

### Brief profile

- 5 years of Research and development in thin film photovoltaics, glass based encapsulation, flexible EL displays and their encapsulation
- PhD awarded (**Oct 23, 2021**) on Perovskite solar cells (PSC's) from **Indian Institute of Technology Mandi**, India under the guidance of **Dr. Satvasheel Powar (IIT Mandi)** and **Prof. Nripan Mathews (NTU Singapore)**
- Internship (Jan 2019- Feb 2021) at ERI@N NTU Singapore on Carbon based perovskite solar cells from small device (**0.7 cm<sup>2</sup>**) to modules (**100 cm<sup>2</sup>, 900 cm<sup>2</sup>**); and development of screen printing pastes/inks for solar cells, LED application under the supervision of Prof. Nripan Mathews.
- Utilization of slot die coating, blade coating, screen printing as main techniques in minimodules fabrication during PhD and post PhD.
- Currently working as research analyst with establishment of research related facilities in industries and mentoring of perovskite start-ups in India.

### FIELD OF RESEARCH INTEREST

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Thin film PV technology, Scaling up processes from lab to industrial scale, Nanomaterials synthesis, coatings, inks formulations, Flexible electronics.

### EDUCATION

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<b>August 2016 to Oct 2021</b>	<b>Doctor of Philosophy (PhD)</b>	<b>CGPA</b>
	School of Engineering, Indian Institute of Technology Mandi, India	9/10
	<b>Thesis Title:</b> <i>Scale up engineering with the techno-economic study of screen-printed carbon counter electrode-based perovskite solar cells.</i>	
	<i>Supervisors:</i> Dr. Satvasheel Powar (IIT Mandi), Prof. Nripan Mathews (ERI@N NTU Singapore)	
<b>2014-2016</b>	<b>Master of Technology (M. Tech)</b>	<b>CGPA</b>
	School of Material Science and Nanotechnology, National Institute of Technology, Kurukshetra	9.4/10
	<b>Thesis Title:</b> <i>Growth and characterization of 1D ZnO nanostructures and their composites for gas sensing applications.</i>	

**Supervisors:** Prof. Neena Jaggi (NIT Kurukshetra), Scientist Pooja D. (CSIR- CSIO Chandigarh)

<b>2010-2014</b>	<b>Bachelor of Technology (B. Tech)</b>	<b>Score</b>
	Electronics and Communication Engineering, Kurukshetra University Kurukshetra, India	4855/6180
	<b>Major Project:</b> <i>Wireless power theft monitoring</i> <b>Minor Project:</b> <i>Cellphone operated device control system with voice acknowledgement</i>	<b>Grade:</b> <i>First Class with Honors</i>

## RESEARCH EXPERIENCE and PROJECTS

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**Nov 2021- Present** **Research analyst**, AnanyaVijaya consultancy LLP, Bangalore India

### Projects:

- Mentoring of a perovskite module manufacturing startup in India by industry-academia collaboration (for scaling up it from lab to commercial scale).
- Analysis of various research projects (around the globe) in silicon, perovskite, organic solar cells etc. and finding their future trend;
- Finding a better action plan for solar PV manufacturing companies before starting their manufacturing unit on any new technology/ modifications.
- Report writing on the basis of data analysis performed on any technology with future forecast of any technology to find its effectiveness.

Extra: Meeting organization, and active participation in meetings with startups and industry representatives.

**Jan 2019- Feb 2021** **Internship**, Energy Research Institute @ NTU (ERI@N), Nanyang Technological University, Singapore.

### Research Projects:

- Synthesis & development of screen printing and blade coating pastes for perovskite solar cell applications.
- Fabrication of carbon based perovskite solar cells: small devices (0.7 cm<sup>2</sup>) and modules (100 cm<sup>2</sup> and 900 cm<sup>2</sup>).
- Preparation and characterization of carbon pastes to meet industrial standards.
- Fabrication of perovskite modules using slot die coating technique.
- Fabrication of low temperature carbon based solar cells and their characterization.
- Fabrication of thermally evaporated Au based planar/ mesoporous perovskite solar cells and their characterization.
- Temperature based encapsulation studies of perovskite solar cells.
- Preparation of resistive metal oxide pastes for electronic applications.
- Preparation of screen printing pastes for perovskite LED application.

**July 2016-  
Oct 2021**    **PhD Scholar** at Indian Institute of Technology, Mandi

**Research Projects:**

- Screen printing pastes preparation and their utilization in flexible electroluminescent A4 size displays.
- Frequency controlling circuit designing for EL displays.
- Encapsulation of flexible EL displays.
- Perovskite solar cells fabrication using ALD and sputtering techniques.
- Preparation and optimization of security inks.
- Cleaning, cutting and handling of Silicon wafers .

**Jan 2016-  
June 2016**    **Internship**, CSIR-Central Scientific Instruments Organisation (CSIO), Ministry of Science & technology, Govt. of India

**Research Projects:**

- Synthesis of conducting polymer (Polypyrrole) from pyrrole monomer.
- Synthesis of nanofibers from 1D metal oxide nanomaterials using electrospinning technique.
- Deposition of conducting polymers on nanofibers using physical vapor deposition (PVD) technique.
- Fabrication of electro-spun gas sensors using metal oxide: conducting polymer as p-n junction for volatile organic compounds sensing.

**Aug 2014-  
June 2016**    **Masters of Technology**, School of material science and nanotechnology (MNT), National institute of Technology (NIT) Kurukshetra, India

**Research Projects:**

- Preparation and analysis of ZnO nanowires using thermal decomposition technique.
- Preparation of highly stable ZnO nanorods using hydrothermal synthesis technique and their analysis.
- Growth of ZnO nanowires on glass substrate by seed layer approach.

**July 2013-  
August 2013**    **Internship**, Oriental Science Apparatus Workshops (OSAW), Scientific equipment supplier, Ambala, India

- PCB design (etching and circuit designing) on bare copper clad.
- Circuit designing and project preparation for automatic railway gate controller.

**July 2012-  
August 2012**    **Internship**, Alvert technologies

- VLSI designing of logic gates, combinational circuits, sequential circuits, Johnson counter using Tanner EDA tools (S-Edit, T spice and W-Edit).

**Aug 2010-  
June 2014**    **Bachelor of Technology**, Electronics and communication engineering, Kurukshetra University Kurukshetra, India.

- Basics of soldering, circuits connection on bread board and on PCB,

components identification and selection for different applications.

## SCHOLARSHIPS & ACHIEVEMENTS

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<b>2022</b>	Best thesis presentation award in Innovation, sustainability, and surveillance for development of smart cities category at research conclave 2022, IIT Indore, India
<b>2021</b>	Technoeconomic analysis work highlighted by <i>PV Magazine</i> on November 2, 2021 entitled "Analyzing the opportunity for perovskite solar module production in India".
<b>2021</b>	Invited speaker on <i>carbon based perovskite solar cells</i> organized by IEEE-Nanotechnology Council (NTC) Student Chapter at Indian Institute of Technology Indore.
<b>2020</b>	Interviewed by <i>Channel News Asia (CNA)</i> news channel for carbon based perovskite solar cells development at NTU create lab Singapore.
<b>2020</b>	Invited <i>speaker</i> for IEEE AcSIR CSIO Virtual Talk Series (VTSAM-2020) focused on the Emergence of advanced materials for various applications.
<b>2020</b>	Fundamentals of solar photovoltaics <i>course</i> by <i>Denmark technical University (DTU)</i>
<b>2019</b>	<u>Best poster</u> presentation award "10 <sup>th</sup> Trilateral Conference on: Nanoscience: Energy, Water & Healthcare 2019. Singapore".
<b>2019</b>	Utilization of prepared resistive metal oxide pastes for electronic devices research applications by <u>Singapore Defense forces</u> .
<b>2018</b>	<u>Best oral</u> presentation award "3rd international conference on sustainable energy and environmental challenges (3rd SEEC) 2018. IIT Roorkee, India".
<b>2018</b>	Founder of first women's cricket team at IIT Mandi.
<b>2017</b>	3 <sup>rd</sup> Prize for Himalayan <u>startup</u> Trek in innovative technologies category from <u>Govt. of India</u> .
<b>2017</b>	1 <sup>st</sup> prize in 5 km, 2.5 km and 400m races in IIT Mandi inter undergraduate-postgraduate sports event.
<b>2016- Present</b>	HTRA- MHRD fellowship by <u>Ministry of Education</u> (MoE) India.
<b>2016</b>	Among first three academic position holder in Masters.
<b>2016</b>	Elected to conducted Master's thesis project work at CSIR-Central Scientific Instruments Organisation (CSIO), Ministry of Science & technology, Govt. of India.
<b>2014- 2016</b>	HTRA- MHRD fellowship by Ministry of Education (MoE).
<b>2015</b>	Qualified Graduate Aptitude Test in Engineering ( <u>GATE</u> ) with > 90 percentile in Electronics and Communication Engineering.
<b>2014</b>	Qualified Graduate Aptitude Test in Engineering ( <u>GATE</u> ) with > 90 percentile in Electronics and Communication Engineering.
<b>2013, 2014</b>	Best academic performance award in B.Tech 7 <sup>th</sup> and 8 <sup>th</sup> semester.
<b>2012, 2013</b>	National Cadet corps (NCC) B and C certificates in Air wing
<b>2012</b>	Student coordinator in 3 <sup>rd</sup> international conference on "Emerging trends in engineering and technology" November 2012.
<b>2011</b>	Secured 2 <sup>nd</sup> position in district essay writing competition.

## PUBLICATIONS

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- Singh Rana, P. J., Febriansyah, B., Koh, T. M., Salim, T., Hooper, T., Kanwat, A., Ghosh, B., Muhammad, B., **Kajal, P.**, Lew, J. H., Aw, Y., Bruno, A., Pullarkat, S., Ager III, J., Mhaisalkar, S., Mathews, N. *Alkali additives enable bottom-up crystallization in efficient large area (>55 cm<sup>2</sup>) slot-die coated perovskite solar modules with long operational stability (>4500 h).* **Advanced Functional Materials (2022).**
- Kanwat A., Ghosh B., Ng Si En., Singh Rana, P. J., Lekina Y., Hooper T. J. N., Yantara N., Kovalev M., Chaudhary B., **Kajal P.**, Febriansyah B., Tan Q. Y., Klein M., Shen Z. X., Ager J. W., Mhaisalkar S. G., Mathews N. *Reversible photochromism in <110> oriented layered halide perovskite.* **ACS Nano (2022).**
- **Kajal P.**, Lew J. H., Kanwat A., Rana P. J. S., Nutan G. V., Koh T. M., Mhaisalkar S. G., Powar S., and Mathews N. *Unveiling the role of carbon black in printable mesoscopic perovskite solar cells.* **Journal of Power Source (2021).**
- **Kajal P.**, Verma B., Rao V.S.G Rao V. S. Gangadhara, and Powar S. *Costing analysis of scalable carbon-based perovskite modules using bottom-up technique.* **Wiley (Global challenges) (2021).**
- Shukla, S., Koh T. M., Patidar R., Lew J. H., **Kajal P.**, Mhaisalkar S., Mathews N., “*Suppressing  $\delta$ -Phase and Photo-Instability through Hypophosphorous Acid Additive in Carbon based Mixed Cation Perovskite Solar Cells.* **The Journal of Physical Chemistry C (2021).**
- **Kajal P.**, Ray R., Powar S. & Pal S. S. *Performance analysis of charge transporting layers in perovskite solar cells with varying deposition techniques.* **Proceedings of the Third International Conference on Sustainable Energy and Environmental Challenges, (2019).**
- **Kajal, P.**, Pooja, D. & Jaggi, N. *Structural and optical properties of ZnO nanorods synthesized via template free approach.* **Mater. Res. Express (2016).**

## BOOK CHAPTERS

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- **P. Kajal**, K. Ghosh, S. Powar\*, *Manufacturing Techniques of Perovskite Solar Cells*, 341-364, Application of Solar Energy, **Springer (2018).**

## PATENTS

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- **P. Kajal**, S. Goswami, S. Powar, “*Low Temperature UV Blocking Transparent TiO<sub>2</sub> Paste*”- Indian patent: 367354 **(Granted-2021)**
- **P. Kajal**, S. Powar, Shweta Singh, Faruk Kazi, “*Integrated Device For Generating And Storing Electric Energy*”- Indian patent **(Submitted)**
- S. Powar, M. Doddamani, **P. Kajal**, S. Doddamani, “*System And Method Of Fabricating Perovskite Based Solar Cell*”- Indian patent **(Submitted)**

## CONFERENCE/ WORKSHOP

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- *Attended Virtual Perovskite Conference 2020, ViPerCon2020 held on Apr 14, 2020 on the*

current development and future outlook of perovskite optoelectronics.

- *Poster Presentation*, 10th Trilateral Conference on : "Nanoscience: Energy, Water & Healthcare 2019. Singapore
- *Poster Presentation*, 10<sup>th</sup> International Conference on Materials for Advanced Technologies (ICMAT) 2019. Singapore
- *Workshop* about Electrochemical Impedance Spectroscopy (EIS) analysis by Metro ohm Singapore, at NUS Singapore 2019.
- *Oral Presentation*, 3<sup>rd</sup> ISEES international conference on Sustainable Energy and Environmental challenges (III-SEEC) 2018. IIT Roorkee, India.
- *Workshop*, Organic Photovoltaics' and Electronics Technology, 2018. CSIR- NPL, Delhi, India.
- *Workshop*, 3<sup>rd</sup> IEEE workshop on Nanotechnology and Sensors 2017. IISC Bangalore, India.
- *Workshop*, 3<sup>rd</sup> IEEE workshop on Nanotechnology and Sensors 2017, Silvaco TCAD. IISC Bangalore, India.
- *Workshop*, 3<sup>rd</sup> IEEE workshop on Nanotechnology and Sensors 2017, MEMS design software. IISC Bangalore, India.
- *Poster presentation*, Spectroscopy of emerging Functional Materials 2017. Mandi, India.
- *Poster presentation*, International Conference on Advances in Light Technologies and spectroscopy of Materials (ICALTSM) 2016. Lucknow, India.
- *Oral presentation*, National conference on Advances in Chemical and environmental engineering 2016. Jalandhar, India.
- *Poster presentation*, National Conference on Nano science and Instrumentation Technology (NCNIT) 2016. Kurukshetra, India
- *Workshop*, Nanomaterials for Two Dimensional Devices and Energy Application 2015, Kurukshetra, India.

## TECHNICAL SKILLS

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- ***Material synthesis and paste preparation techniques:***

Thermal decomposition, hydrothermal technique, solution based techniques, polymerization, centrifugation, rota-evaporation, horn sonication, ultra-sonication, Ball milling, three roll milling.

- ***Material characterization techniques:***

X- ray Diffraction (XRD), Thermal Gravometric Analysis (TGA), DSC, FTIR, ATR analysis, Scanning electron microscopy (SEM), EDAX, UV-Vis Spectrophotometer, Photoluminescence (PL) spectrophotometer, Optical Microscope, ATR analysis, BET analysis, Scotch tape based scratch testing, contact angle measurement, Surface energy analysis, XPS analysis, Rheometry (viscosity measurement), surface profilometer, four probe.

- ***Thin film deposition Techniques:***

Slot die coating, blade coating, Spin coating, screen printing, Electro spinning, thermal evaporation, sputtering, chemical bath deposition (CBD), Atomic layer deposition (ALD), spray pyrolysis.

- ***Device fabrication and characterization techniques:***

Laser scribing, wet etching, encapsulation using: thermal encapsulation, Vacuum based encapsulation of solar cells using EVA, PoE; PMMA based encapsulation using spray gun technique, epoxy based encapsulation and its UV curing, ultrasonic soldering.

Electrochemical impedance spectroscopy (EIS), IV measurement using solar simulator, MPPT testing of solar cells, thermal stability analysis at 65 °C and 85 °C, IPCE measurement, surface and cross section analysis using SEM, masking, Light vs Voc measurement, humidity based stability analysis

- **Software skills:**

Auto CAD, Open office, Origin, Microsoft office tools.

## **EXPERIENCE**

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- Working as a *Research analyst* for renewable energy at Ananyavijaya Consultancy LLP.
- Worked as temporary Project research Scientist for *flexible perovskite solar cells and modules using slot die and rapid curing technique with mentoring of a PhD scholar*.
- *Mentorship of project officer, graduated intern student and lab manager* for fabrication of carbon based perovskite solar cells and preparation of screen printing pastes at NTU Singapore, 2021.
- Non-executive advisory member in a organic food startup Kissanatural organics 2020-2021.
- Working in clean room atmosphere at NTU Singapore 2019-2021.
- Glove box handling from 2018- 2021 at NTU Singapore and IIT Mandi, India.
- *Mentorship of undergraduate exchange student* for preparation of screen printing pastes at NTU Singapore, 2019.
- Basic safety and chemical spill training by Material Science and engineering (MSE) department, NTU Singapore.
- Cleared basic safety courses including fire, electric, chemical etc. at NTU Singapore.
- *Teaching assistant* in courses, Material Science for engineers, Reverse engineering since 2016 to 2018.
- *Lab setting, equipment procurements and chemicals procurement* for solar PV and Electroluminescent displays lab at IIT Mandi India 2017-2019.
- *Mentorship of two undergraduate intern students* from 2017-2019 at IIT Mandi.
- Idea pitching, product design and fabrication for *startup* IMITO at Himalayan startup trek organized by Govt. of India at IIT Mandi, 2017.
- *Product development officer* for the flexible electroluminescent displays based startup IMITO in 2017.
- *Lab setting, equipment procurement* for gas sensing lab during masters at NIT Kurukshetra, India 2016.

## **HOBBIES**

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Hiking and Trekking, Playing basketball, Cycling and Sketching