Synthesis and Fire-Resistant Capabilities of Novel Ionic Polymers for Space Exploration

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Introduction

- Our rapidly advancing society developing new technologies for space exploration bears newfound safety challenges to tackle which includes fire safety and prevention.
- Fire resistant (FR) polymers have recently been popular materials to address this issue, but many FR polymers are not versatile in application and are toxic upon combustion.
- Phosphine oxide containing FR polymers are a safer alternative and provide the needed versatility for NASA's objectives.
- Novel ionic polymers containing phosphine oxide and pyridinium salt moieties will be synthesized and investigated for its FR properties and use in applications such as crew clothing, electronics, and electric vehicles.

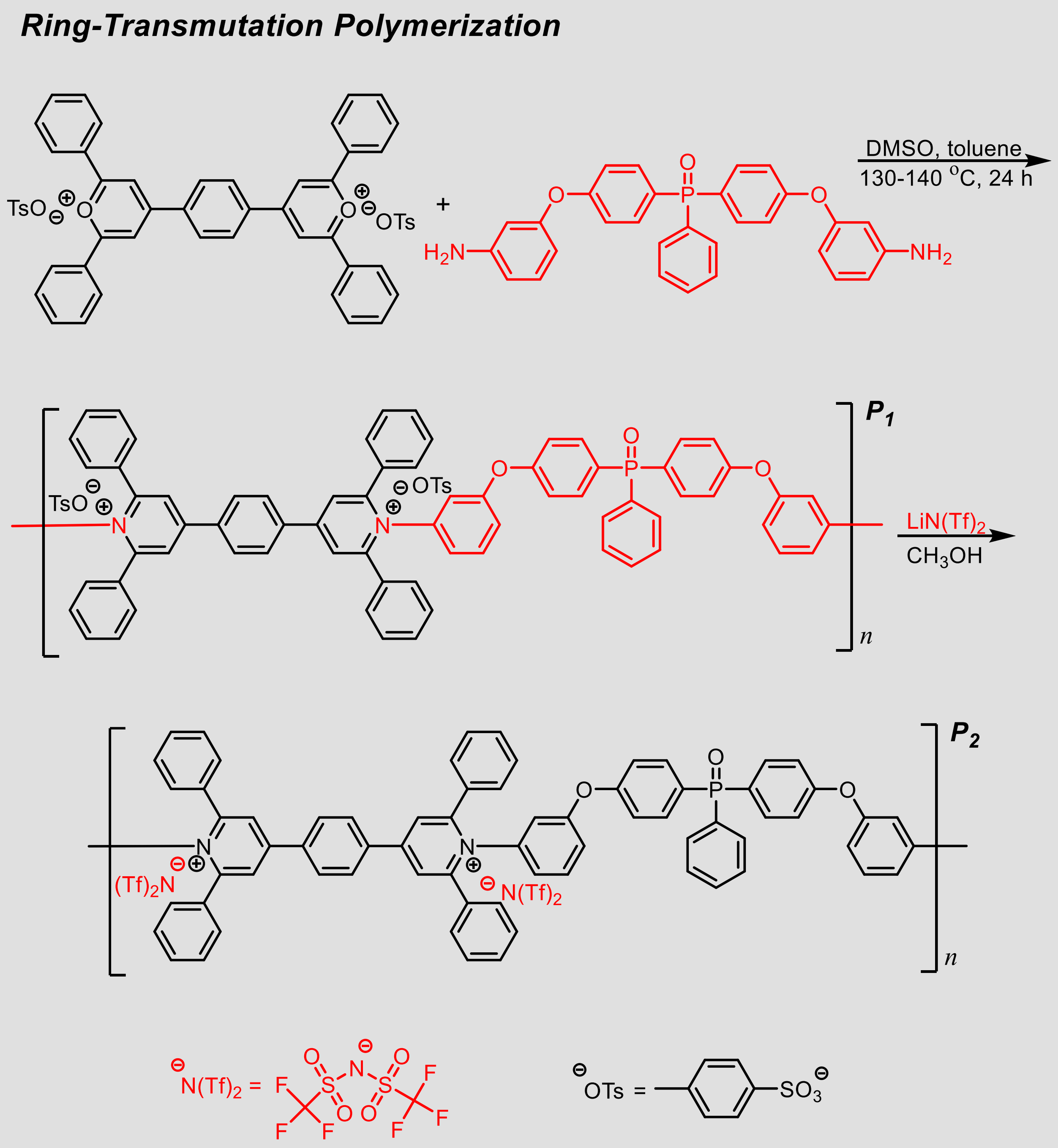
Objectives

- To synthesize, purify, and characterize a new environmentally safe FR polymer with improved FR capabilities, increased durability, releases less toxic combustion byproducts, and offer a versatile set of important applications that is relevant to NASA's mission.
- This polymer will effectively mitigate fire-safety risks, protect electronics, wires, and combustible material from easily catching fire, and comply with fire performance regulations.
- To characterize the final probes by ^{1}H and ^{13}C nuclear magnetic resonance (NMR) spectroscopy and elemental analysis (EA).
- To determine the fluorescence properties through UV-Visible spectroscopy and fluorometry.
- To test fire-resistance capabilities using common fabric material.

Future Work

- The final polymers can undergo ion exchange reactions to enhance fire-resistant properties for textiles, electronics and electric vehicles.
- Structural modifications for *ortho* and *para* positions possess different molecular properties (solubility, fire-resistance, etc.)
- Expanded materials testing such as wires, car batteries, and other fire-prone materials.
- Measurement of fluorescence properties will be done in different solvents.
- Assessment of different synthetic routes for the goal of large-scale synthesis/commercialization for consumer and industrial use.

Synthetic Methods



Scheme 1. Synthesis of Fire-Resistant Polymers.

Results

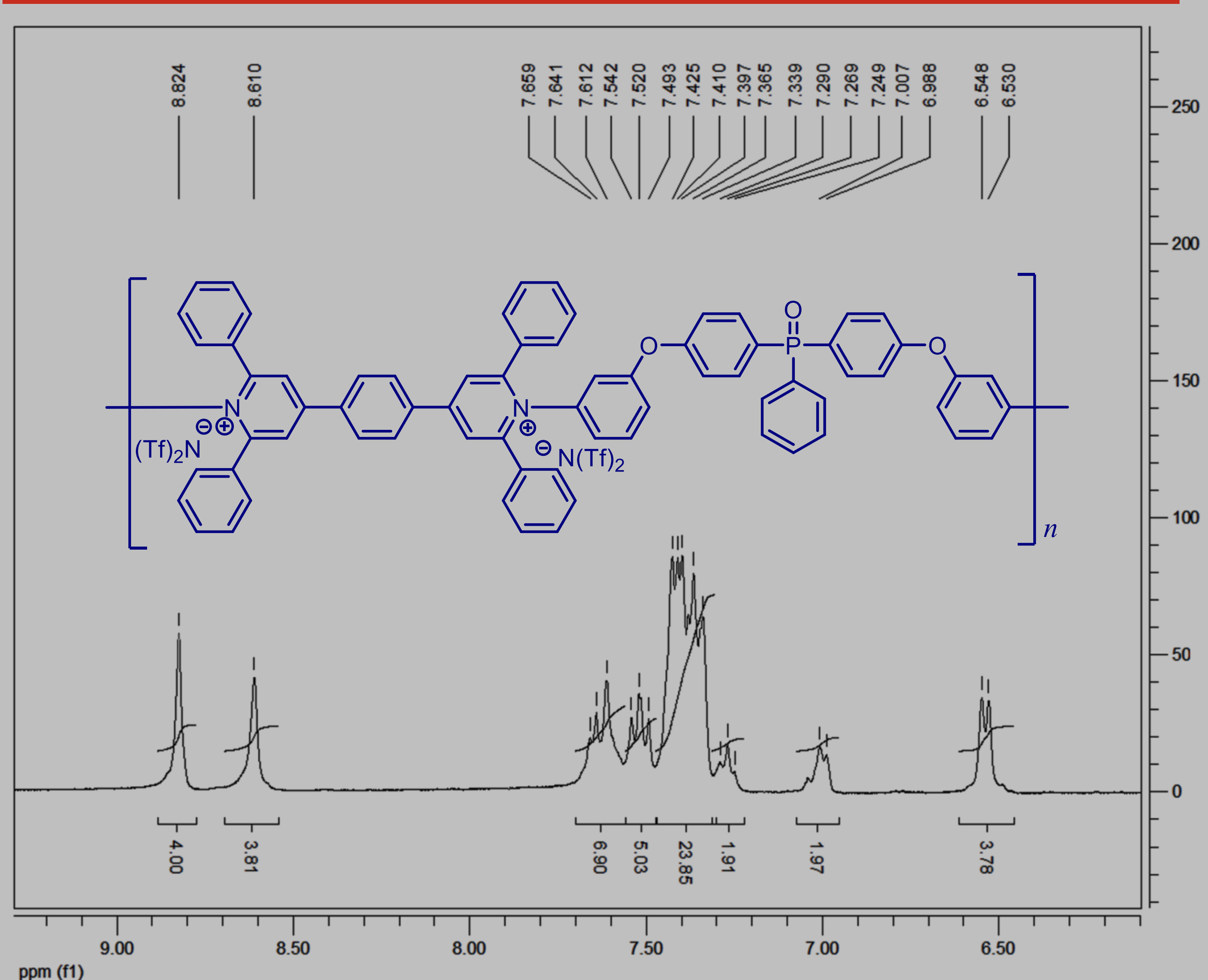


Figure 1. ^{1}H NMR spectrum of $\mathbf{P_2}$ in DMSO-d_6.

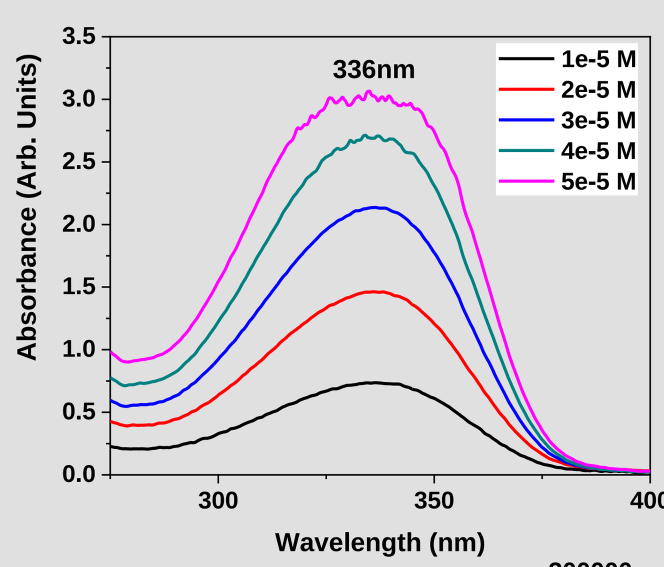


Figure 2. UV-Visible absorption spectra of $\mathbf{P_2}$ in acetonitrile. λ_{max} = 336 nm

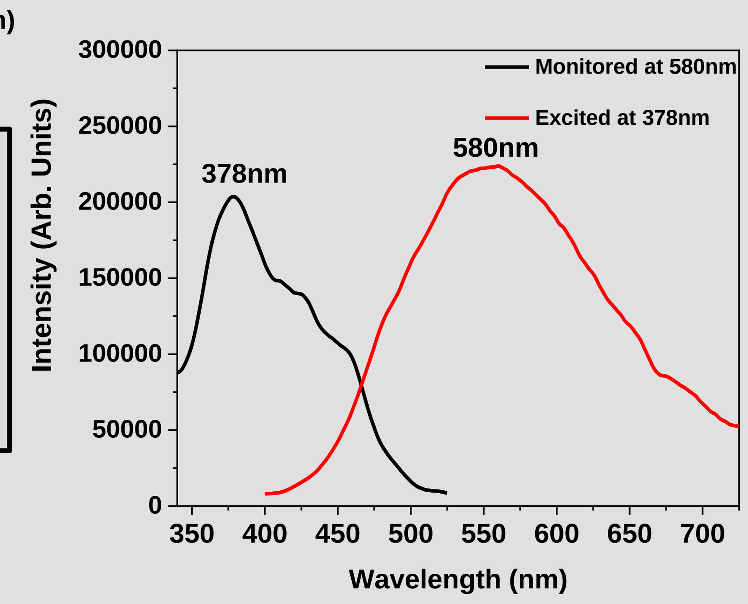


Figure 3. Emission/Excitation spectra of $\mathbf{P_2}$ in acetonitrile. λ_{em} = 580 nm

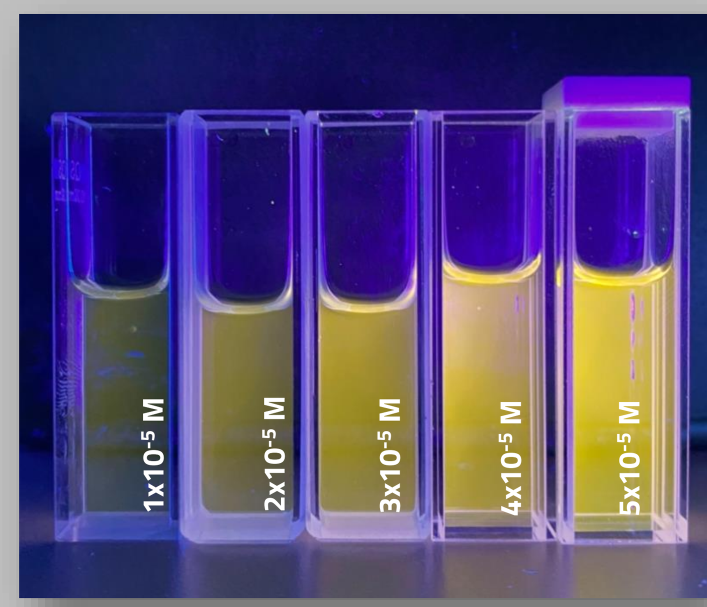


Figure 4. Dilute concentrations of $\mathbf{P_2}$ in acetonitrile (10^{-5} M) showing fluorescence under UV-light. Fluorescence can be used as a sensor or for degradation studies.

Figure 5. Qualitative fire-resistance studies. On the left: untreated 70% Polyester/30% Cotton fabric combusting after 3 seconds of flame exposure. Right: Same fabric but treated with 10^{-3} M $\mathbf{P_2}$ combusting after 10 seconds of flame exposure.

Conclusion

- A series of novel ionic fire-resistant polymers containing tosylate and triflimide counterions were synthesized.
- The identities of the polymers were confirmed using ^{1}H and ^{13}C NMR spectroscopy and elemental analysis.
- The emission spectrum of $\mathbf{P_2}$ shows a λ_{em} peak at 580 nm in acetonitrile.
- The UV-Vis spectrum shows a λ_{max} peak at 336 nm in acetonitrile.
- A 70% Polyester/30% Cotton fabric with $\mathbf{P_2}$ applied demonstrated robust fire-resistance.

Acknowledgements

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