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Preface

The Scientific Project Colloquium offers a platform for publishing Diploma Science final year projects (FYP). The objective is to effectively distribute research findings throughout all scientific disciplines. The primary objective of including final year projects into the course curriculum is to encourage students to put their theoretical knowledge into practical applications.

We would like to express our gratitude to our primary establishment, the Faculty of Applied Sciences and Universiti Teknologi MARA, Perak Branch, for their invaluable assistance.

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PRELIMINARY INVESTIGATION OF POLYCATIONIC POLYURETHANE ON IONIC CONDUCTIVITY

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Abstract: This study investigates five types of polycationic Polyurethane (PU) with an emphasis on their ionic conductivity performance. These preliminary studies reveal that each of the polycationic PU shows promising electrochemical properties, indicating their potential suitability for advanced applications in energy storage systems and electronic devices. By examining different formulations and compositions, this research identifies key factors that influence ionic conductivity and overall performance. The initial findings suggest that these polycationic PUs could significantly enhance the efficiency and functionality of next-generation technologies. This foundational research lays the groundwork for more detailed studies, aiming to explore the full potential of polycationic PUs in high-performance applications, such as batteries, supercapacitors, and other electronic components.

Keywords: Polycationic PUs, Synthesis, Electrochemical Properties, Ionic Conductivity, Polymerization Techniques

INTRODUCTION

Polyurethane (PU) that carries a positive charge is known as cationic PU. In these materials, the cationic groups are attached to the polymer backbone as pendant groups (El-Rahman,2018). This type of PU, recognized as a single-ion conductor, was proposed in the early 1980s (Blonsky, Shriver, Austin, & Allcock, 1986; Tikekar, Archer, & Koch, 2014). Cationic PUs are synthesized by incorporating alkyl halide groups into the polymer matrix through amine alkylation reactions. In the field of electrolytes research, cationic PUs are employed as polymer hosts to facilitate ion transfer, aiming to enhance ion mobility and improve ionic conductivity. Cationic PUs are also significant in various applications, including protective coatings, biocides, antistatic agents, antimicrobial nano-filters, and polymeric colorants. A typical synthesis involves using diols with tertiary amines as chain extenders, followed by tertiary amine alkylation to produce ammonium cations. Abdelsalam Sabbah's study noted the disappearance of an absorption band at 660 cm^{-1} and the emergence of a new band at 3040 cm^{-1} corresponding to C-N (Abdelsalam et al., 2018). This research is relevant for future applications of cationic PUs in solid films for electrochemical devices, focusing on how ion conductivity affects bulk resistance and the performance of the polymer in various applications. Figure 1 shows the Preparation of Cationic Polyurethane Surfactants by AbdelSalam et al.2018 studies.

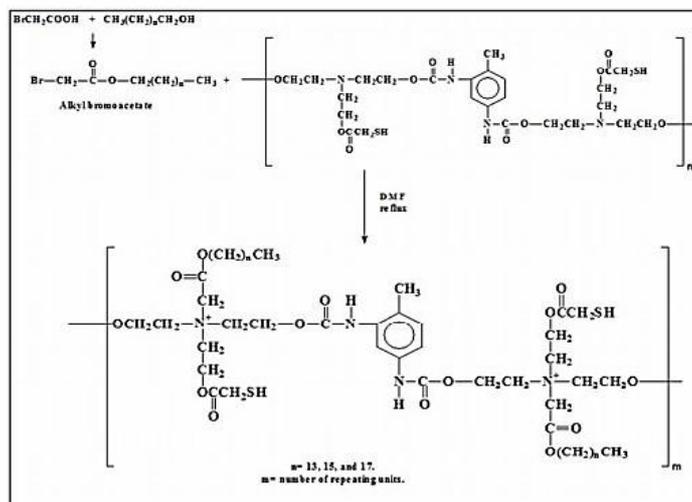


Figure 1: Preparation of Cationic Polyurethane Surfactants (Abdelsalam et al.2018)

METHODOLOGY

For this study, the most relevant research was selected based on key terms such as Polycationic Polyurethanes, Synthesis, Electrochemical Properties, Ionic Conductivity, and Polymerization Techniques. The focus was on studies that specifically address the performance of ionic conductivity in cationic polyurethanes without the inclusion of salts. This approach highlights the credibility of these materials and provides a foundation for future research aimed at further enhancing the performance of cationic polyurethanes.

RESULTS

The exploration of cationic PUs began in 2004 with Hiraoka et al., who incorporated ammonium ions into the polymer matrix. Their results revealed an ionic conductivity of approximately $\times 10^{-11}$ S/cm, a value that highlights the low ion mobility within the polymer matrix or potential inefficiencies in the interaction between ammonium ions and the polymer chains. This early research set a benchmark for understanding the limitations of ion conduction in cationic PUs. Building upon these findings, Liu et al. (2014) investigated the effect of adding 5 wt.% lithium perchlorates (LiClO₄) to cationic PUs. The introduction of LiClO₄, a well-known ionic salt, improved the ionic conductivity to approximately $\times 10^{-8}$ S/cm by increasing the concentration of free mobile ions. However, the conductivity remained relatively low, suggesting that further optimization was required for more effective interaction between the salt and the polymer matrix. Khutia et al. (2015) presented another approach by blending cationic PUs with polyvinyl alcohol (PVA). Despite the potential benefits of PVA in film-forming and compatibility with PUs, the resulting ionic conductivity was reported to be about $\times 10^{-11}$ S/cm. This extremely low conductivity suggests that while PVA offers certain advantages, it does not significantly enhance ionic conductivity in this context, indicating that the polymer blend and its microstructure play crucial roles in determining the performance. Subsequently, Xu et al. (2016) explored the incorporation of graphene into cationic PU composites, aiming to leverage graphene's high conductivity to improve the overall performance. Although the addition of graphene achieved an ionic conductivity of about $\times 10^{-8}$ S/cm, the results indicated that the dispersion of graphene within the PU matrix was not optimal. This finding underscores the need for improved integration strategies to enhance the effectiveness of graphene in boosting ionic conductivity. Finally, Su'ait et al. (2016) studied cationic PU PKO-p, which exhibited an ionic conductivity of approximately $\times 10^{-7}$ S/cm. This study indicated that while PKO-p shows relatively higher conductivity compared to earlier studies, it is still low compared to other conductive polymers. The research highlights the potential for further modifications to the PU matrix and cationic groups to improve conductivity. Table 1 provides a comprehensive summary of these studies, illustrating the progression and ongoing challenges in enhancing the ionic conductivity of cationic PUs.

Table 1: Cationic PUs in Solid Form Ionic Conductivity Performance

Sample (Solid Film)	Conductivity of PU S cm ⁻¹	References
Cationic PU-C ₃ H ₁₀ N ⁺	$\sim 10^{-11}$	Hiraoka et al. 2004
Cationic PU-5 wt. % LiClO ₄	$\sim 10^{-8}$	Liu et al. 2014
Cationic PU-PVA	$\sim 10^{-11}$	Khutia et al., 2015
Cationic PU-graphene	$\sim 10^{-8}$	Xu et al., 2016
Cationic PU PKO-p	$\sim 10^{-7}$	Su'ait et al., 2016

COMPLIANCE OF ETHICAL STANDARDS

Not applicable.

SUMMARY

Overall, this preliminary investigation establishes a foundation for future research aimed at optimizing polycationic polyurethanes for enhanced performance in high-tech applications. The study highlights key factors influencing ionic conductivity, such as the type and concentration of cationic groups and the overall polymer structure. It also evaluates the effects of different synthesis methods and processing conditions on ionic conductivity. The results underscore the potential of polycationic polyurethanes for energy storage and electronic devices due to their improved conductivity. Future research should focus on several critical areas to further enhance the ionic conductivity of cationic polyurethanes. This includes exploring various cationic groups and combining them with conductive additives to significantly improve conductivity. Investigating the impact of polymer morphology and processing conditions is also crucial for designing more efficient cationic polyurethanes. Efforts should be directed towards optimizing graphene dispersion and functionalization techniques or exploring alternative nanomaterials to boost conductivity in composite materials. For PU-PVA blends, identifying alternative polymers or additives that enhance conductivity while retaining desirable properties is essential, as is adjusting blending ratios and processing techniques to improve performance. Additionally, experimenting with different salt types, concentrations, and combinations, as well as optimizing their solubility and distribution within the polymer matrix, could further increase ionic conductivity. Finally, exploring alternative cationic species, polymerization methods, and cross-linking techniques may offer new insights and improvements in ionic conductivity. Initial findings suggest that incorporating cationic groups into the polyurethane matrix significantly impacts its ionic conductivity, with some formulations demonstrating promising results

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Kelulusan daripada pihak tuan dalam perkara ini amat dihargai.

Sekian, terima kasih.

“BERKHIDMAT UNTUK NEGARA”

Saya yang menjalankan amanah,

Setuju.

27.1.2023

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