March 2024

CSI Communication

Monthly Newsletter of Catalysis Society of India

Circulated to all CSI Members

Important Announcement:

CSI newsletter shall be pleased to publish a brief write-up under the title, Centre of Excellence in Catalysis Research in India from any Indian Academics, Research laboratories, or Industrial organizations to highlight their activities to wider catalysis community. We request you to send us write -up on your team research activities to which will be published in the coming issues of CSI.

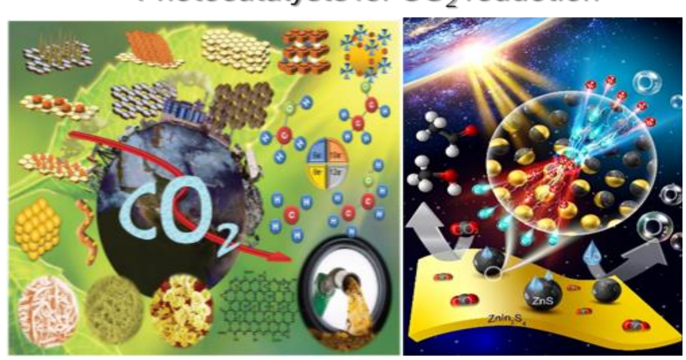
Please do share your recent accomplishments like publications, granted patents, technology commercialization, fellowship, awards to highlight in the CSI communication.

Nonprecious nanocatalysts for addressing environmental & energy challenges @ Prof. Indrajit Shown Group, Hindustan Institute of Technology & Science (HITS), Chennai

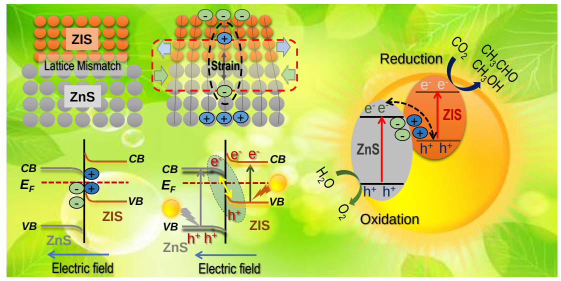
Professor Indrajit Shown's research group is dedicated to advancing non-precious nanocatalyst materials for applications in both photocatalysis and electrocatalysis, particularly focusing on photochemical CO_2 reduction, photochemical hydrogen production, electrochemical water splitting, oxygen reduction reaction (ORR) in fuel cell technologies and energy storage applications.

Harnessing solar energy to convert CO_2 or water into solar fuels represents a dual-purpose approach to address both energy & environmental challenges. One notable contribution from their work includes the introduction of 2D graphene oxide as a potential candidate for photocatalytic CO_2 reduction. This breakthrough was first reported in a **2013** publication in ***Nanoscale (5, 262)*** and followed by Cu-NP modified graphene oxide for CO_2 reduction photocatalyst published in **2014** ***Nano Letters (14, 6097)***. In their pursuit of more efficient photocatalyst systems, Professor Shown's group developed in situ-doped, strain-induced 2D tin disulfide materials, which have proven to be highly effective photocatalysts for CO_2 reduction, achieving an impressive 0.7% photochemical quantum efficiency under visible light. ***(Nature***

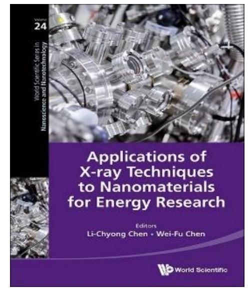
Photocatalysts for CO_2 reduction



Communications, 2018, 9, 169*)* (***U.S. patent No. US 10,967,361 B2***) (***Taiwan patent No. TWI644727B***) (***Nano Energy, 2018, 72, 104717***) (***Nature Communications, 2022, 13, 1, 1-8***)



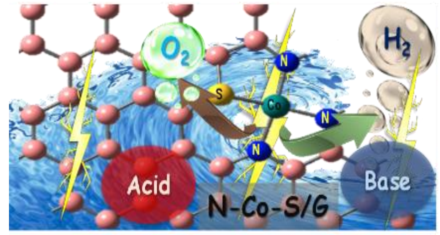
Recently together with National Taiwan University and Academia Sinica Taiwan, they have developed strain-induced $ZnS/ZnIn_2S_4$ direct Z-scheme heterostructure photocatalyst for CO_2 reduction with nearly 1 % photochemical quantum efficiency under visible light with and additional in-situ DRIFT study they identified the reactive species those are responsible to C2 hydrocarbon formation. This novel strain-induced band gap engineering approach is one of the crucial design approaches towards the mechanistic understanding of the direct Z-scheme photocatalysis for CO_2 reduction to higher hydrocarbon formation. (***Nano Energy, 2022, 93, 106809***).



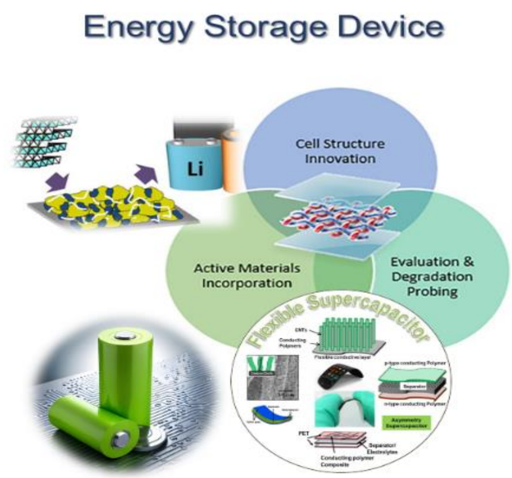
Recently his group published one book chapter on "Applications of X-ray Spectroscopy in Carbon Dioxide Reduction" in Applications of X-ray Techniques to Nanomaterials for Energy Research, under World Scientific Series in Nanoscience and Nanotechnology, World Scientific Publisher) Chapter 5, p-155-186, **2024**, (https://doi.org/10.1142/9789811284649_0005).

To establish fuel-cell and hydrogen electrolyzer technologies for green hydrogen applications at an affordable cost, scientists need to draw inspiration from nature and find alternatives to the expensive platinum electrocatalyst used in cathodes. Through collaboration with National Taiwan University (CCMS) & Academia Sinica (IAMS) Taiwan, Professor Shown's group have successfully developed a range of promising non-precious metal-N4 electrocatalysts for the oxygen reduction reaction (ORR) in fuel-cell cathodes. Specifically, they have demonstrated the potential of pyrolyzed vitamin B12 (Co-corrine), Co/Fe corrole, and their bimetallic derivatives in terms of ORR and HER activity. These research findings open the door to non-precious metal-N4 macrocyclic compounds as suitable substitutes for platinum in polymer electrolyte fuel cells and proton exchange membrane (PEM) electrolyzers, facilitating the generation of green hydrogen (***Advanced Functional Materials, 2012, 22, 3500***) (***J. Mater. Chem. A, 2013, 46, 1, 14692***) (***J. Mater. Chem. A, 2017, 5, 9279***) (***J. Mater. Chem. A, 2019, 7, 7179***) (***Small, 2023, 19, 45, 2303598).***

His group showed through electronic structure modulation of isolated Co-N4 electrocatalyst with sulfur towards sea water electrolysis, paving the way for green hydrogen production. Harnessing the power of nature's abundance, this innovation promises a cleaner, brighter future for generations to come, free from the shackles of carbon emissions. (***Nano Energy, 80, 105544, 2021***). They wrote a book chapter “Basics of water electrolysis” in Handbook of Energy Materials, Springer Publication, *https://doi.org/10.1007/978-981-16-4480-1_36-1,* ***2023***.



His group collaborated with researchers from Taiwan to develop flexible lithium-ion batteries. Conventional lithium-ion batteries use copper as a current collector at the anode and aluminum at the cathode. They prepared a free-standing flexible electrode film from lithium iron phosphate and aluminum to replace one of the pure metal electrodes. (***RSC Advances, 2022, 12, 15, 9249-9255***) (***ACS Omega, 2022, 7, 12) 10205–10211***) (***Highlighted in Current Science Vol. 122, No. 8, 25 April 2022, Page 882***). The researchers replaced the aluminum foil cathode with this flexible, freestanding electrode to assemble a lightweight coin-type cell. The fabrication method for the flexible batteries is simple. And it does not compromise the capacity of the battery. Portable and wearable device manufacturers need to explore the use of these flexible batteries to reduce the weight and size of their devices. His group has recently shown a cost-effective solvothermal method, yielding carbon-free SnS_2-MoS_2 nanostructures ideal for lithium-ion battery anode material. With an impressive gravimetric capacity, stability, and unmatched rate performance, these nanostructures promise a new standard in battery technology. With utmost confidence, they anticipate that their findings will stimulate further exploration, bridging the gap between laboratory discovery and large-scale application. This work has been recently summarized in the ***Journal of Alloys and Compounds, 2024, 984,173886***.



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For further information of CSI please visit, http://www.catalysisindia.org, https://www.begellhouse.com/journals/catalysis-in-greenchemistry-and-engineering.html & https://www.linkedin.com/groups/13923122/

Commercial & Policies

- **Jindal Group Company installs Indian stainless-steel sector's first green hydrogen plant**

The first commercial-scale green hydrogen plant in India's stainless-steel sector was inaugurated on March 4^{th}, 2024 at Jindal Stainless Ltd's (JSL) manufacturing unit in Haryana's Hisar. The plant, which is expected to start with an initial production of 78 tonnes per year of green hydrogen, will be owned and operated by green hydrogen facilities developer Hygenco India for 20 years, after which the ownership and operations will be transferred to JSL. The pact between JSL and Hygenco marks the first-ever commercial long-term offtake agreement of green hydrogen in India, according to the two companies. To be sure, a few Indian companies, including Larsen & Toubro, Indian Oil Corporation, Oil India, and NTPC, have built a few demonstration and pilot plants for green hydrogen production.
Source: https://indianexpress.com/article/business/companies/jindal-group-jsl-installs-indian-stainless-steel-sector-first-green-hydrogen-plant-hygenco-india-9194920/

- **Rs. 20,600 crore petrochemicals complex of Petronet LNG**

Prime Minister laid the foundation stone of petrochemicals complex of including Ethane and Propane handling facilities worth over Rs. 20,600 crore at Dahej, Gujarat. The complex will have a capacity of 750 KTPA PDH & 500 KTPA PP. Setting up the Petrochemicals complex in proximity to the existing LNG regasification terminal would result in significant savings in the capex and the opex cost of the project. The complex will help boost hydrogen production and demand for polypropylene in the country.
Source: https://www.indianchemicalnews.com/petro-chemical/pm-modi-lays-foundation-stone-of-rs-20600-crore-petrochemicals-complex-of-petronet-lng-20978

- **Deepak Chem Tech launches fluorination plant in Gujarat**

Deepak Chem Tech Limited commenced operations at their state-of-the-art Fluorination plant at Dahej, District Bharuch in Gujarat. Fluorination chemistry plays a significant role in various fields, including materials science, pharmaceuticals, agrochemicals, and electronics, offering a diverse range of properties and applications.
Source: https://www.technologyforyou.org/deepak-chem-tech-launches-fluorination-plant-in-gujarat/

- **Bloom Energy and Shell forge hydrogen alliance**

Bloom Energy and Shell will collaborate to develop replicable, large-scale, solid oxide electrolyzer (SOEC) systems that would produce hydrogen for potential use at Shell assets. Bloom's SOEC technology can produce clean hydrogen at scale to augment or replace existing fossil fuel-powered "grey" hydrogen supplies produced at refineries by high carbon dioxide-emitting emitting steam-methane reformation. Clean or "green" hydrogen is produced from water electrolysis, using renewable energy, essentially eliminating greenhouse gas emissions.
Demand for the Bloom Electrolyzer, which is manufactured in California and Delaware, has been growing given the increased interest in the low-carbon economy. According to an independent

analysis, Bloom now has the largest operating electrolyzer manufacturing capacity in the world of any electrolysis technology, double that of its closest rival.

Source: https://www.indianchemicalnews.com/hydrogen/bloom-energy-and-shell-forge-hydrogen-alliance-20962

- **Toray develops ion-conductive polymer membrane for batteries**

Toray Industries announced that it has developed an ion-conductive polymer membrane that delivers 10-fold the ion conductivity of predecessors. This new offering could accelerate the deployment of solid-state batteries, air batteries, and other lithium metal batteries, greatly expanding the cruising ranges of electric vehicles, industrial drones, urban air mobility systems, and other and other transportation modes. Toray developed polymer membranes offering ion conductivity through hopping conduction This mechanism enables lithium ions to traverse between interacting sites within polymer membranes and remain non-porous. This breakthrough leveraged the company's expertise in molecular design technology, particularly with aramid polymers, which it refined over many years.

Source: https://www.indianchemicalnews.com/battery/toray-develops-ion-conductive-polymer-membrane-for-batteries-20957

- **JSW Energy arm signs purchase agreement for battery energy storage**

JSW Renew Energy Five Limited (JSW Renew Five), a wholly-owned subsidiary of JSW Neo Energy Limited (or JSW Neo) has signed battery energy storage purchase agreement (BESPA) for the first project of 250 MW / 500 MWh standalone battery energy storage system with Solar Energy Corporation of India Limited (SECI). The company aims to reach 20 GW generation capacity and 40 GWh of energy storage capacity before 2030. JSW Energy has set an ambitious target for a 50 percent reduction in carbon footprint by 2030 and achieving Carbon Neutrality by 2050.

Source: https://www.business-standard.com/companies/news/jsw-energy-arm-signs-purchase-agreement-for-battery-energy-storage-124030501167_1.html

- **Gujarat Fluorochemicals' subsidiary announces Rs. 6,000 crore investment for EV and ESS battery solutions**

GFCL EV Products, a 100% subsidiary of Gujarat Fluorochemicals (GFL), today announced a groundbreaking investment of Rs 6000 over the next 4-5 years. This investment shall enable a supply of approx. 200 GWh/annually of Electric Vehicle (EV) and Energy Storage System (ESS) battery solutions. With an eye on the future, GFCL EV is poised to enter high-demand regions of the US, Europe, and India..

Source: https://www.business-standard.com/markets/capital-market-news/gujarat-fluorochemicals-arm-commits-rs-6000-cr-investment-for-ev-and-ess-battery-solutions-124020700688_1.html

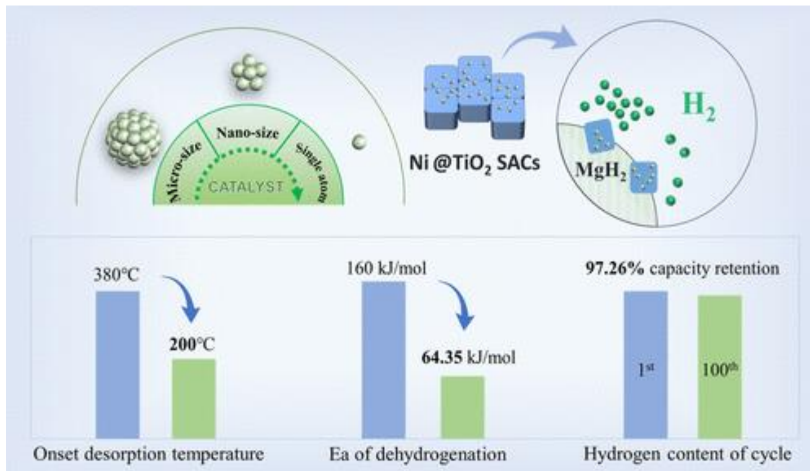
- **SECI unveils India's largest solar-battery project, pioneering renewable energy innovation in Chhattisgarh**

The Solar Energy Corporation of India Limited (SECI), under the aegis of the Ministry of New and Renewable Energy, has successfully commissioned India's largest Battery Energy Storage System

(BESS), which stores energy using solar energy. The 40 megawatts (MW) / 120MWh BESS with a solar photovoltaic (PV) plant which has an installed capacity of 152-megawatt hour (MWh)and dispatchable capacity of 100MW AC (155 MW peak DC) is located in Rajnandgaon, Chhattisgarh.
Source: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2008681

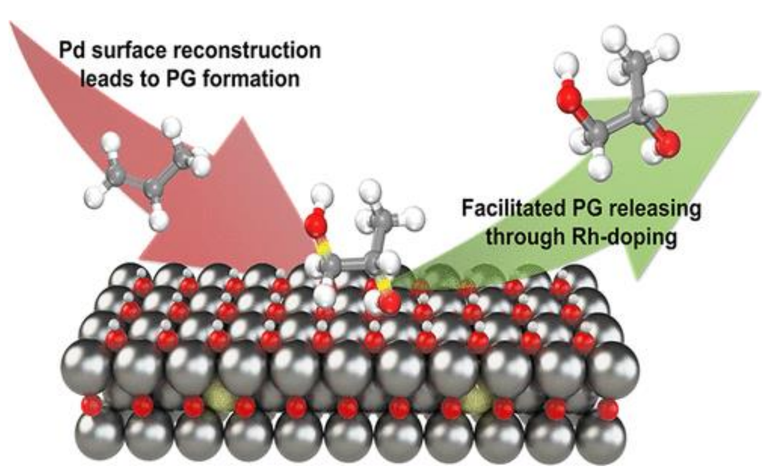
Scientific Updates

- **Single-Atom Ni Supported on TiO_2 for Catalyzing Hydrogen Storage in MgH_2**



Authors designed a single-atom Ni-loaded TiO2 catalyst with superior thermal stability and catalytic activity. The optimized 15wt%-Ni0.034@TiO2 catalyst reduced the onset dehydrogenation temperature of MgH2 to 200 °C. At 300 °C, the H2 released and absorbed 4.6 wt % within 5 min and 6.53 wt % within 10s, respectively. The apparent activation energies of MgH_2 dehydrogenation and hydrogenation were reduced to 64.35 and 35.17 kJ/mol of H_2, respectively. Even after 100 cycles of hydrogenation and dehydrogenation, there was still a capacity retention rate of 97.26%. The superior catalytic effect is attributed to the highly synergistic catalytic activity of single-atom Ni, numerous oxygen vacancies, and multivalent Tix+ in the TiO_2 support, in which the single-atom Ni plays the dominant role, accelerating electron transfer between Mg2+ and H– and weakening the Mg–H bonds.
Source: J. Am. Chem. Soc. 2024, https://doi.org/10.1021/jacs.3c13970

- **Selective Electrified Propylene-to-Propylene Glycol Oxidation on Activated Rh-Doped Pd**

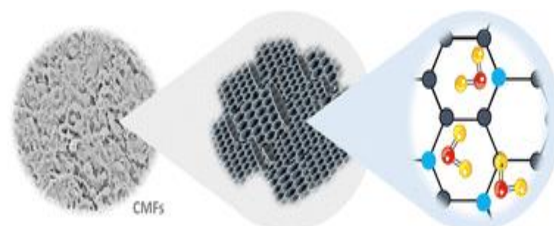


Renewable-energy-powered electrosynthesis has the potential to contribute to decarbonizing the production of propylene glycol, a chemical that is used currently in the manufacture of polyesters and antifreeze and has a high carbon intensity. Unfortunately, to date, the electrooxidation of propylene under ambient conditions has suffered from a wide product distribution, leading to a low faradic efficiency toward the desired propylene glycol. Reported work focused on the mechanistic investigations and found that the reconstruction of Pd to PdO occurs, followed by hydroxide formation under anodic bias. The formation of this metastable hydroxide layer arrests the progressive dissolution of Pd in a locally acidic environment, increases the activity, and steers the reaction pathway toward propylene glycol. Rh-doped Pd further improves propylene glycol selectivity. Density functional theory (DFT) suggests that the Rh dopant lowers the energy associated with the production of the final intermediate in propylene glycol formation and renders the desorption step spontaneous, a concept consistent with experimental studies. 75% faradic efficiency toward propylene glycol maintained over 100 h of operation is reported.

Source: J. Am. Chem. Soc. 2024, https://doi.org/10.1021/jacs.3c13970

- **SO_2 capture and detection with carbon microfibers (CMFs) synthesized from polyacrylonitrile**

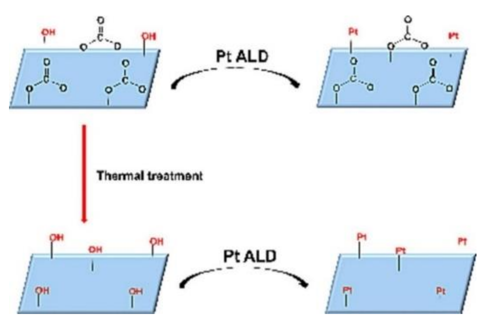
SO2 adsorption–desorption capacity of carbon microfibers (CMFs) at 298 K is reported. CMFs showed a reversible SO_2 uptake capacity (5 mmol g−1), cyclability over ten adsorption cycles with fast kinetics and good selectivity towards SO2/CO2 at low-pressure values. Additionally, CMFs' photoluminescence response to SO_2 and CO_2 was evaluated.



Source: Chemical Communication 2024, https://doi.org/10.1039/D3CC04437H

- **Critical removal of surface carbonates on γ-Al_2O_3 to enhance nucleation of Pt atomic layer deposition**

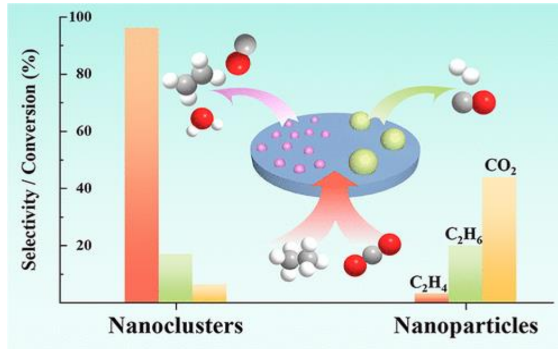
Authors present a simple thermal treatment approach to activate the surface of γ-Al_2O_3, significantly enhancing the Pt loading and the density of Pt nanoparticles compared to raw γ-Al_2O_3 under identical deposition conditions. Detailed mechanism investigations reveal that removing carbonates on the surface of γ-Al_2O_3 during thermal treatment induces the generation of isolated –OH groups, which are verified to be nucleation sites of Pt ALD. The increase in the number of isolated –OH and its high reactivity towards anchoring Pt precursor molecules in ALD reaction both contribute to a high density of Pt nanoparticles. This work provides a novel approach to promote Pt ALD nucleation on the surface of γ-Al_2O_3 and an in-depth understanding of the mechanism for the nucleation promotion, which can be applied to other oxide supports.



Source: Journal of Catalysis, 2024 (431) 115364 https://doi.org/10.1016/j.jcat.2024.115364

- **Evolution of Co Species in CO_2-Assisted Ethane Dehydrogenation: Competing Cleavage of C–H and C–C Bonds**

The influence of the introduction of CO_2 on the state of Co species and the corresponding dehydrogenation performance over Co/Silicalite-1 was investigated in detail in this work. The manipulation of the CO_2/C_2H_6 feeding ratios dictated the selective bond breakage of either C–H or C–C in ethane, which was derived from the differentiated nanostructuring of Co species during reactions through a series of designed control-reaction tests and characterization results. At a CO_2/C_2H_6 feeding ratio of 4.0, Co nanoparticles transformed active metallic Co species, which facilitated dry-reforming reaction with an ethene selectivity below 2%. When the CO_2/C_2H_6 feeding ratio was below 2.0, the generation of active metallic Co species was suppressed, and the dehydrogenation reaction dominated the Co^{2+} sites. The effective suppression of reduction and sintering of active Co^{2+} species led to a stable dehydrogenation performance lasting over 120 h, with ethene selectivity consistently exceeding 95% during this period. The elucidation of the state changes of Co species holds significant implications for the design of dehydrogenation catalysts.



Source: ACS Catalysis, 2024, https://pubs.acs.org/doi/10.1021/acscatal.4c00324

Catalysis Research out of India

1. Mohd Hasnain Sayed, Amid L Sadgar, Bhalchandra M Bhanage, Radha V Jayaram "Particle shape anisotropy in pickering interfacial catalysis for Knoevenagel condensation", **Journal of Colloid and Interface Science, 2024, (659) 413-421**
2. Kirtikumar C Badgujar, Jagruti K Badgujar, Bhalchandra M Bhanage "Improved biocatalytic activity of steapsin lipase in supercritical carbon dioxide medium for the synthesis of benzyl butyrate: A commercially important flavor compound", **Journal of Biotechnology, 2024,** https://doi.org/10.1016/j.jbiotec.2024.02.010
3. Nina Kuchkina, S. Sorokina, M.Grigoriev, M. Sulman, Alexey Bykov, Shraddha Shinde, Zinaida Shifrina, Bhalchandra Bhanage "Polymer supported Ru nanoparticles for highly selective hydrogenation of biomass-derived levulinic acid to γ-valerolactone: Does the polymer affect the catalytic performance?" **Journal of Nanoparticle Research, 2024, 26(2), 38**
4. Ru Loaded MCM-22: A Potential Catalyst for the Isomerization and Cracking of 1-Dodecene "Ru Loaded MCM-22: A Potential Catalyst for the Isomerization and Cracking of 1-Dodecene" **Catalysis Letters, 2024,** 154 (4) 1694-1714
5. Kalyani Motghare, Diwakar Shende, Dharam Pal, Kailas L Wasewar, "Recovery of Biobutanol Using Ionic Liquids", **Handbook of Ionic Liquids: Fundamentals, Applications, and Sustainability, 2024**, 333-351, Wiley-VCH GmbH
6. D. S Doke, Mohan K Dongre, Shubhangi B Umbarkar,"Dehydration of Lactate to Acrylate Using Alkaline Earth Metal Modified Hydroxyapatite" **Catalysis Letters, 2024,** 154(2) 569-581

7. S. Patil, A. Rajmane, Sanjay Jadhav, Chandrashekhar Rode, Arjun Kumbhar, “CuNPs@ Al2O3-cellulose composite for the ligand-free Suzuki cross-coupling reactions in batch and continuous flow process”, **Journal of Organometallic Chemistry, 2024,** 1004, 122954
8. Pinki Sehrawat, Astha Raj, Shafali Singh, Surinder Kumar Mehta, Surinder Singh Bhinder, Sushil Kumar Kansal, “Solar-driven S-scheme Zn0. 5Cd0. 5S/MoS2 composite for photocatalytic ketorolac tromethamine degradation and hydrogen generation coupled with benzyl alcohol oxidation” **International Journal of Hydrogen Energy, 2024**, 62, 17-30
9. K. Arya, A. Kumar, Indu Sharma, Surinder Singh, S. K. Mehta, Sushil Kumar Kansal, Ramesh Kataria, “A highly sensitive and selective Zn-based luminescent MOF for specific detection of trinitrotoluene in aqueous phase” **Journal of Molecular Structure, 2024,** 138008
10. S. Dash, S. P. Tripathy, S. Subudhi, P. Behera, B. P. Mishra, Jayashree Panda, Kulamani Parida “A Visible Light-Driven α-MnO2/UiO-66-NH2 S-Scheme Photocatalyst toward Ameliorated Oxy-TCH Degradation and H2 Evolution” **Langmuir, 2024,** 40, 8, 4514–4530.

Upcoming Symposium/Conferences/Seminars/Workshop

1. International Conference on "Catalysis for Clean Energy Technologies and Sustainable Development" Organized under the aegis of the Catalysis Society of India in association with Dr. SSB UICET Panjab University Chandigarh on 5th & 6th April 2024.
2. Conference on Catalysis for Energy, Environment & Sustainability (CEES-2024) & 3rd CO_2 India Network Meet from 18th-20th September 2024 at IICT, Hyderabad.
3. 18th International Congress on Catalysis from July 14-19, 2024, LYON, France.
4. XXIII International Symposium on Homogeneous Catalysis at Trieste, July 21-26, 2024.
5. "19th Edition of Global Conference on Catalysis, Chemical Engineering & Technology" at Rome, Italy, from September 19th-21st, 2024.
6. Decarbonizing the chemical industry and 2nd Sustainable feedstocks for the future of chemicals and plastics, 23-24, May 2024 – Antwerp, Belgium.
7. 18th Edition of International Conference on Catalysis, Chemical Engineering, and Technology" (CCT 2024) during June 17-19, 2024, at Paris.
8. 19th Edition of Global Conference on Catalysis, Chemical Engineering & Technology, September 19-21, 2024, | Rome, Italy | Hybrid Event

Quote of the Month

"All you need is the plan, the road map,
& the courage to press on to your destination."

—Earl Nightingale