

## **ORIGINAL RESEARCH**

# **Dissolving Cellulose into Ionic Liquid for Regenerated Fiber Production: A Scientific Review**

Md. Sobuj\*<sup>1</sup>

<sup>1</sup> Senior Lecturer, Department of Apparel Merchandising and Management, International Standard University, Dhaka, Bangladesh. email: sobuj@isu.ac.bd

\* Corresponding author

### **Abstract**

Cellulose, one of the most abundant biopolymers, is widely used in natural and regenerated fibers for textiles. Conventional regenerated fibers, such as viscose and Lyocell, rely on solvents that are either environmentally hazardous or limited in processing efficiency. Ionic liquids (ILs) have emerged as promising alternatives, capable of directly dissolving cellulose without chemical modification, offering high thermal stability, low vapor pressure, and recyclability. This mini-review summarizes cellulose dissolution in ILs, emphasizing the roles of cations and anions, dissolution mechanisms, and factors affecting solubility, including temperature, water content, and cellulose crystallinity. Methods for fiber production—such as dry-jet wet spinning, electrospinning, and coagulation—are discussed along with the influence of process parameters on fiber properties. IL-regenerated fibers exhibit superior mechanical performance, higher crystallinity, and tunable functionalities compared with viscose and Lyocell, and can utilize diverse feedstocks, including recycled textiles. Despite these advantages, challenges such as high dope viscosity, water sensitivity, IL cost, and solvent recovery hinder large-scale adoption. Emerging trends, including task-specific ILs, co-solvent systems, and processing of other biopolymers, highlight opportunities for sustainable and circular fiber production.

**Keywords:** Cellulose, Ionic Liquids, Chemical modifications, Low vapor pressure.

## **1 | Introduction**

Cellulose is one of the most abundant biopolymers. Cellulosic fibers like cotton, flax, jute, hemp is widely used in textile and apparel industry that we get directly from nature. Apart from natural cellulosic fibers, there are also regenerated cellulosic fibers like viscose, lyocell, modal which are also used in textile product. During the regeneration process of cellulosic fibers, at first, they are dissolved into a suitable solution and then fibers are regenerated by removing the solvents. Cellulose can't be melted as their decomposition temperature lower than the melting point.

This inherent recalcitrance stems from its hierarchical structure: linear chains of D-glucopyranose units form a dense network of intra- and intermolecular hydrogen bonds. These bonds create highly ordered crystalline regions that prevent conventional solvent molecules from penetrating the polymer matrix [1]. Traditional solvents that are used in viscose process are not environmentally friendly and the solvent used for Lyocell process has its own limitation. In search for new solvent, researchers discovered ionic liquids (ILs) that can directly dissolve cellulose without any chemical modification of the original cellulose. There other advantage of ILs are they are

environmentally friendly. ILs have excellent solvent capacity, high thermal stability and low vapor pressure [2]. This mini-review explores the current understanding of cellulose dissolution in ILs, its mechanism and subsequent processes for regenerating cellulose into fiber. This study also addresses the advancements and challenges in this evolving field.

## **2 | Cellulose Structure and Challenges for Dissolving**

At the molecular level, the chemical reactivity of cellulose is governed by the three hydroxyl (-OH) groups located at the C2, C3, and C6 positions of each anhydroglucose unit (AGU).

While the Introduction noted the general difficulty of dissolution, the specific orientation of these groups allows for a dual-layered stability: intramolecular bonds provide axial rigidity to the chain, while intermolecular bonds facilitate the "stacking" of chains into microfibrils [3]. The challenge for any solvent is not merely to wet the surface, but to competitively bond with these specific hydroxyl sites to decouple the chains from their crystalline lattice [4].

### 3 | Ionic Liquids as Solvents for Cellulose Different Ionic Liquids for Cellulose Dissolution

Ionic liquids are practically Ionic Salts which are liquid below 100°C. ILs may contain organic and/or inorganic ions and often may contain multiple anion and cations. While a wide variety of ILs exist, only certain types are effective in dissolving cellulose. Generally, hydrophilic ILs with specific anionic and cationic structures are found to be suitable solvents. The most commonly studied and effective ILs for cellulose dissolution are those based on imidazolium cations, such as 1-butyl-3-methylimidazolium chloride ([BMIM]Cl) [5], 1-allyl-3-methylimidazolium chloride ([AMIM]Cl) [6], and 1-ethyl-3-methylimidazolium acetate ([EMIM]OAc) [7]. Other effective cations include pyridinium, ammonium, and phosphonium, especially when paired with appropriate anions [8].

The choice of anion is particularly critical for cellulose dissolution. Anions with high hydrogen bond accepting capabilities are generally more effective in disrupting the cellulose hydrogen bonding network. Halide anions (Cl<sup>-</sup>, Br<sup>-</sup>), acetate (OAc<sup>-</sup>), and formate (HCOO<sup>-</sup>) are among the most efficient in dissolving cellulose. In contrast, ILs with non-coordinating anions such as tetrafluoroborate ([BF<sub>4</sub>]<sup>-</sup>) and hexafluorophosphate ([PF<sub>6</sub>]<sup>-</sup>) are typically poor solvents for cellulose, as they lack the ability to form strong hydrogen bonds with the hydroxyl groups of cellulose [9].

Ionic Liquid	Cation	Anion	Key Features	Citation
[BMIM][Cl]	1-butyl-3-methylimidazolium	Chloride (Cl <sup>-</sup> )	Strong hydrogen bonding; widely studied for cellulose dissolution	[10]
[EMIM][OAc]	1-ethyl-3-methylimidazolium	Acetate (OAc <sup>-</sup> )	Excellent solubility; recyclable; used in fiber spinning	[11]
[AMIM][Cl]	1-allyl-3-methylimidazolium	Chloride (Cl <sup>-</sup> )	Allyl group enhances interaction with ether oxygen atom	[12]
[EMIM][DEP]	1-ethyl-3-methylimidazolium	Diethyl phosphate	Less corrosive; suitable for cellulose derivatization	[13]
[EMIM][DMP]	1-ethyl-3-methylimidazolium	Dimethyl phosphate	Biocompatible; used in biomedical cellulose applications	[13]
[PMIM][Cl]	1-propyl-3-methylimidazolium	Chloride (Cl <sup>-</sup> )	Less effective due to steric hindrance from propyl group	[14]
[EMIM][BF <sub>4</sub> ]	1-ethyl-3-methylimidazolium	Tetrafluoroborate	Poor hydrogen bonding; limited cellulose solubility	[13]
[EMIM][Tf <sub>2</sub> N]	1-ethyl-3-methylimidazolium	Bis (trifluoromethylsulfonyl) imide	Hydrophobic; used in composite materials	[13]

#### Factors Influencing Cellulose Dissolution

Several factors influence cellulose dissolution: Temperature generally enhances dissolution by

increasing ion kinetic energy and reducing IL viscosity, though excessive heat can degrade cellulose [18]. Water content significantly hinders dissolution by competing for hydrogen bonding sites, making anhydrous conditions preferable [19]. Cellulose characteristics (source, molecular weight, crystallinity) impact solubility; lower crystallinity and molecular weight facilitate dissolution [20]. The ionic liquid structure, particularly the cation and anion combination, is crucial, with imidazolium-based ILs with halide or acetate anions being most effective [21]. Co-solvents like DMSO or DMF can enhance dissolution by reducing IL viscosity and improving mass transfer [22].

Several factors influence cellulose dissolution in ionic liquids (ILs), each playing a critical role in the efficiency and outcome of the process. Temperature is a key parameter: it generally enhances dissolution by increasing the kinetic energy of ions and reducing the viscosity of the IL, thereby improving mass transfer and molecular mobility. However, excessive heat can lead to cellulose degradation, particularly through depolymerization or oxidation, which compromises the integrity of the final product [23].

Water content is another crucial factor. While trace amounts may sometimes aid in disrupting cellulose's crystalline structure, higher water concentrations typically hinder dissolution [20]. This occurs because water competes with IL anions for hydrogen bonding sites on cellulose, weakening the IL-cellulose interaction network. Therefore, maintaining anhydrous conditions is often essential for optimal solubility [24].

The structure of the ionic liquid itself is perhaps the most decisive factor. Imidazolium-based ILs paired with halide (Cl<sup>-</sup>) or carboxylate (Ac<sup>-</sup>, HCOO<sup>-</sup>) anions are among the most effective solvents due to their strong hydrogen bond basicity and ability to disrupt cellulose's internal hydrogen bonding network [25]. The cation's side chains also influence solubility: bulky alkyl groups may hinder anion access to cellulose, while allyl or aromatic groups can enhance interactions through π-π stacking or dipole interactions [26].

To further improve dissolution, co-solvents such as dimethyl sulfoxide (DMSO) or dimethylformamide (DMF) are often added. These solvents reduce the viscosity of the IL system, facilitate better mass transfer, and can help solubilize cellulose without significantly interfering with the IL's hydrogen bonding capabilities [27]. The synergistic effect of ILs and co-solvents has led to the development of more efficient and scalable cellulose processing techniques.

### 4 | Regenerated Fiber Production from Cellulose/IL Solutions

### **Dry-jet wet spinning with ILs**

The predominant method for producing continuous regenerated cellulose fibers from ionic liquid (IL) solutions is dry-jet wet spinning. In this process, a cellulose-IL dope of controlled viscosity is extruded through a spinneret and passes through a short air gap before entering a coagulation bath. The air gap provides an opportunity for partial alignment of cellulose chains under extensional stress, which contributes to higher orientation and strength in the final fibers [28]. IL systems such as [EMIM][OAc] and [DBNH][OAc] have demonstrated excellent spinnability under dry-jet wet conditions, yielding fibers with tenacities comparable to or exceeding those of commercial Lyocell [29]. Compared to NMMO-based Lyocell, IL spinning offers greater flexibility in solvent design and potential compatibility with recycled feedstocks [30]

### **Electrospinning and hollow fiber formation**

In addition to continuous filament spinning, ILs have been employed in electrospinning to produce cellulose nanofibers and nonwoven mats. Electrospinning benefits from the high conductivity of many ILs, which stabilizes the jet under an applied electric field [31]. Cellulose solutions in imidazolium chlorides and acetates have been electrospun into nanofibers with diameters ranging from tens to hundreds of nanometers, suitable for applications in filtration and biomedical scaffolds. Hollow fibers can also be fabricated by modifying the spinneret geometry or introducing a bore fluid during extrusion. For example, [EMIM][OAc] dopes have been successfully spun into hollow fibers with controlled wall thickness, broadening the potential applications of IL-based spinning to membranes and adsorption devices [32].

### **Coagulation and regeneration (role of water/alcohols)**

Fiber regeneration is achieved by precipitating cellulose from the IL dope in a coagulation bath. Water is the most commonly used antisolvent, but alcohols (e.g., ethanol, isopropanol) have also been explored to control skin-core structure, porosity, and regeneration kinetics. The efficiency of coagulation depends on the mutual diffusivity of IL and nonsolvent, as well as bath temperature and flow conditions. A rapid exchange favors the formation of dense, smooth skins but may entrap residual IL, while slower diffusion leads to more homogeneous coagulation and porous structures. Optimizing coagulation media and dynamics is thus critical to ensuring mechanical performance and minimizing residual solvent in the fiber [33].

### **Functional modifications**

IL-based processing not only enables fiber regeneration but also provides opportunities for in situ modification and nanocomposite formation. Acetylation of IL-regenerated cellulose fibers reduces hydrophilicity and improves dimensional stability, producing fibers with tailored moisture sorption [34]. The incorporation of nanofillers such as cellulose nanocrystals, graphene oxide, or metal nanoparticles into IL dopes results in nanocomposite fibers with improved modulus, flame retardancy, conductivity, or antimicrobial activity. In addition, ILs can dissolve and co-spin other biopolymers, including lignin, chitin, and silk fibroin, enabling hybrid fibers with novel functionalities (e.g., UV protection, antibacterial properties, enhanced toughness) [31]. Post-spinning surface treatments can further introduce hydrophobic, catalytic, or responsive properties, extending IL-regenerated fibers into fields beyond apparel, such as filtration, biomedical textiles, and smart materials.

## **5 | Challenges and Limitations**

Despite the promising performance of ionic liquid (IL)-regenerated fibers, several technical and economic challenges remain before large-scale commercialization can be fully realized. One of the most critical challenges lies in the rheological behavior of IL-cellulose solutions. Cellulose dissolution in ILs produces dopes with very high viscosities, even at relatively low cellulose concentrations (8–15 wt%). This high viscosity complicates dope handling, pumping, and spinning stability, often requiring high temperatures or co-solvents (e.g., DMSO, DMAc) to reduce viscosity [35]. However, elevated temperatures may lead to IL degradation, while co-solvent use introduces additional recovery steps and environmental considerations. Balancing viscosity reduction with process stability remains a central challenge. ILs are inherently hygroscopic and highly sensitive to water content. Even trace levels of water can affect cellulose solubility, dope stability, and ultimately fiber morphology. During spinning, the coagulation step is particularly sensitive to the choice of nonsolvent (e.g., water, alcohol, or mixtures), as differences in diffusivity and phase separation kinetics directly impact fiber structure and properties [32]. Process control must therefore be extremely precise to maintain reproducibility, which increases the technical complexity of IL-based spinning lines. Although ILs can be recycled in closed-loop systems, their initial cost is substantially higher than that of conventional solvents (e.g., NMMO). Furthermore, some ILs, particularly imidazolium-based salts, may undergo thermal or hydrolytic degradation, leading to loss of solvent quality over multiple cycles [36]. Certain ILs also exhibit corrosive behavior toward stainless steel and other standard reactor materials,

necessitating specialized corrosion-resistant equipment. This not only increases capital investment but also raises concerns regarding long-term solvent stability and material compatibility in industrial environments. While pilot-scale demonstrations, such as the Ioncell® process, have established the technical feasibility of IL-regenerated fibers, the transition from laboratory to industrial-scale production remains challenging. One major barrier is the energy-intensive nature of solvent recovery systems, particularly when separating ILs from water or other nonsolvents, which significantly increases operational costs. Another limitation lies in the lack of standardized IL supply chains, leading to variability in quality and restricted large-scale availability. Furthermore, regulatory uncertainties persist, since ILs are relatively new compared to established solvents, and their long-term environmental and toxicological impacts remain under investigation [37]. Collectively, these barriers highlight the need for targeted process innovations, robust solvent recovery technologies, and clearer regulatory frameworks before IL-based fiber production can be implemented on a commercial scale.

### ***Emerging Trends and Future Perspectives***

The application of ionic liquids (ILs) in regenerated fiber production is evolving rapidly, with several research directions offering promising opportunities to overcome current limitations and expand the scope of the technology. These developments encompass innovations in IL chemistry, process optimization strategies, circular economy integration, and broadening of the material base beyond cellulose. One of the most dynamic areas of progress is the design of task-specific ionic liquids (TSILs) tailored for cellulose dissolution. Unlike conventional imidazolium-based ILs, which suffer from stability and cost issues, TSILs can be engineered with functionalized cations and anions to enhance dissolution efficiency, reduce toxicity, and improve recyclability [38]. Protic ionic liquids (PILs), synthesized via proton transfer reactions, represent another promising class due to their relatively simple synthesis, lower cost, and favorable environmental profiles [39]. The exploration of deep eutectic solvents (DESs), often regarded as IL analogues, further complements these trends by offering biodegradable and less expensive alternatives that retain the ability to dissolve cellulose [40]. Moreover, optimized solvent blends may reduce energy demand in spinning and recovery stages, thereby enhancing overall process efficiency and techno-economic viability. The integration of IL-based processing into textile-to-textile recycling frameworks represents a key pathway toward sustainable fiber production. Unlike viscose or Lyocell, IL systems demonstrate a unique capacity to dissolve cellulose from

diverse feedstocks, including post-consumer textiles, industrial waste, and non-wood biomass [36]. Importantly, ILs can tolerate certain levels of residual dyes, finishes, or polymer blends, allowing for upcycling of waste textiles into high-performance regenerated fibers. This capability aligns with circular economy principles by reducing textile waste, extending the life cycle of cellulose resources, and lowering dependence on virgin pulp. Looking ahead, the application of ILs is not limited to cellulose [41]. Recent studies highlight their ability to dissolve and regenerate other biopolymers, including chitin, silk fibroin, keratin, and lignin, thereby opening avenues for the development of novel fiber types. For instance, IL-spun chitin fibers offer biocompatibility and antimicrobial properties suitable for biomedical applications, while silk fibroin regenerated from ILs demonstrates enhanced mechanical performance compared with traditional aqueous dissolution methods [42]. Blends of cellulose with lignin or protein-based biopolymers may yield multifunctional fibers with advanced properties such as UV protection, conductivity, or flame retardancy, significantly broadening the potential application spectrum of IL-based fiber technologies [43]

## **6 | Conclusion**

Ionic liquids (ILs) have emerged as highly versatile and effective solvents for the regeneration of cellulose into high-performance fibers. Their key advantages include the ability to dissolve cellulose without derivatization, compatibility with diverse feedstocks—including post-consumer textiles and the capacity to produce fibers with superior mechanical properties, enhanced crystallinity, and low fibrillation tendency. Moreover, IL-based processes offer opportunities for functional modification and nanocomposite formation, thereby extending the application of regenerated fibers beyond conventional textiles to high-value technical and biomedical domains. At the same time, a balanced assessment reveals that significant hurdles remain. The high viscosity of IL--cellulose dopes, water sensitivity, and challenges in process control continue to complicate spinning operations. Economic and technical limitations, including the high cost of ILs, potential degradation during recycling, and corrosion issues, raise barriers to industrial deployment. Furthermore, scaling from laboratory to commercial production is constrained by energy-intensive solvent recovery, variability in IL supply, and uncertain regulatory frameworks regarding environmental safety.

Looking forward, advances in task-specific IL chemistries, protic ionic liquids, and solvent blends hold

promise for overcoming viscosity and cost challenges. Integration of ILs into textile-to-textile recycling frameworks represents a particularly compelling pathway toward circular economy models. Expanding IL-based processing beyond cellulose to other biopolymers such as chitin, silk fibroin, and lignin may further broaden the scope of regenerated fibers. Overall, while IL-based fiber production is not yet ready for widespread industrial adoption, sustained interdisciplinary research, pilot-scale trials, and techno-economic optimization could transform ILs into a viable cornerstone of future sustainable fiber technologies.

## References

- [1] T. Heinze, "Cellulose: Structure and Properties," in *Cellulose Chemistry and Properties: Fibers, Nanocelluloses and Advanced Materials*, vol. 271, O. J. Rojas, Ed., in *Advances in Polymer Science*, vol. 271, Cham: Springer International Publishing, 2015, pp. 1–52. doi: 10.1007/12\_2015\_319.
- [2] S. Mallakpour and M. Dinari, "Ionic Liquids as Green Solvents: Progress and Prospects," in *Green Solvents II*, A. Mohammad and Dr. Inamuddin, Eds., Dordrecht: Springer Netherlands, 2012, pp. 1–32. doi: 10.1007/978-94-007-2891-2\_1.
- [3] N. N. Deshavath, V. D. Veeranki, and V. V. Goud, "Chapter 1 - Lignocellulosic feedstocks for the production of bioethanol: availability, structure, and composition," in *Sustainable Bioenergy*, M. Rai and A. P. Ingle, Eds., Elsevier, 2019, pp. 1–19. doi: 10.1016/B978-0-12-817654-2.00001-0.
- [4] R. S. Abolore, S. Jaiswal, and A. K. Jaiswal, "Green and sustainable pretreatment methods for cellulose extraction from lignocellulosic biomass and its applications: A review," *Carbohydr. Polym. Technol. Appl.*, vol. 7, p. 100396, June 2024, doi: 10.1016/j.carpta.2023.100396.
- [5] L. Xing, Z. Wu, and G. Gong, "Dissolution of Cotton Cellulose with Ionic Liquids 1-Butyl-3-Methylimidazolium Chloride and 1-Allyl-3-Methylimidazolium Chloride to Prepare Reducing Sugar," *J. Energy Eng.*, vol. 140, no. 2, p. 04013013, June 2014, doi: 10.1061/(ASCE)EY.1943-7897.0000121.
- [6] Y. Yuan, J. Wang, N. Fu, and S. Zang, "Hydrolysis of cellulose in 1-allyl-3-methylimidazolium chloride catalyzed by methyltrioxorhenium," *Catal. Commun.*, vol. 76, pp. 46–49, Feb. 2016, doi: 10.1016/j.catcom.2015.12.024.
- [7] "Co-solvent facilitated in situ esterification of cellulose in 1-ethyl-3-methylimidazolium acetate :: BioResources." Accessed: Oct. 05, 2025. [Online]. Available: <https://bioresources.cnr.ncsu.edu/>
- [8] A. Al-Bodour et al., "Ionic Liquids as Multidimensional Materials: A Review from Fundamentals to Applications," *Energy Fuels*, vol. 39, no. 27, pp. 12791–12829, July 2025, doi: 10.1021/acs.energyfuels.5c01280.
- [9] R. S. Payal, K. K. Bejagam, A. Mondal, and S. Balasubramanian, "Dissolution of Cellulose in Room Temperature Ionic Liquids: Anion Dependence," *J. Phys. Chem. B*, vol. 119, no. 4, pp. 1654–1659, Jan. 2015, doi: 10.1021/jp512240t.

- [10] M. Iguchi, T. M. Aida, M. Watanabe, and R. L. Smith, "Dissolution and recovery of cellulose from 1-butyl-3-methylimidazolium chloride in presence of water," *Carbohydr. Polym.*, vol. 92, no. 1, pp. 651–658, Jan. 2013, doi: 10.1016/j.carbpol.2012.09.021.
- [11] L. P. Hinner, J. L. Wissner, B. Hauer, and B. A. Nebel, "Efficient cellulose dissolution in a tertiary [EHMIM]-[EMIM]OAc-water system," *J. Mol. Liq.*, vol. 281, pp. 236–242, May 2019, doi: 10.1016/j.molliq.2019.02.096.
- [12] "Dissolution of Collagen Fibers from Tannery Solid Wastes in 1-Allyl-3-methylimidazolium Chloride and Modulation of Regenerative Morphology | ACS Sustainable Chemistry & Engineering." Accessed: Oct. 09, 2025. [Online]. Available: <https://pubs.acs.org/doi/10.1021/acssuschemeng.8b05428>
- [13] S. Taokaew and W. Kriangkrai, "Recent Progress in Processing Cellulose Using Ionic Liquids as Solvents," *Polysaccharides*, vol. 3, no. 4, pp. 671–691, Dec. 2022, doi: 10.3390/polysaccharides3040039.
- [14] M. Babicka, M. Woźniak, K. Dwiecki, S. Borysiak, and I. Ratajczak, "Preparation of Nanocellulose Using Ionic Liquids: 1-Propyl-3-Methylimidazolium Chloride and 1-Ethyl-3-Methylimidazolium Chloride," *Molecules*, vol. 25, no. 7, p. 1544, Mar. 2020, doi: 10.3390/molecules25071544.
- [15] J. Zhang et al., "Understanding cellulose dissolution: effect of the cation and anion structure of ionic liquids on the solubility of cellulose," *Sci. China Chem.*, vol. 59, no. 11, pp. 1421–1429, Nov. 2016, doi: 10.1007/s11426-016-0269-5.
- [16] B. Lu, A. Xu, and J. Wang, "Cation does matter: how cationic structure affects the dissolution of cellulose in ionic liquids," *Green Chem.*, vol. 16, no. 3, pp. 1326–1335, Feb. 2014, doi: 10.1039/C3GC41733F.
- [17] X. Lu et al., "Cellulose dissolution in ionic liquid from hydrogen bonding perspective: first-principles calculations," *Cellulose*, vol. 30, no. 7, pp. 4181–4195, May 2023, doi: 10.1007/s10570-023-05140-9.
- [18] S. Acharya, Y. Hu, and N. Abidi, "Cellulose Dissolution in Ionic Liquid under Mild Conditions: Effect of Hydrolysis and Temperature," *Fibers*, vol. 9, no. 1, p. 5, Jan. 2021, doi: 10.3390/fib9010005.
- [19] Y. Chen, Y. Cao, X. Sun, and T. Mu, "Hydrogen bonding interaction between acetate-based ionic liquid 1-ethyl-3-methylimidazolium acetate and common solvents," *J. Mol. Liq.*, vol. 190, pp. 151–158, Feb. 2014, doi: 10.1016/j.molliq.2013.11.010.
- [20] K. Xie et al., "The effect of cellulose molecular weight on internal structure and properties of regenerated cellulose fibers as spun from the alkali/urea aqueous system," *Polymer*, vol. 215, p. 123379, Feb. 2021, doi: 10.1016/j.polymer.2021.123379.
- [21] N. Mousa, B. Abu-Jdayil, and A. Y. Zekri, "Recent Advances in the Utilization of Imidazolium-Based Ionic Liquids for Chemical-Enhanced Oil Recovery: A Comprehensive Review," *Chem. Rec.*, vol. n/a, no. n/a, p. e202500096, doi: 10.1002/tcr.202500096.
- [22] J.-M. Andanson, E. Bordes, J. Devémy, F. Leroux, A. A. H. Pádua, and M. F. C. Gomes, "Understanding the role of co-solvents in the dissolution of cellulose in ionic liquids," *Green Chem.*, vol. 16, no. 5, pp. 2528–2538, Apr. 2014, doi: 10.1039/C3GC42244E.
- [23] S. Taokaew, "Recent Advances in Cellulose-Based Hydrogels Prepared by Ionic Liquid-Based Processes," *Gels*, vol. 9, no. 7, p. 546, July 2023, doi: 10.3390/gels9070546.
- [24] M. Mazza, D.-A. Catana, C. Vaca-Garcia, and C. Cecutti, "Influence of water on the dissolution of cellulose in selected ionic liquids," *Cellulose*, vol. 16, no. 2, pp. 207–215, Apr. 2009, doi: 10.1007/s10570-008-9257-x.
- [25] K. Dong, S. Zhang, D. Wang, and X. Yao, "Hydrogen Bonds in Imidazolium Ionic Liquids," *J. Phys. Chem. A*, vol. 110, no. 31, pp. 9775–9782, Aug. 2006, doi: 10.1021/jp054054c.
- [26] Y. Zhao, X. Liu, J. Wang, and S. Zhang, "Effects of Cationic Structure on Cellulose Dissolution in Ionic Liquids: A Molecular Dynamics Study," *ChemPhysChem*, vol. 13, no. 13, pp. 3126–3133, 2012, doi: 10.1002/cphc.201200286.
- [27] M. Gericke, P. Fardim, and T. Heinze, "Ionic Liquids — Promising but Challenging Solvents for Homogeneous Derivatization of Cellulose," *Molecules*, vol. 17, no. 6, pp. 7458–7502, June 2012, doi: 10.3390/molecules17067458.
- [28] L. K. J. Hauru, M. Hummel, K. Nieminen, A. Michud, and H. Sixta, "Cellulose regeneration and spinnability from ionic liquids," *Soft Matter*, vol. 12, no. 5, pp. 1487–1495, Jan. 2016, doi: 10.1039/C5SM02618K.
- [29] W. Fang, E. Y. Lim, K. L. Nieminen, and H. Sixta, "Optimization of Dry-Jet Wet Spinning of Regenerated Cellulose Fibers Using [mTBDH][OAc] as a Solvent," *ACS Omega*, vol. 8, no. 37, pp. 34103–34110, Sept. 2023, doi: 10.1021/acsomega.3c05133.
- [30] P. Verdía Barbará et al., "Recent Advances in the Use of Ionic Liquids and Deep Eutectic Solvents for Lignocellulosic Biorefineries and Biobased Chemical

- and Material Production," *Chem. Rev.*, vol. 125, no. 12, pp. 5461–5583, June 2025, doi: 10.1021/acs.chemrev.4c00754.
- [31] B. Azimi et al., "Cellulose-based fiber spinning processes using ionic liquids," *Cellulose*, vol. 29, no. 6, pp. 3079–3129, Apr. 2022, doi: 10.1007/s10570-022-04473-1.
- [32] W. T. Wulandari, A. Rochliadi, and I. M. Arcana, "Nanocellulose prepared by acid hydrolysis of isolated cellulose from sugarcane bagasse," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 107, p. 012045, Feb. 2016, doi: 10.1088/1757-899X/107/1/012045.
- [33] A. Kirchberg and M. A. R. Meier, "Regeneration of Cellulose from a Switchable Ionic Liquid: Toward More Sustainable Cellulose Fibers," *Macromol. Chem. Phys.*, vol. 222, no. 6, p. 2000433, Mar. 2021, doi: 10.1002/macp.202000433.
- [34] G. Frisoni et al., "Natural cellulose fibers: heterogeneous acetylation kinetics and biodegradation behavior," *Biomacromolecules*, vol. 2, no. 2, pp. 476–482, 2001, doi: 10.1021/bm0056409.
- [35] C. K. Falkenreck, J.-C. Zarges, H.-P. Heim, M. Seitz, and C. Bonten, "Degradation of regenerated cellulose fiber-reinforced bio-polyamide in hydrothermal environment," *Compos. Part Appl. Sci. Manuf.*, vol. 188, p. 108584, Jan. 2025, doi: 10.1016/j.compositesa.2024.108584.
- [36] S. Elsayed et al., "Recycling of Superbase-Based Ionic Liquid Solvents for the Production of Textile-Grade Regenerated Cellulose Fibers in the Lyocell Process," *ACS Sustain. Chem. Eng.*, vol. 8, no. 37, pp. 14217–14227, Sept. 2020, doi: 10.1021/acssuschemeng.0c05330.
- [37] Y. S. Khoo, T. C. Tjong, J. W. Chew, and X. Hu, "Techniques for recovery and recycling of ionic liquids: A review," *Sci. Total Environ.*, vol. 922, p. 171238, Apr. 2024, doi: 10.1016/j.scitotenv.2024.171238.
- [38] A. Bikmukhametov et al., "Task-specific ionic liquid and organic salts based on catechol-containing hydrazones: Synthesis, selective Cu(II) binding, thermal properties, and redox-activity," *J. Mol. Liq.*, vol. 425, p. 127234, May 2025, doi: 10.1016/j.molliq.2025.127234.
- [39] "Protic ionic liquids for sustainable uses," *Green Chem.*, vol. 26, no. 3, pp. 1092–1131, Feb. 2024, doi: 10.1039/d3gc03297c.
- [40] R. Umapathi et al., "Deep eutectic solvents induced changes in the phase transition behavior of smart polymers: a sustainable future approach," *Phys. Chem. Chem. Phys.*, vol. 25, no. 32, pp. 21131–21148, Aug. 2023, doi: 10.1039/D3CP01913F.
- [41] A. Anceschi, C. Riccardi, and A. Patrucco, "The Role of Ionic Liquids in Textile Processes: A Comprehensive Review," *Molecules*, vol. 30, no. 2, p. 353, Jan. 2025, doi: 10.3390/molecules30020353.
- [42] Y. Liang, Y. Zou, S. Wu, D. Song, W. Xu, and K. Zhu, "Preparation and properties of chitin/silk fibroin biocompatible composite fibers," *J. Biomater. Sci. Polym. Ed.*, vol. 34, no. 7, pp. 860–874, May 2023, doi: 10.1080/09205063.2022.2147746.
- [43] R. Dungani et al., "Potential of lignin and cellulose as renewable materials for the synthesis of flame-retardant aerogel composites," *Mater. Today Commun.*, vol. 41, p. 110501, Dec. 2024, doi: 10.1016/j.mtcomm.2024.110501.