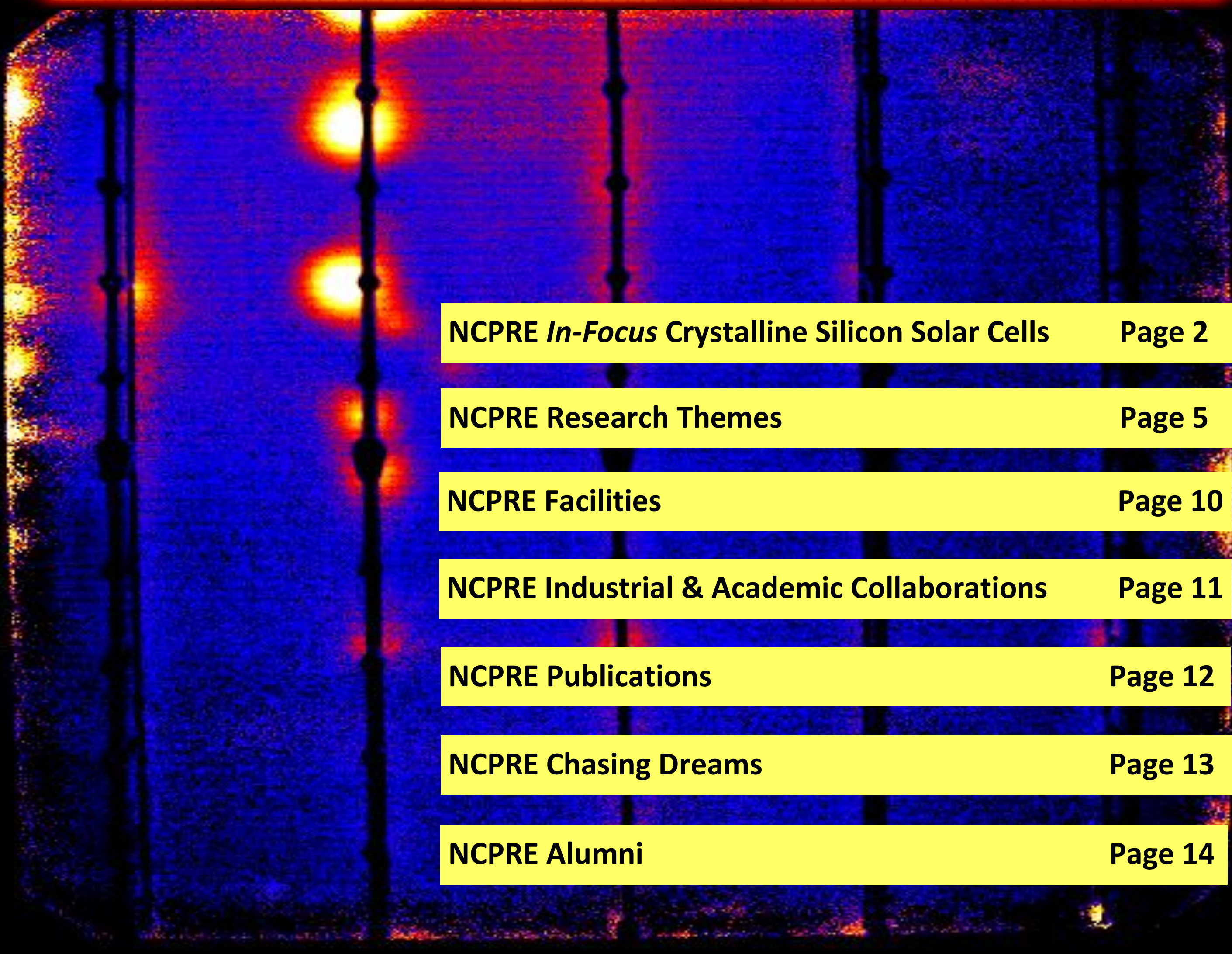
NewsLetter

July 2021 Edition »

10 YEARS Making a Difference NCPRE



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 10 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 experience. 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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Lock-In-Thermography (LIT): An advanced characterization tool for solar cells and modules

The latest addition to the advanced characterization capabilities of NCPRE is a lab-scale lock-in-thermography system for crystalline silicon solar cells and solar PV modules. The high-end camera unit consists of a cooled InSb detector with a mid-wave infrared spectral range (MWIR) of 2-5µm. The temperature resolution at 30°C is < 25mK, typically 20mK. With appropriate control and data acquisition hardware and software, thermal images of solar cells are captured after applying suitable biases across the solar cell. These images are then processed to analyse local shunts and local dark and illuminated current-voltage (I-V) characteristics of solar cells according to the two-diode model using "Local IV2" software developed by Prof. Otwin Breitenstein in Max Planck Institute of Microstructure Physics, Germany. One of the primary advantages of lock-in-thermography over other stationary methods is that it significantly improves the sensitivity due to the ac averaging technique and improves the image's spatial resolution.

Fig: Lock-In-Thermography for silicon solar cells

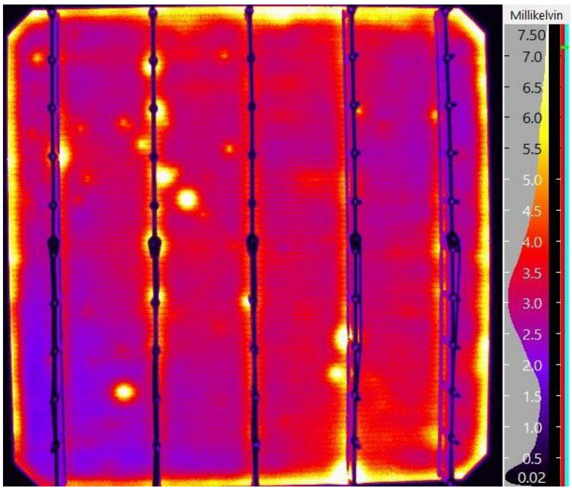

Fig: DLIT Image of Solar cell

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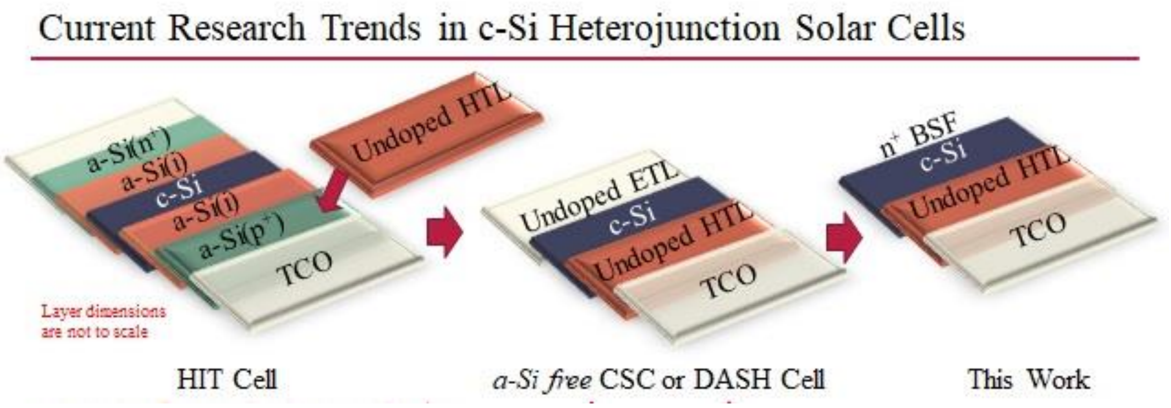
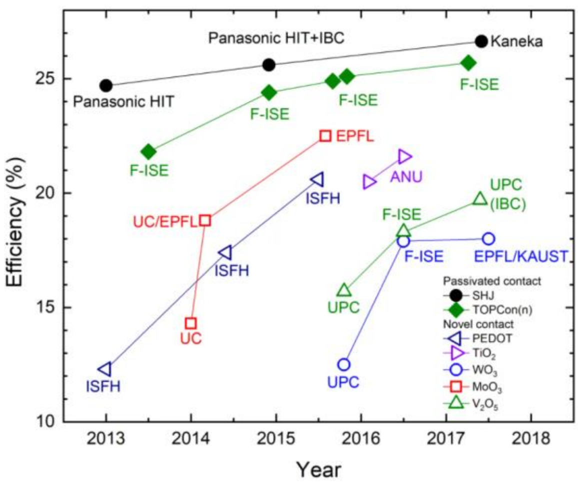
Carrier-selective contact Si solar cells – A Promising technology

The second half of the last decade saw progressive research towards making Si solar cells with dopant-free carrier selective (CSC) architecture as a promising candidate for high-efficiency solar cells. These devices do not rely on P-N junction for charge separation; instead, they utilize a transition metal oxide such as molybdenum (MoO_x), tungsten (WO_x) or vanadium (V_2O_x) for selectively separate electrons and holes, respectively, still with silicon as an absorber layer for incoming light. Heterojunction (HIT) solar cell with doped amorphous silicon is its closest approximation to a silicon CSC solar cell. CSC solar cells have already demonstrated a world record efficiency of 26.7% solar cell fabricated at Kaneka Corporation (Japan) in 2017.

Here, at NCPRE, we explore MoO_x as a hole-selective and a passivating layer for Silicon surface offering a low-cost fabrication route compared to other HIT structures. In silicon, PV MoO_x is often coupled with amorphous silicon (a-Si) which yields very high open-circuit voltage (V_{oc}) exceeding 700 mV. In our past studies, we have observed that the passivation and selective property depend heavily on the thickness of the MoO_x layer, which is one of our process optimization's primary objectives.



Schematic diagram



Champion efficiency of various carrier selective solar cells (Ref. PV-Manufacturing.org)

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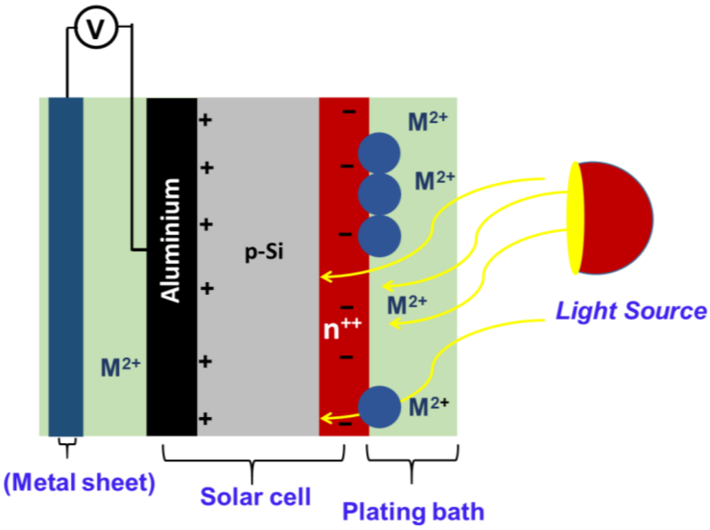
Nickel (Ni)/Copper (Cu) Plated Contacts for the Front Side Metallization – an Alternative to Silver Screen-Printed Contacts

Conventionally, silver (Ag) screen-printed (SP) front side contacts are used in Si-based solar cells. Such contacts with costly Ag cause efficiency losses in the cells due to shading, poor line conductivity and contact resistance. A promising alternative contact is based on cheap and readily available Cu, which forms a good contact comparable to Silver (Ag). However, large scale implementation in the industry remains elusive due to its reliability concerns. Statistics show that by 2029, only 10% of the total cells produced will be those with Cu contact. The significant drawback of Cu is that it causes junction breakdown by diffusing into the Si layer. To prevent the diffusion of Cu in Si, Ni can be used as an effective barrier layer. At NCPRE, a team of researchers has adopted light-induced plating (LIP) developed by Fraunhofer ISE for the metallization of the silicon solar cell. LIP utilizes the photovoltaic effect, and it is attractive from the perspective of overcoming background plating. Further studies are being conducted to study its feasibility in a commercial environment further.



Schematic of LIP for front-contact metallization.

Prof. Manoj Neergat

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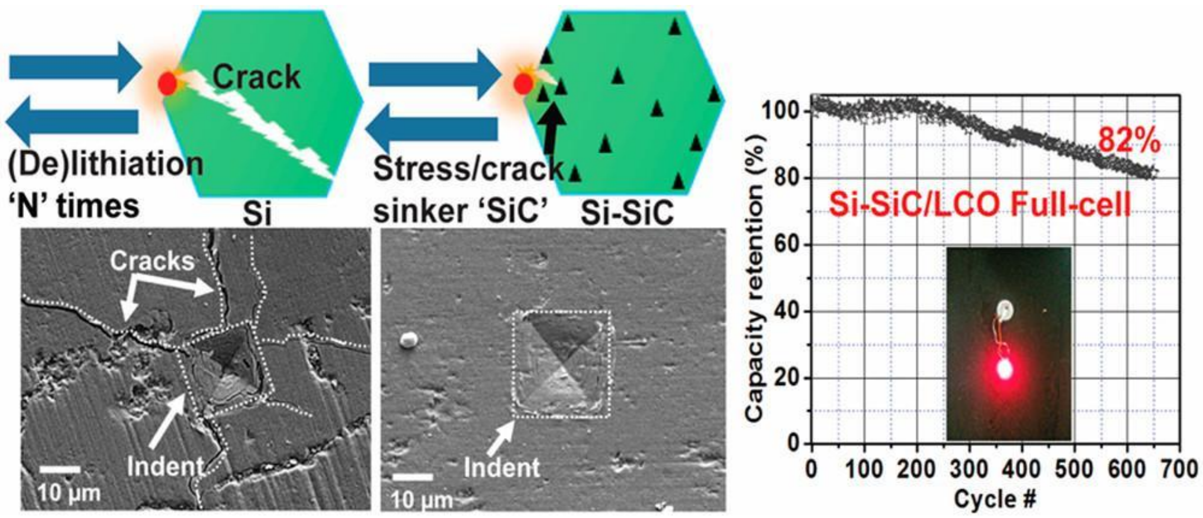
Better and crack free nano Si as high-performance anode from Sand for Lithium-ion battery Applications

Silicon (Si)-based materials are one of the anode materials for next-generation lithium-ion batteries with high theoretical capacity and low working potential. However, extreme volume changes and mechanical instabilities in these anodes are responsible for premature failure in lithium-ion batteries. Thus, it is a crucial hurdle towards developing high-performance Si-based batteries, especially in the current scenario of electric vehicles. To improve the mechanical properties of Si-based anodes, various strategies have been explored. Here, the energy storage group demonstrated a significant improvement in the mechanical stainability of Si-based anode material via in-situ incorporations of carbide with a specific design, thereby bestowing outstanding stability in the electrochemical performance. A bridge between nanomechanical and electrochemical properties, investigated via advanced in-situ measurements during electrochemical cycling for Si and in-situ reinforced Si–SiC (Silicon-Carbon) composite, is established. Enhancing the hardness (H) of Si–SiC composite to almost twice and enhancing the hardness to effective Young's modulus ratio of the same to almost thrice than that of Si, helped resist the occurrence of plastic deformation and cracking in compelling terms.

By contrast, monotonous stress profiles and the absence of the signature of plastic flow/cracking are observed for the Si–SiC electrode, which is an advantage for long cycle life, as observed here. Overall, the experimental study has established the nanomechanical to electrochemical tie-up leading to 82% capacity retention over 650 cycles in a Li-ion full-cell along with the Si–SiC composite anode and LCO cathode, as shown in the figure below. The "power cycle" of the Si–SiC composite anode, with a variation of current density from 0.5 to 6.0 A g^{-1}, also reveals excellent stability up to 2500 cycles.



Mechanical and the Electrochemical Stability Improvement of SiC-Reinforced Si-based Composite Anode for Li-ion Battery by Furquan Mohammad, Jangid Manoj, K Anish Raj, Savithri Vijayalakshmi, Mukhopadhyay Amartya, Mitra Sagar, ACS Applied Energy Materials, 3(12), 12613–12626,2020.

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Md. Furquan

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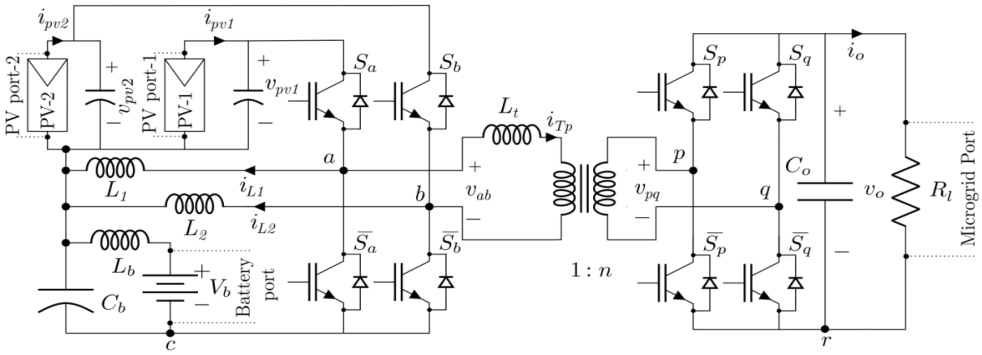
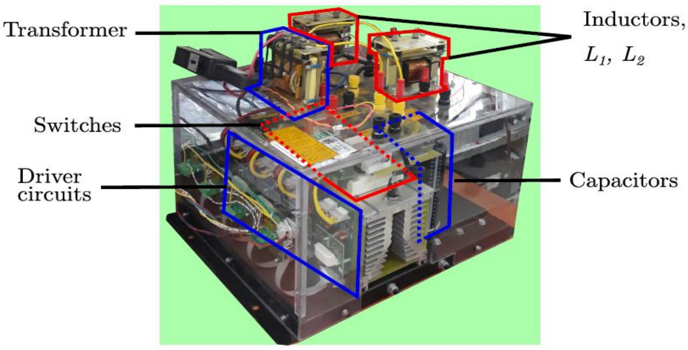
A Single Interface for two Solar Panels and Battery

Energy harvesting from solar photovoltaic (PV) systems has become the order of the day to meet the ever-increasing energy demand without increasing the dependency on fossil fuels. However, the intermittent nature of the solar energy has propelled its usage along with other complementary renewable energy sources and storage systems by forming a microgrid, which can be either ac or dc in nature. As the solar PV modules, battery, and other renewable energy sources generate power in the form of dc, and most of the modern consumer appliances utilize dc power for their operation, dc microgrids are becoming increasingly popular.



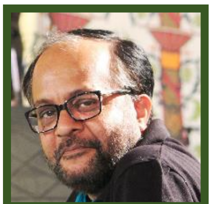
Circuit diagram of the developed multiport converter



Laboratory prototype of the multiport converter

A novel multiport converter (MPC) to interface two solar photovoltaic modules (SPM), and the battery with a 380 V dc microgrid is developed. All the photovoltaic modules are operated at their respective maximum power points (MPPs), which is a unique feature of the proposed scheme. The boosting of the low voltages of the SPMs and that of the battery to 380 V is accomplished by involving a dc–dc converter along with a high-frequency transformer. The battery banks are charged directly from the power of the SPM without involving the high-frequency transformer. This significantly reduces the length of power flow paths within the system. The MPC can operate in stand-alone mode or in microgrid connected mode as and when required. In the microgrid-connected mode, it is capable of realizing the MPP tracking and control the charging current of the battery as per the requirement of its charge controller. When the MPC is operated in stand-alone mode, the voltages across the local loads are regulated at 380 V. The proposed MPC is modelled using the first component approximation method to facilitate the design of the appropriate controllers. A laboratory prototype of the MPC is fabricated and experimental studies are carried out utilizing the developed prototype.


Dr. Anees Vettuparambil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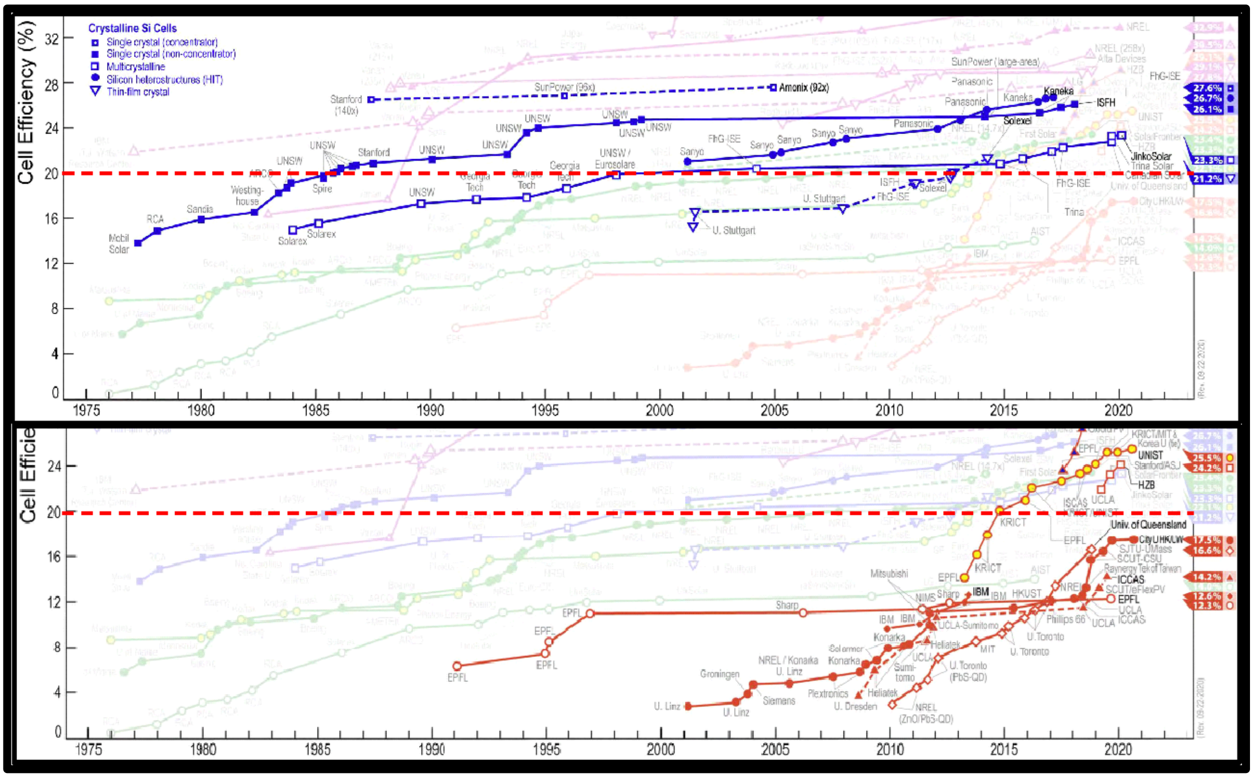
Solution-processed Efficient Single Junction Perovskite Solar Cells

(Opportunity with Emerging Technologies)

Renewable energy sources are standing out as a prominent candidate for the energy supply without affecting the environment. In India, photovoltaic (PV) technology plays a pivotal role in energy harvesting. Over the decade, halide perovskites have an unprecedented success rate in photovoltaic technology. The power conversion efficiency (PCE) of the single-junction perovskite solar cell is now 25.5%, comparable to Si (27.6 %) solar cells in a short period. The current status of NCPRE in perovskite solar cells (PSCs) has reached over 20% with an excellent chance to compete hand-to-hand with the rest of the world for this emerging technology. Known challenges of scalability and stability are rapidly addressed in the PSC community, and these efforts are underway at NCPRE. For further improvement in efficiency using existing cells, we plan to make a tandem structure by stacking the PSCs and Silicon solar cells to improve the performance of the solar cells which can give rise to PCE > 25%.



Wiki efficiency chart with current status of India in year 2020 for established Silicon solar cell and halide perovskite solar cell's efficiency.

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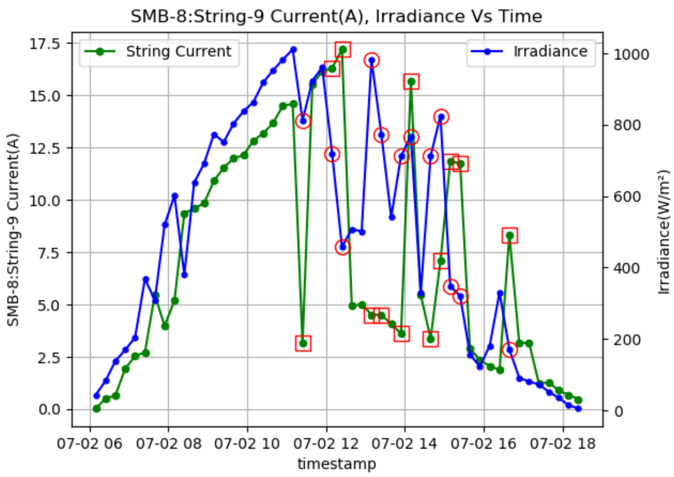
PV SCADA Data Analysis: Identification of Cloud Signature

PV has seen rapid growth in recent years. With this growth, it is important to ensure that these PV systems are delivering the desired performance. A suitable performance monitoring system is used for logging energy output and weather parameters. With more PV plants turning online, data that is collected during PV plant operation is also increasing. The effective and accurate data analysis can help overall progress of PV ecosystem. The SCADA (Supervisory Control and Data Acquisition) data is being explored for predictive operation and maintenance (O&M). This involves detecting anomaly in data and origin of that anomaly and further, identification of signatures of different faults.

In this study, one-month SCADA data from multi-MW PV plant was collected, having one weather station for the measurement of weather parameters. In this data, anomalous PV generation data was observed where generated DC current was not following expected relation with irradiance, as shown in figure. Ideally, it is expected that generated DC current should follow the observed irradiance. But, it can be seen from figure that these points go out of sync randomly.

The question is whether this should generate an alert for Operation & Maintenance team suggesting some possible issue to check out.



Soiling, encapsulant browning or partial shading due to some nearby objects can cause lower than expected current, but there was no consistency in lower currents. Also, it was known from site inspection that the modules did not suffer from partial shading. Also, one would expect smooth increment and then decrement in observed irradiance, but it shows some random oscillations over typical behaviour. This suggests the possibility of cloud cover over irradiance sensor.

Further, standard deviation in SMB currents as well as string currents was calculated at each time instance. It was observed that the data points which follow expected relation have shown lower standard deviation than the points that do not follow expected relation. Through this process of elimination, this behaviour can be explained by cloud movement causing partial shading of various blocks of modules and irradiance sensor.

Such issues caused due to cloud cover over the plant can be minimized by installing more sensors spread over the plant, to capture actual variation in weather parameters. Alternatively, these anomalous data points can be filtered out from further data analysis by investigating time-series of current and irradiance.

To know more about this topic, please refer to the following paper:

- Ruchita Korgaonkar, Subhasree Mondal, Hemant K. Singh, Anil Kottantharayil, Juzer Vasi, Narendra Shiradkar, "Role of Cloud Movement in Generation of Anomalous Data in SCADA Systems of PV Power Plants", presented in 2020 IEEE 47th Photovoltaic Specialists Conference (PVSC), IEEE, 2020.

People involved in this work –

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Lab Planetary Vacuum Mixer Machine (LPVM)

The industrial designed planetary mixing machine is best suited for both solid and liquid state mixing of materials. The specifically designed twin blades make it possible for the controlled and good quality of the materials mixing. One blade is designed in helix shape for slow and continuous mixing and another blade with its teeth shaped design is especially for high speed rotation for easy mixing. The pressure and vacuum control adds extra quality to the final product. The minimum capacity for the mixing of materials is 2-5 Liters.

LPVM SPECS	
Design total volume	8L
Elective volume	2-5L
Tempering jacket form	The bottom and the barrel jacket can input water for cooling, heat preservation and heating
Design environment temperature	-10～+120°C
Mixing blade model	Variable cross-section spiral twist type
Control System	electronic control, Digital temperature display gauge, Over-temperature alarm, over-temperature alarm shutdown, alarm shutdown,
Operation mode	Touch screen
Vacuum hold	-0.098Mpa, holding pressure for 24 hours＞-0.085Mpa, do not leak to the barrel <±0.3mm

Please refer below link for list of NCPRE Facilities:
http://www.ncpre.iitb.ac.in/ncpre/pages/equipment_status.html
Facilities are on chargeable basis, please refer below link for details of charges:
http://www.ncpre.iitb.ac.in/ncpre/uploads/eqp_usage_charges_NCPRE_tools.pdf

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Academic Collaboration

- Prof. Henry J Snaith, University of Oxford, UK. (Halide Perovskite solar cells advanced characterization and tandem structure with organic solar cells: SUNRISE joint project funded by EPSRC).
- Prof. Feng Gao, Linkoping University, Sweden (On quasi-2D perovskites towards stability aspect of halide perovskite optoelectronic devices under joint research grant project).

Industrial collaboration

- The NCPRE's energy storage group is currently collaborated with KPIT, Pune for the manufacturing of 10 Ah pouch cells and 2.5 Ah 18650 cylindrical cells for Sodium-ion battery development at IITB-Monash Battery manufacturing facility.
- The NCPRE's energy storage group is going to collaborate with Tata Chemicals for the development of high energy pouch cells and 18650 cylindrical cells for Lithium-ion battery development at IITB-Monash Battery manufacturing facility.

Publications

- Anagha E R, D. Pratti, S. V. Kulkarni and N. Shiradkar, "Modeling of Leakage Currents in c-Si PV Modules and Investigation of their Arrhenius Behavior," 2020 47th IEEE Photovoltaic Specialists Conference (PVSC), 15 June-21 Aug. 2020, Calgary, OR, Canada, pp. 1105-1109, DOI: 10.1109/PVSC45281.2020.9300731.
- S. Bhaduri, R. Bajhal, S. Mallick, N. Shiradkar and A. Kottantharayil, "Degradation of anti-soiling coatings: mechanical impact of rainfall," 47th IEEE Photovoltaic Specialists Conference (PVSC), 15 June-21 Aug. 2020, Calgary, OR, Canada, pp. 1098-1101, DOI: 10.1109/PVSC45281.2020.9300414.
- S. Bhaduri, M. Farkade, R. Bajhal, L. L. Kazmerski S. Mallick, N. Shiradkar and A. Kottantharayil, "Cleaning efficacy of anti-soiling coatings," 47th IEEE Photovoltaic Specialists Conference (PVSC), 15 June-21 Aug. 2020, Calgary, OR, Canada, pp. 0105-0108, DOI: 10.1109/PVSC45281.2020.9300697.
- Desai, Umang, Bhuwanesh Kumar Sharma, Ashish Singh, and Aparna Singh. "Enhancement of resistance against damp heat aging through compositional change in PV encapsulant poly (ethylene-co-vinyl acetate)." Solar Energy 211 (2020): 674-682, DOI:10.1016/j.solener.2020.09.083.

Chasing dreams

- *Prof. Dipti Gupta*

Flexible and stretchable energy harvesting and storage devices are gaining huge interest all over the globe owing to large surface area coverage, high throughput, light weight and portability, the attributes which are equally appreciated in digital or power electronics world. I, along with my students at Plastic Electronics and Energy Laboratory (PEEL) at Metallurgical Engineering and Material Science department concentrates in a vastly interdisciplinary research in the aforementioned areas by including the incorporation of large-scale techniques such as inkjet printing, screen-printing, 3D printing etc. for the development of scalable, cost effective, high performing flexible devices. My research in NCPRE focuses mainly on the development of flexible, self-charging, thin film printed lithium-ion batteries, and printed perovskite solar cells fabricated in ambient conditions.

Perovskite solar cells has gained great attention of research community in recent years due to its rapid growth in performance from an efficiency of 3.8 % in 2009 to 25.5% in 2020 which is comparable to the performances of single crystalline silicon solar cells. The major road blocks in the path of commercialization of perovskite solar cells are the very few researches aiming for the fabrication of this solution processable solar cell using proper scalable methods.

For the fabrication of printed perovskite solar cells, the important steps involved are the proper formulation of the solutions and thorough study for the development of inks suitable for printing, followed by the optimization of thin films from the so prepared inks for developing high performing printed solar cells. Since, a large range of versatile materials are studied and used in the area of perovskite solar cells, we are towards the aim to fabricate fully printed low-cost perovskite solar cells prepared in ambient conditions. Therefore, I believe my direction of research in NCPRE can contribute largely towards the development of various electronic devices and so is a step nearer towards the benefit of our country and mankind.

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Mehul Raval

NCPRE journey

After completing my M.Sc [Eng] in 2009, I got an opportunity to work as a Research Assistant under Prof. Chetan Solanki. I then converted into PhD with a position of Senior Research Assistant under NCPRE in January 2010. I was involved from NCPRE Phase I as system owner for some of the cell section R&D equipment and got involved in the initial stage of module group activities with Jim and other colleagues.

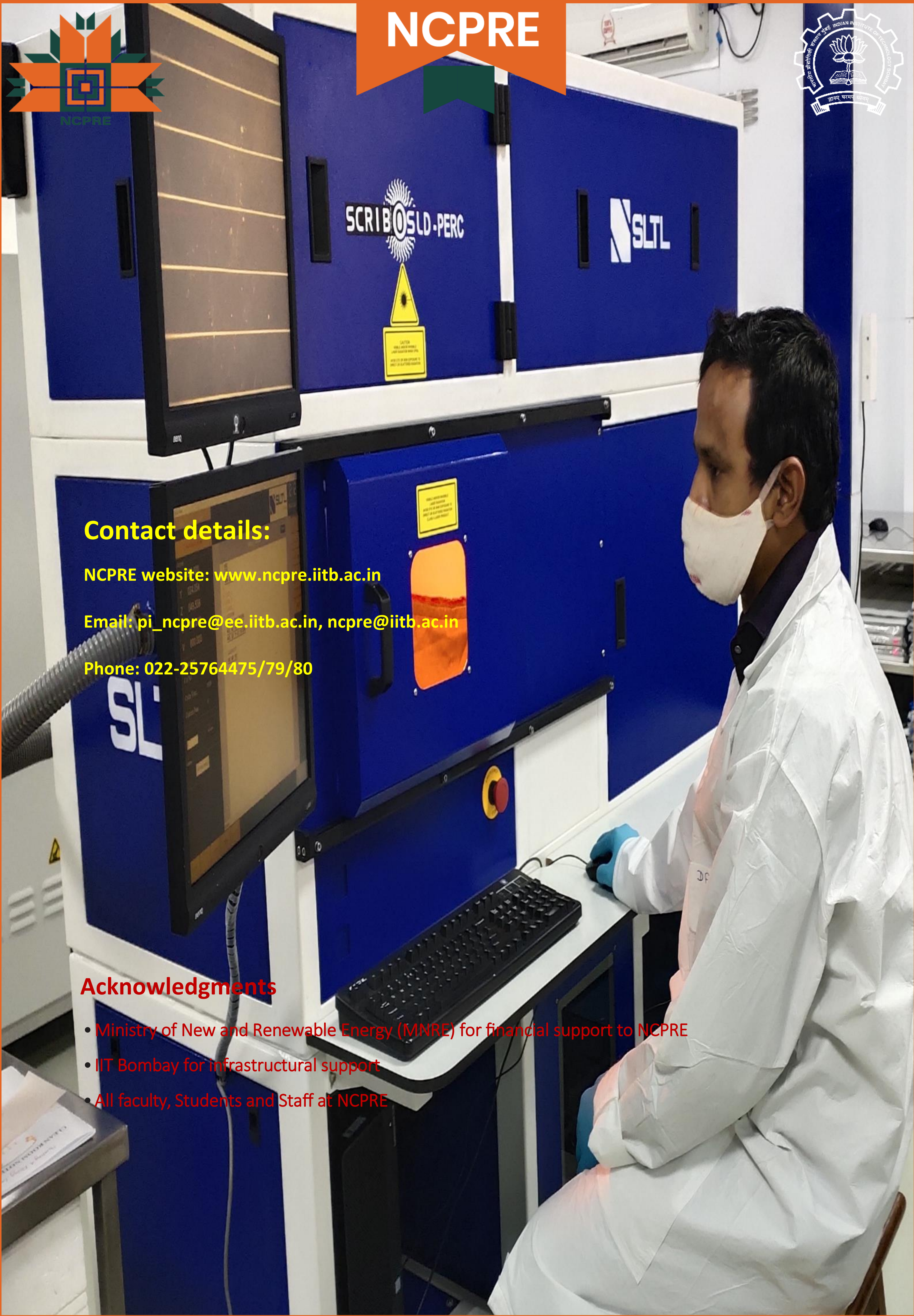
While working on my PhD thesis on Ni-Cu based metallization, I got an opportunity to become familiar with solar cell fabrication steps and characterization equipment. I was actively involved in training and supporting workshops organized by NCPRE. This period helped me to build a good understanding of solar cell fabrication and characterization. Attending various seminars and EUPVSEC, 2012 gave me a glimpse of the broad domain of PV manufacturing.

It was my contact during EUPVSEC that presented me with an opportunity to partner with a German company (via an Indian agency) on an Indian project for a solar cell line ramp-up project. I got excellent exposure to solar cell production equipment, processes and production aspects. This was something that I was precisely looking for after my Ph. D work.

After the Indian project, there were not many avenues in Indian PV manufacturing, so I decided to join a start-up working on integrating PV systems with rain-water harvesting smart canopies. Within few months, I realized the work isn't technically stimulating enough for me and with the love of God, the German company with whom I had worked before offered me a permanent position. After deliberation with my family, I decided to join and started a cell line ramp-up project in Turkey.

Subsequently, we were involved as owner's engineers in another integrated mono PERC 500 MW project in Turkey with which I have been engaged for two years. In this project, we worked with a large Chinese company that is the turnkey supplier. Such a project gave me a broad exposure to the latest technologies, equipment, contractual details and production aspects for larger capacity PV factories.

NCPRE



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