Self-healing polyurethanes: evolution in material engineering

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Our work is framed on the analysis of recent advances in self-healing polyurethanes, focusing on the incorporation of dynamic covalent and supramolecular bonds that allow self-repair under mild stimuli, significantly improving their mechanical properties and repair efficiency [1-4]. The combination of covalent and non-covalent bonds offers a promising synergy, enhancing the balance between mechanical properties and self-healing capability [2,3]. However, challenges in synthesis and production costs remain, driving the search for more sustainable methods.

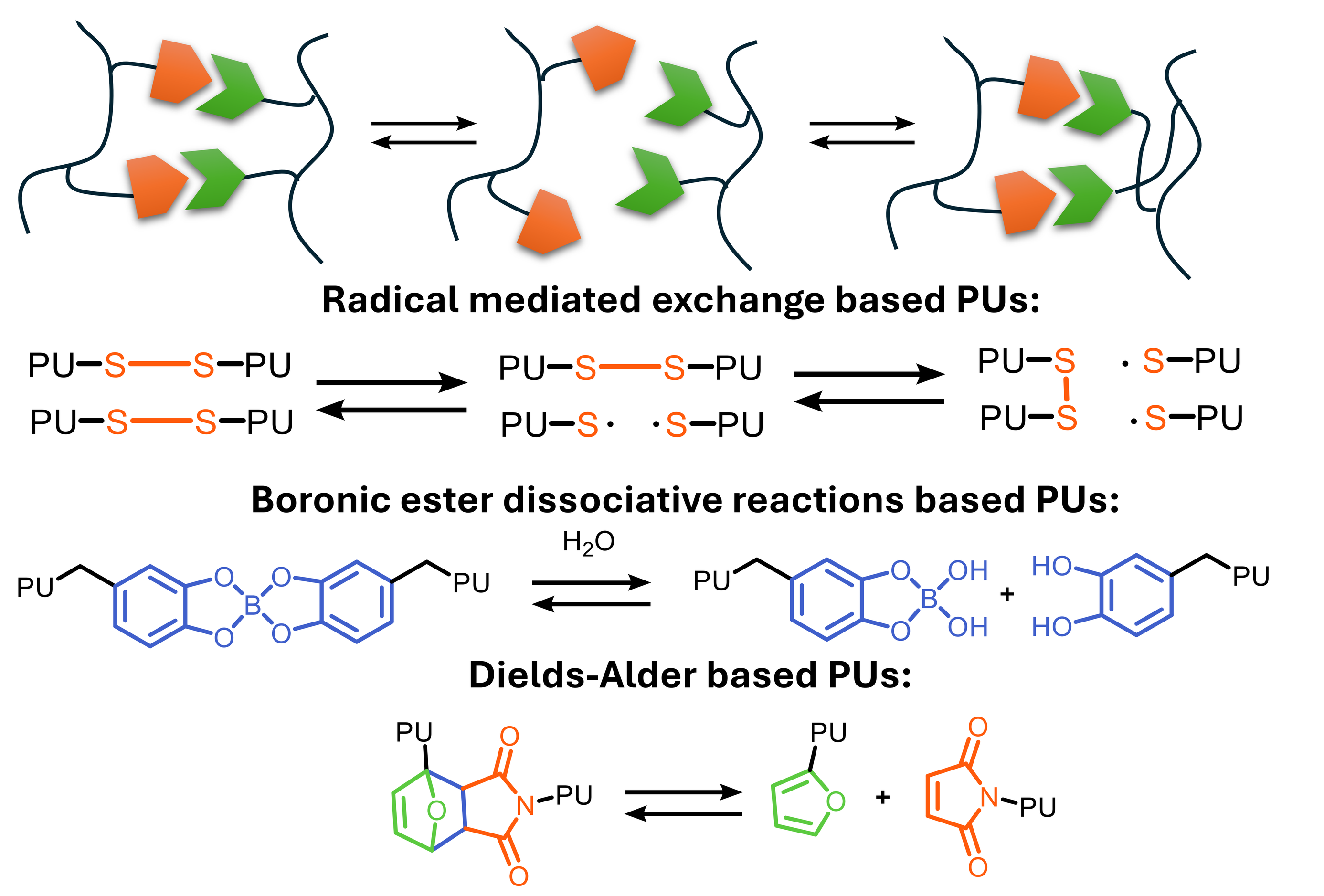
Covalent Approach

Disulfide / Diselenide Bonds: can reform after breaking, allowing self-healing at room temperature under UV irradiation, achieving 100% recovery in tensile strength. recovery Nonetheless, are sensitive to oxidizing agents, which can lead to degradation in harsh conditions.

Boroxine Bonds: form strong yet reversible links, enhancing self-healing capabilities, but require complex synthesis and specific conditions to ensure stability.

Diels-Alder Reactions: enable provide reversible covalent bonds for robust mechanical properties but are limited in uncontrolled environments.

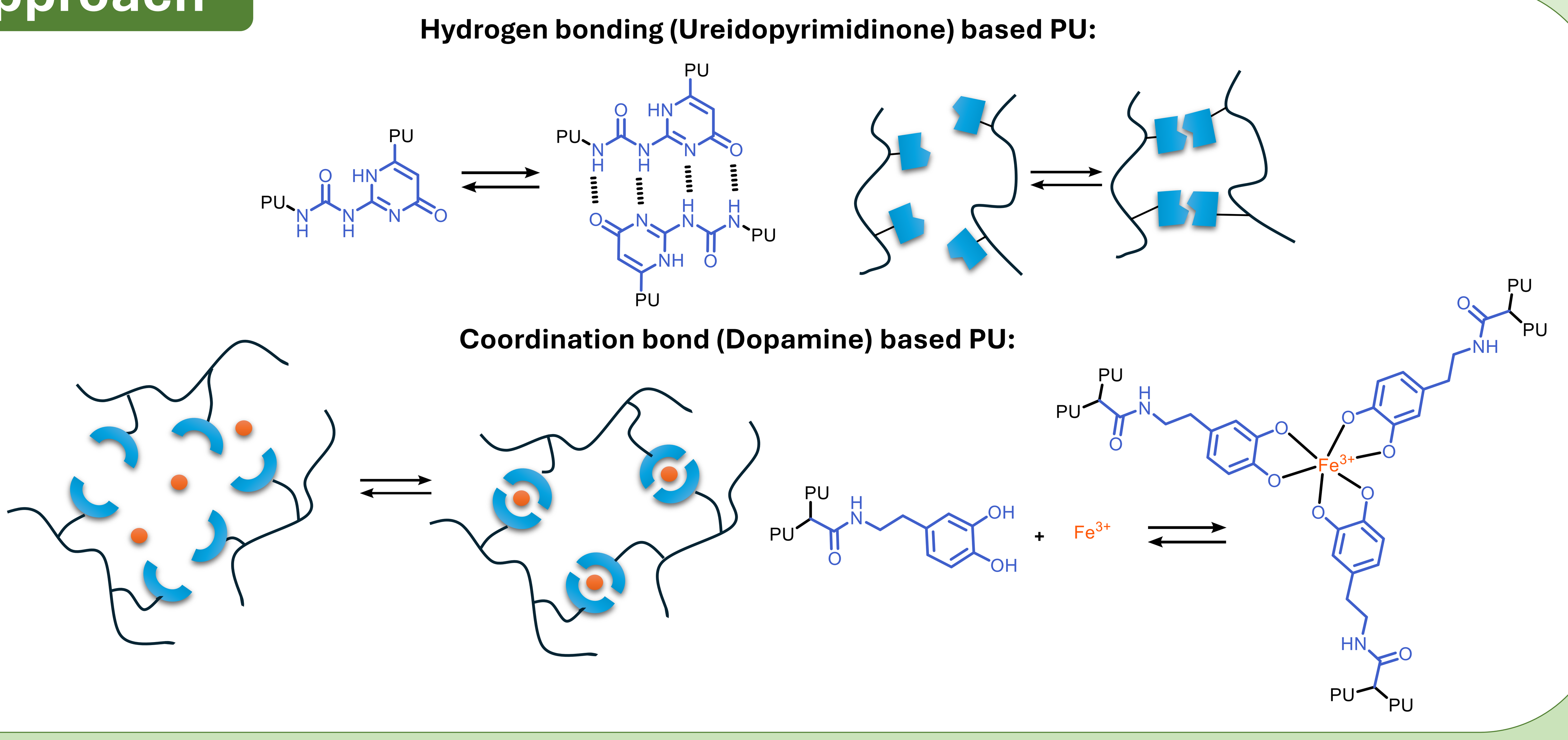
Schematic representatio of dynamic covalent reactions:



Supramolecular Approach

Hydrogen Bonds: provide a quick and reversible self-healing, allowing materials to recovery rapidly from damage, but have lower mechanical strength, limiting material´s overall durability.

Metal Coordination: provide high structural integrity and can be tuned for specific applications. However, the cost and availability of suitable metal ions can be a limiting factor.



Combination Approach

Disulfide & Hydrogen Bonds: demostrate improved repair efficiency due to the rapid recombination of hydrogen bonds and the robust mechanical properties provides by disulfide bonds. Optimal performance requires precise synthesis control to ensure both bondsfunction effectively.

Imine & Metal Bonds: enhances the mechanical strength and self-healing capabilites of the material, allowing it to recover from significant mechanical damage while maintaining structural integrity. However, synthesizing such system can be complex and expensive.

Challenges

Practical Implementation: the main challenge is the complexity of synthesis and the cost of funcional monomers. Developing simpler and more economical methods for producing self-healing polyurethanes is crucial, as current synthesis processes often require complex steps and costly monomers, limiting commerial viability.

Conclusions

- Self-healing polyurethanes represent a significant advance in material science, offering substancial benefits in durability and sustainability.
- The integration of dynamic covalent and supramolecular bonds has shown promise in enhancing the equilibrium between mechanical properties and repair efficiency of these polymers.
- However, achieving practical implementation at an industrial scale will requiere overcoming several challenges.

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