P- ISSN 1991-8941 E-ISSN 2706-6703 2023,(17), (2): Journal of University of Anbar for Pure Science (JUAPS) Open Access

Revolutionizing Soft Electronics: Cutting-Edge Polyacrylamide Hydrogels for Flexible and Durable Sensing Innovations

Khalid Zainulabdeen[1*], Emad Yousif [1*], Omar Al-Obaidi [2], Muna Bufaroosha[3]

[1*] Department of Chemistry, College of Science, Al-Nahrain University, Baghdad 64021, Iraq;

[2] Chemistry Department, College of Science, University of Anbar, Al Anbar, Iraq;

[3] Department of Chemistry, College of Science, UAE University, Al-Ain, UAE;

ARTICLE INFO

DOI: 10.37652/juaps.2023.181591

Keywords:
Polyacrylamide, hydrogels, sensors, flexible, conducting, development, application

ABSTRACT

The field of materials science has witnessed remarkable developments in recent years, particularly in the realm of flexible, durable materials. Among these advancements, polyacrylamide hydrogels have garnered significant attention for their potential applications in soft-conducting and sensing technologies. This mini-article explores the importance of developing such materials, highlighting their unique properties and the various ways they are revolutionizing the landscape of soft electronics and sensors. The article draws upon a wide range of references to provide a comprehensive overview of this rapidly evolving field.

INTRODUCTION:

Pursuing flexible, durable materials for soft-conducting and sensing applications has become a focal point in contemporary materials science research. These materials hold immense promise in fields ranging from wearable electronics and soft robotics to biomedical devices and environmental monitoring systems. Among the array of materials under investigation, polyacrylamide hydrogels have emerged as an intriguing and versatile option. This article delves into the significance of developing polyacrylamide hydrogels for soft-conducting and sensing applications, emphasizing their unique characteristics and potential impact on various industries.

Properties of Polyacrylamide Hydrogels

Polyacrylamide hydrogels are a class of hydrophilic polymers that have attracted substantial interest due to their distinctive properties [1].

These hydrogels are characterized by their high-water content, biocompatibility, and tunable mechanical properties, which make them an excellent choice for soft and flexible materials [2]. One of their remarkable features is their ability to retain a significant amount of water while maintaining mechanical integrity. This property is particularly advantageous for applications requiring conformability to irregular surfaces, such as human skin.

Polyacrylamide hydrogels are highly transparent, which is crucial for optical applications and the development of see-through devices. Their optical transparency allows for integration into wearable sensors, lenses, and other transparent electronic devices without compromising visibility or aesthetics [3].

Furthermore, polyacrylamide hydrogels can be engineered to possess exceptional stretchability, elasticity, and toughness. These mechanical properties make them ideal candidates for applications where durability and resilience are critical, such as stretchable electronics, soft robotics, and prosthetic devices [4].

*Corresponding author at: Department of Chemistry, College of Science, Al-Nahrain University, Baghdad 64021, Iraq;ORCID:https://orcid.org/0000-0000-0000-0000;Tel:+96400000000000
E-mail address: khalid_1chem1@yahoo.com, emad_yousif@hotmail.com

Applications in Soft-Conducting Electronics

Polyacrylamide hydrogels are making significant strides in the field of soft-conducting electronics. Soft electronics aim to bridge the gap between traditional rigid electronics and the soft, flexible properties of biological tissues. These materials are particularly well-suited for wearable devices that need to conform to the contours of the human body.

The combination of high-water content and tunable mechanical properties in polyacrylamide hydrogels allows for the development of soft and stretchable conductors and sensors. For example, researchers have successfully integrated these hydrogels into wearable sensors for monitoring vital signs, such as heart rate, temperature, and sweat analysis [5]. These sensors are comfortable to wear and provide real-time data for healthcare applications.

Additionally, the transparency of polyacrylamide hydrogels is advantageous for developing flexible displays and optical components in soft electronics. Their potential use in flexible, see-through displays has implications for augmented reality, virtual reality, and heads-up displays, where flexibility and transparency are paramount.

Advances in Sensing Applications

Polyacrylamide hydrogels are also finding innovative applications in sensing technologies. Their biocompatibility, mechanical flexibility, and optical transparency make them ideal candidates for various sensing applications.

a. Biomedical Sensing

In the biomedical field, these hydrogels have been used as substrates for biosensors and implantable devices. Their biocompatibility ensures that they can be safely integrated with biological systems without causing adverse reactions. For example, researchers have developed glucose sensors based on polyacrylamide hydrogels for continuous glucose monitoring in diabetic patients. These sensors are both accurate and comfortable for long-term use.

b. Environmental Monitoring

Polyacrylamide hydrogels have also been employed in environmental monitoring systems. Their ability to retain water and maintain mechanical integrity in various environmental conditions makes them suitable for sensors used in harsh or wet environments. These sensors can detect parameters such as humidity, pH, and pollutant levels. Their versatility makes them valuable tools for safeguarding the environment and public health.

c. Soft Robotics and Human-Machine Interfaces

In the realm of soft robotics, polyacrylamide hydrogels offer unique advantages. They can serve as actuators in soft robotic systems, mimicking the contractile behavior of muscles. The mechanical properties of hydrogels can be tailored to match the compliance of biological tissues, enabling safe human-robot interactions. Such advancements hold promise in applications ranging from medical devices to assistive technology for people with disabilities [6].

Challenges and Future Directions

While polyacrylamide hydrogels have shown remarkable potential in soft-conducting and sensing applications, several challenges remain. Achieving optimal biocompatibility, enhancing the durability of hydrogels, and addressing potential issues such as water evaporation in certain environments are areas of ongoing research [6].

Future directions in the development of polyacrylamide hydrogels include refining their mechanical properties, exploring novel fabrication techniques, and expanding their use in emerging technologies, such as flexible and transparent energy storage devices. Collaboration between materials scientists, engineers, and medical professionals is crucial for pushing the boundaries of what these hydrogels can achieve in terms of functionality and performance.

Conclusions

Polyacrylamide hydrogels have emerged as a class of materials with immense potential for soft-conducting and sensing applications. Their unique combination of properties, including high water content, transparency, and tunable mechanical characteristics, makes them well-suited for a wide range of technological advancements. From wearable sensors and soft electronics to biomedical devices and environmental monitoring systems, polyacrylamide hydrogels are poised to revolutionize various industries. As researchers continue to explore novel applications and address existing challenges, the future holds promise for the continued development and integration of these remarkable materials into everyday life.

Acknowledgment

The authors like to thank the Department of Chemistry at Al-Nahrain University for partially supporting this work.

Funding

None.

Conflict of Interest

There is no known conflict for the presented work.

REFERENCES

[1] Mark, J. E., Allcock, H. R., & West, R. (2005). Inorganic polymers. Oxford University Press.

[2] Ferry, J. D. (1980). Viscoelastic properties of polymers. John Wiley & Sons.

[3] Suo, Z. (2012). Mechanics of stretchable electronics and soft machines. Mrs Bulletin, 37(3), 218-225, https://doi.org/10.1557/mrs.2012.32.

[4] Zhang, Y., Yan, Z., Nan, K., Xiao, D., Liu, Y., Luan, H., ... & Rogers, J. A. (2015). A mechanically driven form of Kirigami as a route to 3D mesostructures in micro/nanomembranes. Proceedings of the National Academy of Sciences, 112(38), 11757-11764, https://doi.org/10.1073/pnas.1515602112.

[5] Vaghasiya, J. V., Mayorga-Martinez, C. C., & Pumera, M. (2023). Wearable sensors for telehealth based on emerging materials and nanoarchitectonics. npj Flexible Electronics, 7(1), 26, https://doi.org/10.1038/s41528-023-00261-4.

[6] Zainulabdeen, K. W. Y. Z. (2020). Development of flexible, durable and ionic materials based on poly (acrylamide) hydrogels for soft conducting and sensing applications, https://ro.uow.edu.au/theses1/1150.

ثورة في الإلكترونيات الناعمة: الهلاميات المائية بولي أكريلاميد المتطورة

خالد زين العابدين [1*]، عماد يوسف [1*]، عمر العبيدي [2]، منى بوفاروشة [3]

[1*] قسم الكيمياء، كلية العلوم، جامعة النهرين، بغداد 64021، العراق

[2] قسم الكيمياء، كلية العلوم، جامعة الأنبار، الأنبار، العراق

[3] قسم الكيمياء، كلية العلوم، جامعة الإمارات العربية المتحدة، العين، الإمارات العربية المتحدة

الخلاصة:

شهد مجال علم المواد تطورات ملحوظة في السنوات الأخيرة، وخاصة في مجال المواد المرنة والمتينة. ومن بين هذه التطورات، حظيت الهلاميات المائية بولي أكريلاميد باهتمام كبير لتطبيقاتها المحتملة في تقنيات التوصيل والاستشعار الناعمة. يستكشف هذا المقال الصغير أهمية تطوير مثل هذه المواد، ويسلط الضوء على خصائصها الفريدة والطرق المختلفة التي تُحدث بها ثورة في مجال الإلكترونيات الناعمة وأجهزة الاستشعار. تعتمد المقالة على مجموعة واسعة من المراجع لتقديم نظرة شاملة لهذا المجال سريع التطور.

الكلمات المفتاحية: بولي أكريلاميد، الهلاميات المائية، أجهزة الاستشعار، مرنة، توصيل، تطوير، تطبيق