- https://physicsworld.com/a/perovskites-perform-well-under-pressure/
- R. Pandey et al ACS Energy Letters, Vol. 4, p-1004 (2019)

Passivation of Silicon Surface for Gr-Si MIS Solar Cell

-A project carried out by Prof. Sukruti Kaulgud, Assistant Professor, Department of Electronics and Telecommunication, Thakur College of engineering and Technology, Mumbai at NCPRE under PUMP

In wireless sensor network (WSN), energy conservation is the biggest challenge. Energy harvesting is at the core of energy conservation and this is where Solar cell becomes the most preferred option. Applications in WSN requires solar cells to be highly efficient with smaller dimensions and easy on budget. Graphene promises to be an e ffective solar cell material addressing both these requirements. Metal-Insulator Semiconductor structure of Graphene-Silicon solar cells shows enhanced efficiency over Schottky Junction solar cells. However, small size solar cell using Graphene as one of the electrodes is not providing higher power conversion efficiency. This is where interface tailoring provides us with more avenues to improve efficiency.

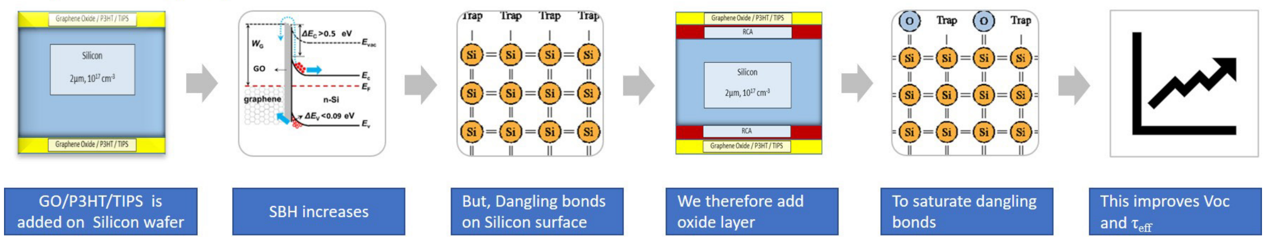
To further boost the efficiency, Graphene Oxide (GO) could be the panacea on the required criteria. Also, inclusion of RCA Oxide layer between Silicon and the electron blocking layer, attributes to the dangling bond saturation which results in reduced interface defects.

To further improve efficiency P3HT and TIPS Pentacene were investigated. A simulation model was developed to investigate their passivation abilities. It was clear that, TIPS pentacene gives better passivation of Silicon surface. The average open circuit voltage (Voc) of the MIS silicon solar cell with TIPS pentacene is higher than that with P3HT and GO. The minority carrier lifetime also enhances. Dangling bonds that were present at the silicon surface were an impediment to improving efficiency to a higher level. Modifying Silicon surface with RCA oxide address this issue. The interfacial layer with a combination of GO + RCA, P3HT + RCA and TIPS pentacene + RCA modifies the Si surface for better passivation. The optimum thickness of the interfacial layer, provides enhanced Voc and minority carrier lifetime.

Fabrication confirms simulated results and adds confidence about the simulated parameters. Fabricating the right configuration posed several challenges. NCPRE lab team supported to carry out several iterations to ensure they replicated the exact simulation conditions to achieve credible validity within 7% average percentage error, which is acceptable.

The work can be extended by adding Graphene layer with optimum doping and antireflection coating to further boost PCE. These solar cells provide the advantage of low cost, ambient temperature fabrication process, and hence are more appealing for large scale production. On the lines of introducing new interfacial layers, the future work can explore introducing newer materials. A slightly different scope can also be explored by considering different solar cell structures beyond the one considered here namely MIS solar cell.

To improve Voc and τ_{eff} for applications for Wireless Sensor Network




Sukruti Kaulgud

Chasing dreams *Prof. Chetan Singh Solanki*

It was a group of 64 people who were working on solar PV technology during my PhD in IMEC Europe. I was one of them. When I graduated and came back to India, way back in 2004, I was only one in the institute working full time on solar cells. There were several groups in India, but all islands on their own. It was clear to me that if we want to do impactful work in the country, it has to be a big group. I always used to think about establishing a large solar PV research centre in the institute. This dream became true in 2010 with the support of the Principle Scientific Advisor to Prime Minister Dr R. Chidambaram, and of course, our ever-green professor, Prof. J. Vasi. Today, the National Center for Photovoltaic Research and Education (NCPRE) is one of the well-recognized centres in the country and parts of the world. In route, I have written several books on PV, taught many and trained thousands of people.

Though NCPRE was focusing on advance technology development at cell, module and electronics level, I did not see an immediate implementation of the technologies for societies. Way back in 2010-11, I realized that the solutions for social problems are simple, like providing a solar lamp to each school children, was simple but not done effectively. I jumped into solving this by taking sabbatical leave. At that time, I never knew that one day it would become the world's most extensive program. Through our Solar Urja through Localization for Sustainability (SoULS), we have now reached to 8.5 million families across 10 states and 40,000+ villages. The model developed was unique wherein locals are involved in assembling, sale, repair and maintain the solar solutions. The SoULS program gave me great insights into real problems, the bottlenecks, and practical approaches to solve them. In the process, we also made several Guinness World Records, Won IEEE's Global Grand Prize of US$100,000, went around the world under Gandhi Global Solar Yatra.

With all this work, several leading newspapers referred me with the title 'Solar Man' or 'Solar Gandhi'. Coming from a small village in MP, where still no buses go and coming to this level has been a very satisfying journey. Nevertheless, I truly realized that Climate Change is the primary threat world is suffering from. I feel that much bigger efforts are required, and the use of solar energy solutions would be great savvier. Now, I am embarking on the journey to create Energy Swaraj of Energy by Locals for Locals. Let us see how well I chase this dream!

**Prof.
Chetan Solanki**

Publications

International Conference Proceedings

Papers presented at the 47th IEEE Photovoltaic Specialists Conference

- Jayshree Bhajipale and Anil Kottantharayil, "Spray-coated SiO_2 Thin Film for Passivation of n-type Cz Silicon Surface with $S_{eff} \sim 6$ cm-sec-[1]," presented in 47th *IEEE Photovolt. Spec. Conf., 2020.*

- K. P. Sreejith, Ashok Kumar Sharma, Siddharth Behera, Sandeep Kumbhar, Prabir Kanti Basu, Anil Kottantharayil, "Optimization of MACE black silicon surface morphology in multi-crystalline wafers for excellent optoelectronic properties" presented in 47th *IEEE Photovolt. Spec. Conf., 2020.*

- S. Bhaduri, M. Farkade, R. Bajhal, L.L.Kazmerski, S. Mallick, N. Shiradkar and A. Kottantharayil "Cleaning efficacy of anti-soiling coatings," presented in 47th IEEE Photovoltaic Specialists Conference, 2020.

- S. Bhaduri, R. Bajhal, S. Mallick, N. Shiradkar and A. Kottantharayil, "Degradation of anti-soiling coatings: mechanical impact of rainfall," presented in 47th IEEE Photovoltaic Specialists Conference, 2020.

- D. P. Vasudevan, P. Bhatt, A. Kottantharayil, "Lateral vibrations experienced by vertically placed PV modules in the pallet during transportation" in 47th IEEE Photovoltaic Specialist Conference, 2020.

- K Naga Bhavya Jyothi, Deepanshu Koshta, Yogeswara Rao Golive, B. M. Arora, K. L. Narasimhan, Narendra Shiradkar, " Biasing conditions for measurement of Quantum Efficiency of a solar cell in a module", presented in 47th IEEE Photovoltaic Specialists Conference(PVSC), Virtual Meeting, June15- August21, 2020.

- Ruchita Korgaonkar, Subhasree Mondal, Hemant K. Singh, A. Kottantharayil, J. Vasi, Narendra Shiradkar, "Role of cloud movement in generation of anomalous data in SCADA systems of PV Power Plants", presented in 47th IEEE Photovoltaic Specialist Conference, 2020

Papers accepted for publication.

- A. K. Das and B. G. Fernandes, "Accurate capacitance calculation of multi-layer foil windings in a medium/high-frequency high-power transformer," accepted for publication in 2020 IEEE Energy Conversion Congress and Exposition (ECCE), Sep. 2020.

- A. K. Das and B. G. Fernandes, "Calculation of model based capacitances of a two-winding high-frequency transformer to predict its natural resonance frequencies," accepted for publication in 2020 IEEE Industrial Application Society Annual Meeting, Sep. 2020.

- R. Kumar, J. Kumar, P. Srivastava, D. Moghe, D. Kabra, M. Bag, "Unveiling Morphology Effect on the Negative Capacitance and Large Ideality Factor in Perovskite Light Emitting Diodes " (Published, July 2020 "ACS Applied Materials & Interfaces")

Announcements

Cancelled – 5 Days workshop on Solar Off-grid Entrepreneurship Training Program (16th - 20th March 2020)

Please note that the Solar off-grid Entrepreneurship training workshop stands Cancelled. Such a decision has been taken in view of the COVID-19 pandemic across India. The registration fees will be refunded to the Participants who have paid for the same.

NCPRE houses state-of-the-art Solar PV research facilities which is being used by Industry and Academia in India

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