

ARIJIT GHORAI

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Materials Science Centre
Indian Institute of Technology Kharagpur (IIT Kharagpur)
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EDUCATIONAL PROFILE:

Doctor of Philosophy (Ph.D) in Polymeric Materials

Materials Science Centre, Indian Institute of Technology Kharagpur, India (2017–2022)

Master of Science (M.Sc) in Chemistry

Department of Chemistry, Indian Institute of Technology Kharagpur, India (2014 – 2016)

Bachelor of Science (B.Sc., Honours) in Chemistry

Midnapore College, Vidyasagar University (2011-2014)

RESEARCH EXPERIENCES:

POSTDOCTORAL RESEARCH ASSOCIATE

Florida State University, Tallahassee, USA | 07/2024 – 08/2026

• **PI: Prof. Hoyong Chung**

• **Topic-1:** Multifunctional sustainable polymers for carbon capture, storage, and utilization (CCS and CCU)

• Project support: Florida State University, Tallahassee, USA

• **Outcomes:** This research was published in [Advanced Materials, 2024, 2406610](#).

(This study introduces a novel lignin polymer that captures CO₂ from air at room temperature, releases it for organic synthesis, and allows continuous CO₂ capture↔ CO₂ release cycles, showcasing a sustainable carbon utilization method.)

Featured in [14 news outlets](#) including [Phys.Org](#), [Newswise](#), [FSU News](#), [Eurekalert.org](#), [AzoMaterials](#) etc.

• **Topic-2:** Non-Isocyanate Polyhydroxyurethanes from Biomass Lignin and CO₂

• Project support: Florida State University, Tallahassee, USA

This class of research has been published in [ACS Sustainable Chemistry & Engineering 2025, 13, 12358](#), and [Macromolecular Rapid Communications, 2025, 2500070](#).

(A sustainable route to non-isocyanate polyhydroxyurethanes (NIPUs) is demonstrated using the greenhouse gas CO₂ and biomass lignin as key building blocks in the presence of different amines.)

Featured in [9 news outlets](#) including [Yahoo news](#), [FSU News](#), [Mirage news](#), [Bioengineer.org](#) etc.

POSTDOCTORAL RESEARCH ASSOCIATE

FAMU-FSU College of Engineering, Florida State University, Tallahassee, USA | 09/2022 - 06/2024

• **PI:** Prof. Hoyong Chung

- Topic: Development of recyclable, sustainable polymers from biomass lignin and CO₂
- Project support: National Science Foundation (NSF), USA
- **Outcomes:** This research was published in [Advanced Functional Materials, 2024, 2403035](#).

(This study presents a cost-effective method to synthesize recyclable polymers from biomass lignin and CO₂, promoting a sustainable circular plastic economy through closed-loop recycling.)

Featured in [18 news outlets](#) including [Advanced Science News](#), [FSU News](#), [Phys.org](#), [Bioengineer.org](#) etc.

POSTDOCTORAL RESEARCH ASSISTANT | 05/2022 - 08/2022

Materials Science Centre, Indian Institute of Technology Kharagpur, India

- **Supervisor:** Prof. Susanta Banerjee (Institute Chair Professor)
- Topic: Synthesis and characterization of high-performance polymers and their membrane-based applications
- Project support: Wacker Metroark Chemicals Private Limited-IIT Kharagpur (Project no. WACKER-IIT Kgp 2020/03)
- **Outcome:** The work published in [Progress in Polymer Science, 2023, 138, 101646](#). (Top journal in polymer field with an **impact factor of 32.8**)

JUNIOR & SENIOR RESEARCH FELOW | 01/2017 - 04/2022

Materials Science Centre, Indian Institute of Technology Kharagpur, India

- **Supervisor:** Prof. Susanta Banerjee (Institute Chair Professor)
- Topic: Phosphorus containing sulfonated polytriazoles: Synthesis, characterization, and proton exchange membrane properties
- Fellowship sponsor: University Grants Commission (UGC), Government of India
- **Outcomes:** 19 research papers, 2 book chapters, and 5 conference presentations (provided in publications)

MASTERS' RESEARCH PROJECT | 05/2015 - 05/2016

Department of Chemistry, Indian Institute of Technology Kharagpur, India

- **Supervisor:** Prof. Manish Bhattacharjee
- Topic: Synthesis of highly regio- and stereo-selective dienyl esters using ruthenium (II) catalyst by anti-Markovnikov addition
- **Outcome:** This work was published in [European Journal of Organic Chemistry, 2016\(36\), 6015–6021](#).

HONORS & AWARDS:

- ✓ Awarded **INSPIRE SCHOLARSHIP (Regn no.: 4429/2011)** for by Department of Science & Technology (DST), government of India (2011-2015, 5 years) for securing a rank within the top 1% of the higher secondary result.
- ✓ Secured all India ranks in CSIR-UGC NET examinations held from 2015 to 2017 (All India Rank 53 in June 2017).

- ✓ Awarded **Junior Research Fellowship** from UGC, Government of India (2017-2019).
- ✓ Awarded **Senior Research Fellowship** from UGC, Government of India (2019-2022).
- ✓ Qualified Graduate Aptitude Test in Engineering (GATE), 2016.
- ✓ Qualified Joint Admission Test for Masters (**JAM 2014**) for perusing masters in IIT Kharagpur.
- ✓ Awarded **International Travel Grant** for conference (EUROMAT 2019, Stockholm, Sweden)
- ✓ Awarded **International Conference Travel Grant** (ACS Spring 2024, New Orleans, USA)

SCIENTIFIC PUBLICATIONS IN JOURNALS:

I. Postdoc (as first author)

1. Gonzalez, C,[#] **Ghorai, A.**,[#] Chung, H.* Sustainable Synthesis Methods of Lignin-Based Copolymers: Recyclable Non-Carbodiimide Catalytic Systems in Aqueous Solvent. **RSC Applied Polymers**, 4(2), 823-838. (<https://doi.org/10.1039/D5LP00387C>) (# **Equally contributed**)
[Featured in **RSC Applied Polymers Blog**]
2. **Ghorai, A.**, Chung, H.* (2025) Biomass Lignin and CO₂-based Non-Isocyanate Polyhydroxyurethanes. **ACS Sustainable Chemistry & Engineering**, 2025, 13(31), 12358–12371. (<https://doi.org/10.1021/acssuschemeng.5c02064>)
[Selected for journal Front Cover image in **ACS Sustainable Chemistry & Engineering (Volume 13, Issue 31)**]; [Featured in 9 news outlets including **Yahoo news, FSU News, Mirage news, Bioengineer.org** etc.]
3. Masa, L.,[#] **Ghorai, A.**,[#] Chung, H.* (2025). Soft-Segment Containing Lignin-Based Polyhydroxyurethanes: Controllable Flexibility Through PDMS Integration. **Macromolecular Rapid Communications**, 2500070. (<https://doi.org/10.1002/marc.202500070>) (# **Equally contributed**)
4. **Ghorai, A.**, Chung, H.* (2024). Ionic Lignin Polymers for Controlled CO₂ Capture, Release, and Conversion into High-Value Chemicals. **Advanced Materials**, 2406610. (<https://doi.org/10.1002/adma.202406610>)
[Featured in 14 news outlets including **Phys.Org, Newswise, FSU News, Eurekalert.org, AzoMaterials** etc.]
5. **Ghorai, A.**, Chung, H.* (2024). CO₂ and Lignin-Based Sustainable Polymers with Closed-Loop Chemical Recycling. **Advanced Functional Materials**, 2403035. (<https://doi.org/10.1002/adfm.202403035>)
[Featured in 18 news outlets including **Advanced Science News, FSU News, Phys.org, Bioengineer.org** etc.]

II. Ph.D. (as first author)

6. **Ghorai, A.**, Banerjee, S.* (2023). Phosphorus-Containing Aromatic Polymers: Synthesis, Structure, Properties and Membrane-Based Applications. **Progress in Polymer Science**, 138, 101646. (<https://doi.org/10.1016/j.progpolymsci.2023.101646>) [Top journal in polymer field with an impact factor of 32.8]
7. **Ghorai, A.**, Sahoo, A., Baitalik, S.*, Banerjee, S.* (2022). Multifunctional Sulfonated Polytriazoles: Proton-Exchange Membrane Properties, Molecular Logic Gates, and Modeling of Stimuli-Responsive Behaviors. **ACS Applied Polymer Materials**, 4 (8), 5583–5595. (<https://doi.org/10.1021/acsapm.2c00629>)
8. **Ghorai, A.**, Banerjee, S.* (2023). Phosphorus containing fluoro-sulfonated polytriazole membranes with high proton conductivity: Understanding microstructural and thermomechanical behaviors as a

- function of degree of sulfonation. *Macromolecular Chemistry and Physics*, 2200031. (<https://doi.org/10.1002/macp.202200031>)
9. **Ghorai, A.**, Kamble, R., Banerjee, S.* (2022). Trifluoromethyl functionalized sulfonated polytriazoles from diphenylphosphine oxide-based dialkyne via click polymerization: Effect of high content of phosphorus on the proton exchange membrane properties. *European Polymer Journal*, 161, 110869. (<https://doi.org/10.1016/j.eurpolymj.2021.110869>)
 10. **Ghorai, A.**, Roy, S., Das, S., Komber, H., Ghangrekar, M. M., Voit, B., Banerjee, S.* (2021). Preparation of sulfonated polytriazoles with a phosphaphenanthrene unit via click polymerization: Fabrication of membranes and properties thereof. *ACS Applied Polymer Materials*, 3(8), 4127–4138. (<https://doi.org/10.1021/acsapm.1c00600>)
 11. **Ghorai, A.**, Roy, S., Das, S., Komber, H., Ghangrekar, M. M., Voit, B., Banerjee, S.* (2020). Chemically stable sulfonated polytriazoles containing trifluoromethyl and phosphine oxide moieties for proton exchange membranes. *ACS Applied Polymer Materials*, 2(7), 2967-2979. (<https://doi.org/10.1021/acsapm.0c00443>)
 12. **Ghorai, A.**, Mandal, A. K., Banerjee, S.* (2020). Synthesis and characterization of new phosphorus containing sulfonated polytriazoles for proton exchange membrane application. *Journal of Polymer Science*, 58(2), 263-279. (<https://doi.org/10.1002/pol.20190030>)

III. Ph.D. (with other group members)

13. Kamble, R., **Ghorai, A.**, Ghanti, B., Pradhan, D., Banerjee, S.* (2022). Fabrication of high proton conducting composite membranes from amino group functionalized MOF and semi-fluorinated sulfonated poly (arylene ether sulfone)s. *European Polymer Journal*, 179, 111574. (<https://doi.org/10.1016/j.eurpolymj.2022.111574>)
14. Roy, S., **Ghorai, A.**, Komber, H., Voit, B., Banerjee, S.* (2020). Synthesis of 2, 2'-hindered pyridine containing semifluorinated polytriazoles and investigation for low-temperature proton exchange membrane application with enhanced oxidative stability. *European Polymer Journal*, 136, 109898. (<https://doi.org/10.1016/j.eurpolymj.2020.109898>)
15. Singh, A.*, Chatterjee, R., **Ghorai, A.**, Banerjee, S. (2021). Membrane properties of sulfonated polytriazoles with molecular branching. *Polymer Engineering & Science*, 61 (12) 3190-3199. (<https://doi.org/10.1002/pen.25834>)
16. Mandal, A. K., **Ghorai, A.**, Banerjee, S.* (2020). Sulphonated polysilsesquioxane–polyimide composite membranes: proton exchange membrane properties. *Bulletin of Materials Science*, 43(1), 1-11. (<https://doi.org/10.1007/s12034-020-02158-8>)
17. Bhattacharyya, S. K., Biswas, D., Pandey, N., Nandi, S., **Ghorai, A.**, Mukherjee, G., Mandal, M., Das, N. C.*, Banerjee, S.* (2024). Synthesis of 1, 2, 3-triazole linked 5 fluorouracil-carbon dots-folate conjugates for target specific anticancer activity and cell imaging applications. *Nano-Structures & Nano-Objects*, 38, 101160. (<https://doi.org/10.1016/j.nanoso.2024.101160>)
18. Roy, S., Saha, S., Kumar, A. G., **Ghorai, A.**, Banerjee, S.* (2020). Synthesis and characterization of new sulfonated copolytriazoles and their proton exchange membrane properties. *Journal of Applied Polymer Science*, 137(13), 48514. (<https://doi.org/10.1002/app.48514>)

IV. Ph.D. (with various collaborators)

19. Chakraborty, D.,[#] **Ghorai, A.**,[#] Chowdhury, A., Banerjee, S., Bhaumik, A.* (2021). A tetradentate phosphonate ligand-based Ni-MOF as a support for designing high-performance proton-conducting

- materials. **Chemistry–An Asian Journal**, 16(12), 1562-1569. (# **Equally contributed**) (<https://doi.org/10.1002/asia.202100270>)
20. Goswami, A., **Ghorai, A.**, Pal, D., Banerjee, S., Biradha, K.* (2024). Proton Conducting Metal-Organic Frameworks (MOFs) via Post Synthetic Transmetallation and Water Induced Structural Transformations. **Chemistry–A European Journal**, e202402165. (<https://doi.org/10.1002/chem.202402165>)
 21. Moi, R., **Ghorai, A.**, Maity, K., Banerjee, S., Biradha, K.* (2022). Correlation of Structures with Proton Conductivity of 1D Coordination Polymers: Higher Proton Conductivity Due to Synergy of Encapsulated Sulfate Ions and Water Molecules. **Crystal Growth & Design**, 22(12), 7215-7220. (<https://doi.org/10.1021/acs.cgd.2c00890>)
 22. Chakraborty, D., **Ghorai, A.**, Bhanja, P., Banerjee, S., Bhaumik, A.* (2022). High proton conductivity in a charge carrier induced Ni(II)-metal-organic framework. **New Journal of Chemistry**, 46 (4), 1867-1876. (<https://doi.org/10.1039/D1NJ04685C>)
 23. Moi, R., **Ghorai, A.**, Banerjee, S., Biradha, K.* (2020). Amino-and sulfonate-functionalized metal–organic framework for fabrication of proton exchange membranes with improved proton conductivity. **Crystal Growth & Design**, 20(8), 5557-5563. (<https://doi.org/10.1021/acs.cgd.0c00732>)
 24. Mohanty, A., Singh, U. P.*, **Ghorai, A.**, Banerjee, S., Butcher, R. J. (2021). Metal–organic frameworks derived from a semi-rigid anthracene-based ligand and sulfonates: proton conductivity and dye degradation studies. **CrystEngComm**, 23(3), 684-693. (<https://doi.org/10.1039/D0CE01275K>)

V. Masters

25. Jena, R. K., Das, U. K., **Ghorai, A.**, Bhattacharjee, M.* (2016). Ruthenium-catalyzed addition of carboxylic acids to propargylic alcohols: An easy route to O-dienyl esters and their tandem atom-transfer radical polymerization. **European Journal of Organic Chemistry**, 2016(36), 6015–6021. (<https://doi.org/10.1002/ejoc.201601091>)

BOOK CHAPTERS :

1. **Ghorai, A.**, Banerjee, S.* (2021). *Recent developments in aromatic polymer-based proton exchange membranes; Current trends in polymer research for advanced applications*; CRC Press, Taylor & Francis Group. (Invited) (<https://doi.org/10.1201/9781003200710>)
2. Banerjee, S.*, **Ghorai, A.**, Roy, S., Voit, B. (2020). *Preparation of high-performance polymers by click chemistry and their membrane-based application*; *Advances in Chemistry Research* (ISBN: 978-1-53618-568-3), James C. Taylor; Nova Science Publishers; Vol. 64, Chapter 2. (<https://novapublishers.com/shop/advances-in-chemistry-research-volume-64/>)

PRESENTATIONS IN CONFERENCES:

1. *Ionic lignin polymers: A sustainable approach for CO₂ capture, release, and chemical valorization*, **Ghorai, A.**, Chung, H.* **ACS Fall 2025, Washington D.C., USA** (17.08.2025–21.08.2025). (*Early career Poster Presentation, In-person*)
2. *Development of sustainable and recyclable polymers from lignin and CO₂*, **Ghorai, A.**, Chung, H.* **ACS Spring 2024, New Orleans, USA** (17.03.2024–21.03.2024). (*Oral Presentation, In-person*)

3. Phosphorus containing sulfonated polytriazoles via Click polymerization: Synthesis, properties and proton exchange membrane applications, **Ghorai, A.**, Komber, H., Voit, B., Banerjee, S.* **European Polymer Congress (EPF 2022), Prague, Czech Republic** (26.06.2022–01.07.2022). (Oral Presentation, In-person)
4. Highly proton conducting, chemically stable sulfonated polytriazoles based on trifluoromethyl and phosphine oxide moieties for proton exchange membranes, **Ghorai, A.**, Komber, H., Voit, B., Banerjee, S.* **ACS Spring 2021, USA** (05.04.2021–16.04.2021). (Oral Presentation, Virtual)
5. The recent development on phosphorus and pyridine containing sulfonated polytriazoles: Proton exchange membrane properties, Banerjee, S.*, **Ghorai, A.**, Roy, S. **APM 2021, Chennai, India** (08.03.2021–12.03.2021). (Oral Presentation, Virtual)
6. Synthesis and characterization of novel phosphorus containing sulfonated polytriazoles in proton exchange membrane applications, **Ghorai, A.**, Banerjee, S.* **ICFM 2020, IIT Kharagpur, India**, (06.01.2020–08.01.2020). (Poster presentation)
7. Synthesis, characterization and investigation of proton exchange properties of phosphorus containing sulfonated polytriazoles, **Ghorai, A.**, Banerjee, S.* **EUROMAT 2019, Stockholm, Sweden**, (01.09.2019–05.09.2019). (Poster presentation)

PROFESSIONAL SERVICE AND MEMBERSHIP:

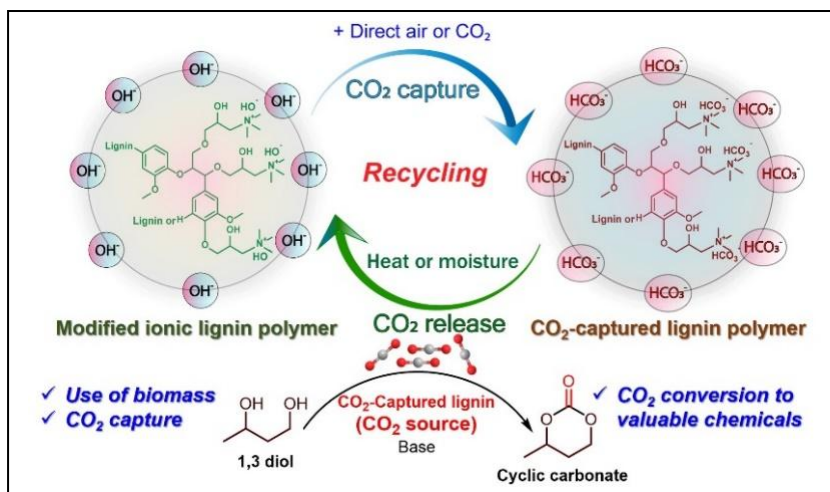
- ❖ **Reviewer for journals** – Green Chemistry, Macromolecular Rapid Communications, Small, iScience, ACS Omega, Chemistry Select, International journal of polymer analysis and characterization.
- ❖ **Judge for an Exhibition** – Capital Regional Science and Engineering Fair, Tallahassee, Florida, (14.02.2025).
- ❖ **Membership** – American Chemical Society (ACS), 2020-present.

Brief outline of previous research contributions

I. Ionic polymers for controlled CO₂ capture, release, and conversion

Overview: Climate change, driven by excessive CO₂ emissions, poses a pressing threat to global ecosystems and human well-being. An advanced ionic lignin polymer was developed for the controlled capture and release of CO₂ gas.

Key findings: The 100% natural biomass lignin-based polymers have used repeatedly for cycles of CO₂ gas storage and release. As an example of the application of the developed ionic lignin polymer, the stored and released CO₂ from the new material were utilized in a productive chemical reaction, cyclic carbonate synthesis. Significantly, the current study underscores the multiple reusability (continuous cycles of CO₂ capture ↔ CO₂ release) of the ionic lignin polymer under moderate conditions, aqueous conditions with heating. Further studies will enable the new material to become a novel, safer, and sustainable method for storing CO₂ gas for various applications.

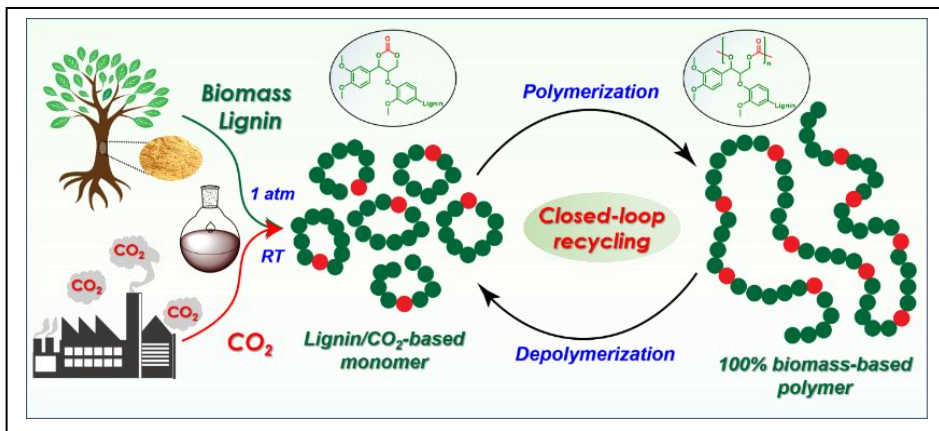


Impact: This study introduces a sustainable and reusable platform for CO₂ management, offering a safer and greener alternative for gas storage and conversion technologies [Adv. Mater. 2024, 2406610]

II. Sustainable polymers from biomass lignin and CO₂ with closed-loop recycling

Overview: An innovative, safe, and cost-effective methodology has developed for synthesizing cyclic carbonate monomers derived from biomass lignin and CO₂, and subsequently producing recyclable polycarbonates.

Key findings: Most notably, this work demonstrated the synthesis of CO₂ and lignin-based cyclic carbonate monomer for the first time. The monomer synthesis involves the direct integration of lignin with CO₂ under safe and moderate conditions, including atmospheric pressure and eliminating the need for hazardous phosgene derivatives used in traditional polycarbonate synthesis. The prepared polycarbonate undergoes systematically depolymerization to the original monomer, enabling the synthesis of polymers multiple times again. The synthetic methodology advances a complete circular economy (biomass/CO₂ → monomer → polymer → upcycle to the original monomer → polymer production), eliminating plastic and chemical waste.

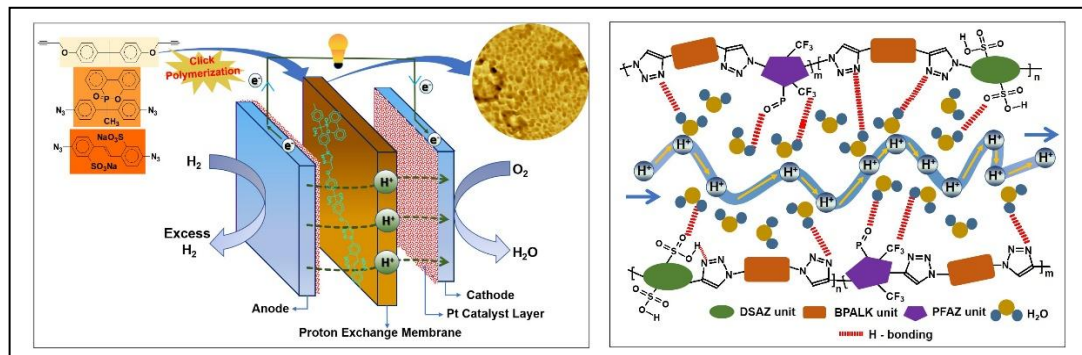


Impact: This work advances the concept of a circular polymer economy, significantly reducing plastic and chemical waste while promoting sustainable materials development. [Adv. Funct. Mater. 2024, 2403035]

III. Synthesis of phosphorus-containing polymers for proton exchange membrane applications:

Overview: The proton exchange membrane (PEM) is vital for fuel cells, facilitating proton transfer and preventing fuel crossover. Nafion® is a leading PEM due to its stability and conductivity, but its complex synthesis, low glass transition temperature, and high fuel crossover prompt the search for alternatives. In this directions, phosphorus-containing sulfonated polytriazole membranes have synthesized with polar phosphine oxide moieties ($-P=O$), trifluoromethyl groups ($-CF_3$), and bulky phosphophenanthrene systems.

Key findings: Novel phosphorus-containing monomers have been developed and employed in the synthesis of polymers via click polymerization. These membranes exhibit enhanced solubility and improved phase-separated morphology, dimensional stability, and proton transport channels. The overall studies explore the impact of high phosphorus content by integrating a diphenylphosphine oxide-containing dialkyne with a triarylphosphine oxide-based diazide. Proposed peroxide decomposition mechanisms and detailed microstructural



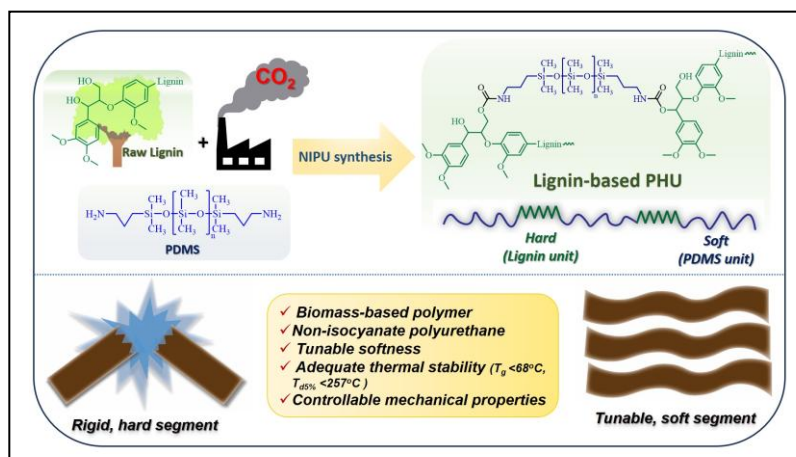
changes as a function of sulfonation degree were established. The research elaborated PEM properties with molecular design, chemical functionality, phosphorus content, sulfonated monomer proportion, and ion exchange capacity.

Impact: These findings contribute to the rational design of next-generation PEMs with improved thermal and chemical stability, offering viable alternatives to Nafion® for fuel cell applications. [Prog. Polym. Sci. 2023, 138, 101646; ACS Appl. Polym. Mater. 2020, 2, 2967–2979; ACS Appl. Polym. Mater. 2021, 3, 4127–4138; Eur. Polym. J. 2022, 162, 110869; Macromol. Chem. Phys. 2023, 224, 2200031; J. Polym. Sci. 2020, 58, 263–279]

IV. Non-Isocyanate Polyhydroxyurethanes (NIPUs)

Overview: This study presents the first report of biomass-based non-isocyanate polyhydroxyurethanes prepared from biomass lignin and CO₂ in presence of the amine monomers.

Key findings: The NIPUs are obtained from the direct use of lignin and CO₂ under normal atmospheric pressure, avoiding the necessity of phosgene-based compounds, epoxide-based synthesis, and specialized reactors. Then, the cyclic carbonate monomer is utilized to develop NIPUs with diverse amine comonomers without external catalysts. Significantly, this study is the first to demonstrate a non-phosgene, metal catalyst-free approach to producing CO₂ and lignin-based NIPUs, overcoming the reactivity, controllability and solubility limitations that typically hinder the wider application of lignin.



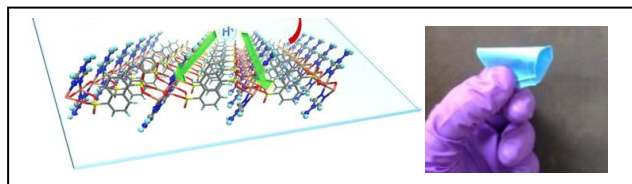
Impact: The current findings indicate that adjusting the chemical structure of biomass-derived polymers can significantly enhance their molecular, thermal, and

mechanical properties, providing greater controllability and making them viable for a wide range of applications. [[Macromol. Rapid Commun. 2025, 2500070](#); [ACS Sustainable Chem. Eng. 2025](#)]

V. Development of composite polymers materials for multifunctional applications

Overview: This research integrates metal-organic frameworks (MOFs) into polymer matrices to create multifunctional composite materials.

Key findings: By integrating various MOF materials into polymer matrices, the study aims to enhance the mechanical, thermal, balancing hydrophilicity and hydrophobicity, and ion conducting properties of these materials. Advanced synthesis and fabrication techniques, such as solution blending, surface functionalization and in situ polymerization, have been employed.



Impact: The resulting materials are expected to offer superior performance, demonstrating improved strength, conductivity, and thermal stability for diverse industrial applications. [[Chem Asian J. 2021, 16, 1–9](#); [Eur. Polym. J. 2022, 179, 111574](#); [Cryst. Growth Des. 2022, 22, 7215–7220](#); [Chem. Eur. J. 2024, e202402165](#); [New J. Chem. 2022, 46, 1867–1876](#); [Cryst. Growth Des. 2020, 20, 5557–5563](#)]