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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 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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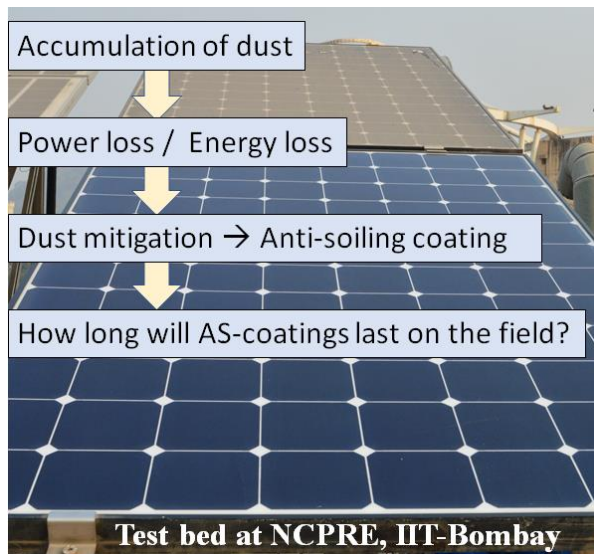
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Test Procedure for Evaluation of Anti-Soiling Coatings



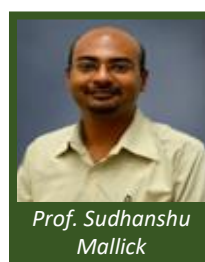
Power loss caused by the dust deposition on photovoltaic (PV) modules (also defined as soiling) introduces a challenge for the economic viability of PV deployment in many of the sun-belt countries, including India. Anti-soiling coatings (AS-coatings) are nano or microlayer coating, which reduces dust settlement on PV modules. AS-coatings are designed to be economical and easy to maintain. It keeps the cover glass clean while requiring less water, less energy and less labour to clean and maintain the PV modules. As the AS-coating is deposited on the outer surface of the PV module, it has to withstand harsh climatic conditions, which makes the durability of these coating a crucial factor. Lot of work is done on the development of anti-soiling coatings, which have made their way to the commercial market. However, there is a lack of data and knowledge on how effective anti-

soiling coating is as a dust mitigation strategy, and what is the life of AS-coating under field exposure.

We, at NCPRE, are developing a standard test protocol for the evaluation of anti-soiling coatings, which will act as a baseline for testing the coatings available in the commercial market and will also direct us to develop durable anti-soiling coatings (designed to withstand Indian climatic conditions). By conducting multiple field exposure and accelerated stress tests, we have identified that rain, UV exposure, frequent cleaning runs, and a combination of UV exposure and condensation significantly affect the life of anti-soiling coatings during field exposure.

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

1. Sonali Bhaduri, Ajeesh Alath, Sudhanshu Mallick, Narendra S. Shiradkar, and Anil Kottantharayil, "Identification of Stressors Leading to Degradation of Antisoiling Coating in Warm and Humid Climate Zones," *IEEE J. Photovoltaics*, vol. 10, no. 1, pp. 166–172, 2020. DOI: 10.1109/JPHOTOV.2019.2946709
2. 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), Calgary, OR, 2020, pp. 1098-1101, DOI: 10.1109/PVSC45281.2020.9300414.
3. 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), Calgary, OR, 2020, pp. 0105-0108, DOI: 10.1109/PVSC45281.2020.9300697.



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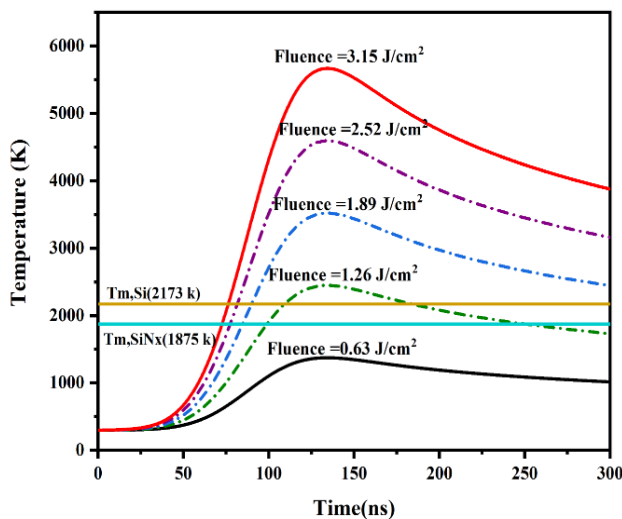
Laser ablation of the rear dielectric layer for PERC solar cells

The Passivated Emitter Rear Contact (PERC) solar cell architecture demands an efficient method to form localized uniform back surface field regions. Hence, the opening of the rear side thin dielectric layer without creating many damages to the silicon substrate underneath holds a vital role. Among the various methods such as photolithography, chemical etching, diamond scratching, laser ablation has the advantage as a fast, accurate, and cost-effective process. However, laser ablation is a thermal process; it is essential to choose optimal process parameters such that thermal damage of the silicon substrate is minimal without compromising on productivity. This has been achieved using a synergistic approach involving computational modelling, experiments, and process optimization (see figure below). We have developed a computational model of the laser heating process incorporating a double layer (passivation layer coated silicon substrate) to determine a ballpark estimate of the range of process parameters based on the temperature profiles as shown in the figure on the left below.

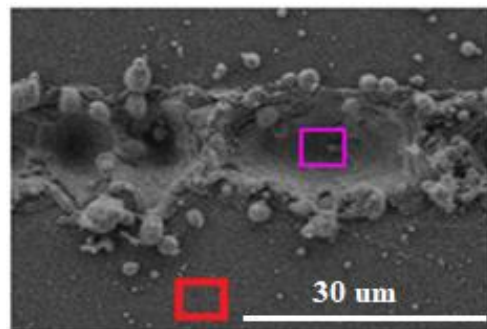
Further, experiments were carried out in the range of process parameters obtained from the computational model. Silicon oxynitride dielectric layer of thickness 85 nm was deposited using plasma-enhanced chemical vapour deposition system on single side polished silicon wafers. Green 532 nm laser developed at Sahajanand Laser Technology Ltd., Gujarat, India was used for carrying out the experiments. The repetition frequency of 30kHz, speed of 60 mm/sec, the pulse width of 80 ns and spot size of 17 μm were used in this study. The effectiveness of laser ablation was studied using surface imaging by field emission scanning electron microscope (FESEM) and energy dispersive spectroscopy (EDS). The reduction in the elemental percentage of nitrogen and oxygen at position 2 in the figure on the right below, validates the ablation of the silicon oxynitride layer.



Methodology used in our study.



Temperature variation with time at different values of fluence in the single pulse laser model.



| Element | Atomic % | |
|---------|------------|------------|
| | Position 1 | Position 2 |
| CK | 10.85 | 2.20 |
| NK | 17.37 | 0.04 |
| OK | 29.32 | 1.85 |
| SiK | 42.46 | 95.91 |
| Totals | 100 | |

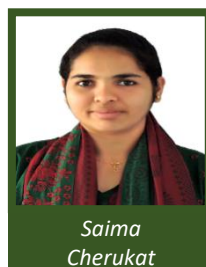
Top surface imaging and EDS analysis at the non-ablated (Position 1) and ablated (Position 2) regions.



Pinal Rana



Durga Prasad Khatri



Saima Cherukat



Prof. Deepak Marla

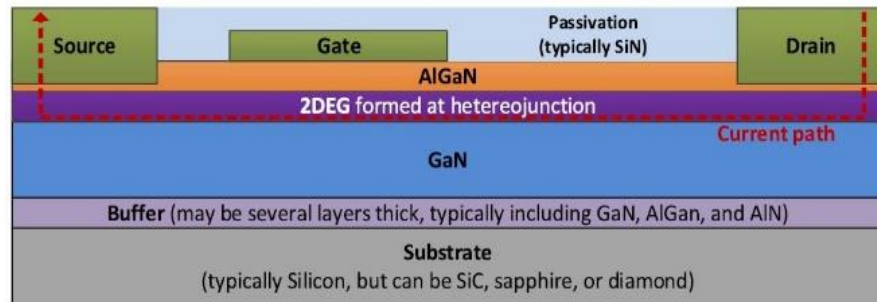


Prof. Anil Kottantharayil



Synchronous Boost Converter using GaN HEMT device

High band gap based GaN HEMT devices are gaining the interest of the industry due to their very fast switching action and very low Figure of Merit in comparison to their Si counterparts. The hetero-junction structure and characteristics of the GaN devices lead to a very different behaviour compared to Si MOSFETs. The ultra-small parasitic capacitance makes it possible to deplete the two-dimensional electron gas (2DEG), the layer responsible for current conduction, even before the switching-off transition. This results in an extremely low switching loss during the turn-off action of the switch.

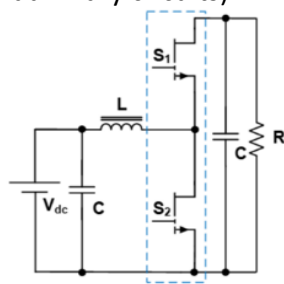


Basic Lateral GaN Structure

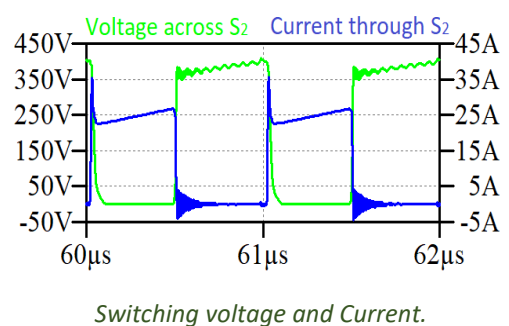
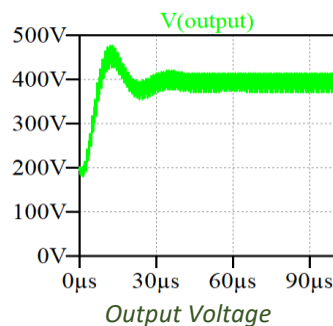
The synchronous boost converter schematic, shown in figure, is fabricated using GaN HEMTs, which is operated at a frequency of 1 MHz. This leads to smaller size of the inductors and capacitors required. In addition, the losses in GaN devices are almost 3 to 5 times lower than similar rated Si devices. Due to the small size of passive elements, and GaN devices in general having small footprint due to their high breakdown strength, it is possible to design very compact and highly efficient converters.

We have designed a synchronous boost converter which is compact (about one third of regular size converter) while achieving high conversion efficiency. Based on the simulation results, an efficiency of 97.8% is obtained for a synchronous boost converter supplying a load of 5kW (neglecting losses in auxilliary circuits).

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Half-bridge-based Synchronous Boost converter





Is Double Perovskite a Future for Stable Photovoltaic Applications?

Photovoltaics (PV) and Photo(electro)catalysis (PEC) remain at the forefront of renewable energy research. For devices based on such technologies, the hunt for cheaper, stable and efficient materials is always ongoing. Oxide perovskites have emerged rapidly in recent years because of their excellent stability and high abundance. Herein, we evaluate a class of double perovskite oxides $Ba_2Bi_{1+x}Nb_{1-x}O_6$ ($0 \leq x \leq 0.8$) (BBNO) from the PV and PEC perspective. BBNO is one of the rare oxides showing band gap (~ 1.5 eV) in the ideal visible region. Such band gap arises naturally due to the introduction of an intermediate band, which originates from this compound being prone towards forming an off-stoichiometric structure. Using an amalgamated theoretical and experimental study, we provide physical insights to this series of compounds, starting from inherent off-stoichiometry to origin of non-radiative recombination. The crux of the study lies in connecting ab-initio defect physics to the experimental observations, while analyzing the effect of growth environment on intrinsic point defects and hence its suitability.

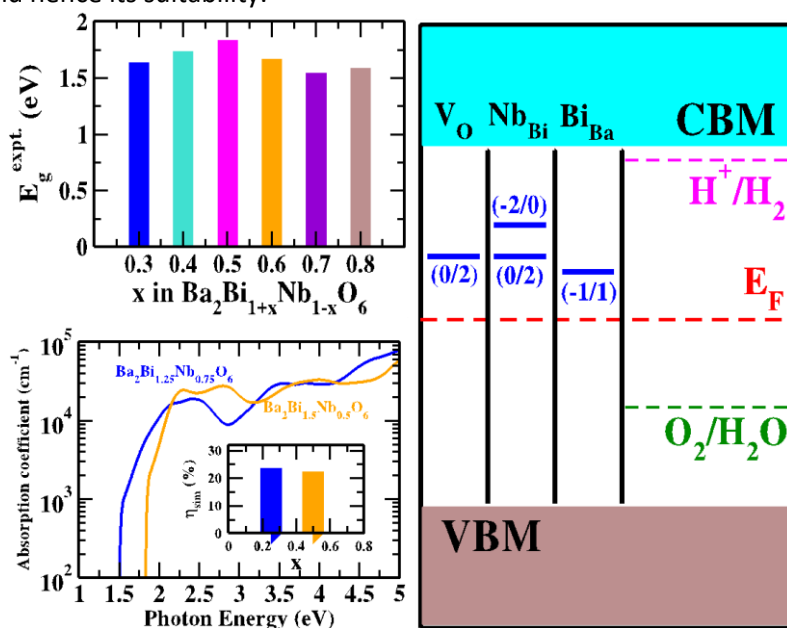
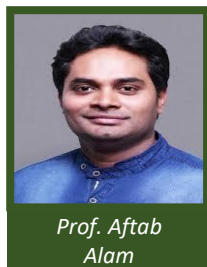
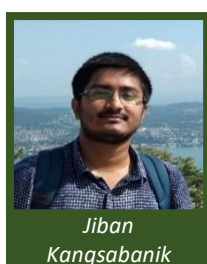


Figure: (top left) Histogram of experimental band gap of $Ba_2Bi_{1+x}Nb_{1-x}O_6$ (BBNO) with varying degree of off-stoichiometry (x).

(Bottom left) Simulated absorption coefficient of BBNO with efficiency (theoretical) in the inset.

(Right) Schematic diagram showing the main defects and their charge transitions in the band gap. Also the predicted position of the water redox level with respect to the band gap.

<https://doi.org/10.1002/adom.202000901>



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BTU Belt Furnace

Enhancement in collection of light generated carriers improves the efficiency (η) of crystalline silicon (c-Si) Aluminum Back Surface Field (Al-BSF) solar cells. The collection of charge carrier can be improved by making better contact in front and rear side of c-Si Al-BSF solar cells. Co-firing of screen-printed wafers is an important step for contact formation during the fabrication of c-Si Al-BSF solar cells. Thick-film pastes of aluminum and silver at the rear side of the cell while another silver composition on the front to serve as the collector grid is screen-printed. The process to co-fire these three components is the key in determining the solar cell efficiency. The quality of the contact influences the series resistance (R_s), shunt resistance (R_{sh}), fill factor (FF) and junction leakage current, which have a significant impact on the efficiency of the c-Si Al-BSF solar cells. Belt Furnace caters to the needs of the contacts formation during the co-firing process.

A state-of-the-art BTU Belt Furnace tool has been procured at NCPRE, IITB. This Belt Furnace is a semi-automated co-firing furnace that uses a conveyor or belt. It features a tunnel structure and is composed of multiple controlled zones, which include zones for preheating, binder burn out, heating, firing and cooling. Screen printed silicon wafers are loaded onto the conveyor belt and moved through heating and cooling zones for drying, firing and cooling in an air atmosphere. It is designed for fast drying, curing and is widely used in solar cell industries. The equipment is operated and monitored through the WINCON software application. This furnace also features fast thermal responses, uniform and stable temperature distribution.

| Specifications | |
|--------------------------------------|--------------------|
| Operating Temperature Rating | 200 °C to 950 °C |
| Number of Heated Zones | 6 |
| Heated Length | 1778 mm |
| Process Atmosphere | Air |
| Product Throughput (Wafers Per Hour) | 1800 |
| Belt Speed Range | 762 to 7620 mm/min |
| Belt Width | 254 mm |
| Belt Material | Nichrome V |



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

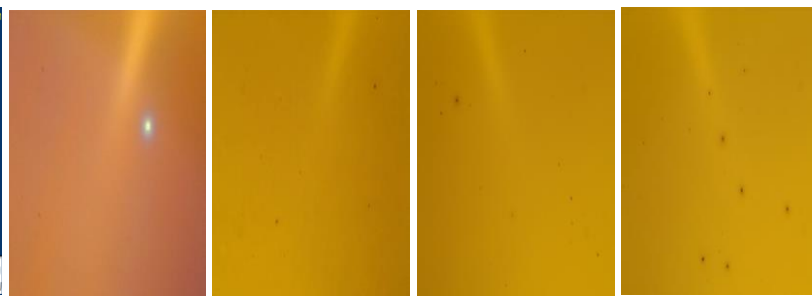
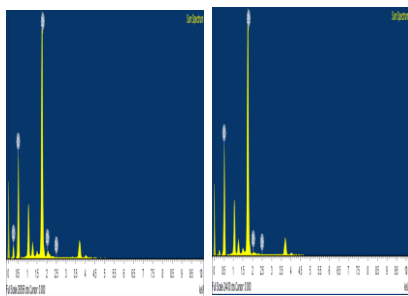


Sol gel synthesized Zirconium oxide for Solar cell applications

A project carried out at NCPRE under PUMP

The conventional energy resources are exhaustible due to the reason that they take millions of years to go through the natural process of renewal and cannot be replaced as fast as they are being consumed. To the best known of all the alternate energy sources, energy from the sun is most pleasing because of its profusion, reliability of sunlight and gifted source of CO₂-free power generation. Here is where solar cells become the most preferred option. In the overall performance of solar cells, anti-reflective coating plays an important role. In the present study, we examined the capability of a-ZrO_x to be employed as a substitute anti-reflection material with respect to existing materials like Si₃N₄, TiO₂, MgF₂, Al₂O₃, a-BTO, etc. in near future for efficient light trapping in Si solar cell. Generally, ARC's involve vacuum and/or high thermal anneals, which end up with higher processing expenses. Thus, we deposited ZrO_x as an anti-reflection coating by an alternative method based on route employing simple chemistry irrespective of methods mentioned above. The chemical path has turned out to be a more successful and competitive candidate due to its inexpensive processing, simple procedures, flexible refractive index, and non-requirement of costly equipment. Our work report on the preparation and characterization of sol-gel synthesized ZrO_x by Ultraviolet light. We present the effect of increased UV exposure on the optical and morphological properties of synthesized ZrO_x.

EDAX images before and after UV exposure confirmed the formation of ZrO_x after synthesis. After confirmation of elemental composition, we tried to improve the uniformity of the film. From the optical images, it is clearly visible that the sample with 1hour UV exposure is highly uniform and free from black pits. Our film is not annealed, which has resulted in the poor PL image depicted in the figure because of the fact that the amorphous film has shown minimum reflectance (~ 3.9%), which is a great achievement with the sol-gel technology. Annealing of the deposited film will further disturb the optical properties of the synthesized material, which is not desirable. The 1 hr UV exposed sample showed the best optical and morphological properties among the rest of the samples, thus the final device fabrication employing a-ZrO_x as an anti-reflection layer consists of UV exposure of 1 hr only. The log I-V characteristics of the diode dictate how well the diode is formed and the approximate value for diode ideality factor. From the figure, it is clearly visible that after the application of ZrO_x, the leakage current reduces thus, increasing the rectification.

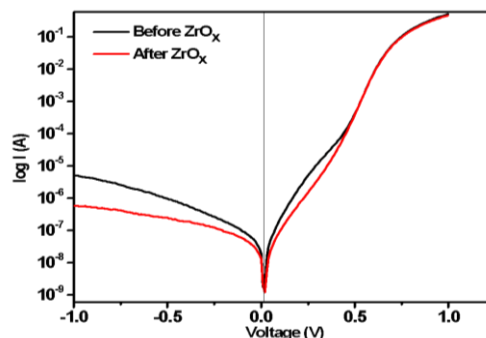


EDAX profile of ZrO_x thin film (a) before UV exposure and (b) after UV exposure

10X Optical microscopic images of spin-coated ZrO_x film for (a) 1hr, (b) 2hr, (c) 3hr and (d) 4hr



Photoluminescence image of spin-coated ZrO_x film



Log I-V of fabricated Solar Cell



Deepika Jamwal





What/how NCPRE is doing, listen from renowned Photovoltaic Experts!

The 10th NCPRE Advisory Committee Meeting was held on Wednesday, 24th February, 2021. This was the fifth meeting of the Committee re-constituted by Director, IIT Bombay in 2016, after the start of Phase II of NCPRE. This meeting happens every year.

The following members of the Advisory Committee were present at the meeting: Prof. Subhasis Chaudhuri (Director, IITB and Chairman, Advisory Committee), Prof. Kamanio Chattopadhyay (IISc), Mr. Ardeshir Contractor (CEO, AA India), Mr. Sandeep Koppikar (Solar PV Consultant), Dr. Bharat Bhargava (ex-DG, ONGC), Dr. Vijaymohan K. Pillai (Professor, IISER Tirupathi), Prof. Ralph Gottschalg (Fraunhofer CSP), Prof. Richard Corkish (UNSW), Prof. Ajeet Rohatgi (Georgia Tech), Prof. Gary Hodes (Weizmann Institute), Dr. William Tumas (NREL), Prof. Armin Aberle (SERIS), Prof. Sir Richard Friend (Cambridge University), Prof. Milind Atrey (Dean, R&D), Prof. Rangan Banerjee (Head ESE, IITB), Prof. Kishore Chatterjee (Head EE, IITB), Prof. Baylon Fernandes (IITB, Co-Convenor) and Prof. Suryanarayana Doolla (IITB, Co-Convenor). It was gratifying to note that all members of the Advisory Committee meeting were in attendance.

Shri Dinesh Jagdale (JS, MNRE) and Dr. Anil Kumar (Scientist D, MNRE) were also present at the meeting as Special Invitees.

The meeting was also attended by many of the NCPRE investigators. In addition, Dr. Lawrence Kazmerski (NREL), Dr. Rajiv Arya (Arya International, and ex-CEO Moser-Baer), who are Distinguished Visiting Professors at IIT Bombay, and have been contributing significantly to NCPRE's activities, also attended the meeting.

Prof. Subhasis Chaudhuri welcomed all the members to the 10th Advisory Committee meeting. In his remarks he mentioned that NCPRE has been receiving guidance by this Advisory Committee in the last two phases. With support from MNRE, NCPRE has escalated the activities in the current phase (phase II). About 600 papers were published till date in international journals and conferences. NCPRE is one of its kind Centre in India with focus on Solar Photovoltaics. Prof. Milind Atrey also emphasized that NCPRE is a very important inter-disciplinary Centre at IIT Bombay with faculty members and students across several departments working in the area of solar photovoltaics.

Shri Dinesh Jagdale, Joint Secretary in the Ministry of New and Renewable Energy (MNRE), gave opening remarks on India's National Solar Mission, and the role that NCPRE can play in it. Shri Jagdale said that it has been a pride and pleasure for MNRE to have conceived NCPRE in 2010, and that NCPRE has stood up to be among the best in the international arena. Shri Jagdale said that India has achieved 92 GW of its 175 GW renewable energy target for 2022. The solar installation is currently 39 GW, and several more plants are under construction. Since the launch, there has been a 54% annual compounded growth of solar, and the latest bid revealed a cost of Rs. 1.99 per kWh. India now has to move from 40 GW to the target of 300 GW by 2030, and the annual deployment of 26 GW/year is the challenge that the government has placed before all of us. He congratulated the NCPRE team on their achievements, which he witnessed during his visit to IITB, including in the area of reliability, storage, power electronics, silicon and thin films. Shri Jagdale said that the Atma Nirbhar Bharat policy of the government will position India as a manufacturing hub across the globe. The global supply chain is very important, and it has to be distributed and inclusive. He said that India now has the scale as well as skill-sets to embark on this. Shri Jagdale said that the Ministry values NCPRE's role and what it has done for the last 10 years. He said that NCPRE's contributions in Atma Nirbhar Bharat will play a huge role.

All the Advisory Members appreciated the progress of NCPRE. They also gave their valuable comments and advice for the future deliverables.



Glimpses of 10th Advisory Committee Meeting of NCPRE





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All faculty, Students and Staff at NCPRE

