sustainability

MDPI

Editorial

Advances in Sustainable Nanocomposites

Mohd Shahneel Saharudin [1,*], R. A. Ilyas [2], Nuha Awang [3], Syafawati Hasbi [4], Islam Shyha [5] and Fawad Inam [6]

[1] School of Engineering, Robert Gordon University, Garthdee Road, Aberdeen AB10 7QB, UK
[2] Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, Johor 81310, Malaysia; ahmadilyas@utm.my
[3] Malaysian Institute of Industrial Technology (UniKL MITEC) Bandar Seri Alam, Universiti Kuala Lumpur, Johor 81750, Malaysia; nuha.awang@unikl.edu.my
[4] Department of Mechanical Engineering, Faculty of Engineering, National Defense University Malaysia, Kuala Lumpur 57000, Malaysia; syafawati@upnm.edu.my
[5] School of Engineering and The Built Environment, Edinburgh Napier University, Edinburgh EH10 5DT, UK; i.shyha@napier.ac.uk
[6] School of Architecture, Engineering and Computing, University of East London, London E16 2RD, UK; f.inam@uel.ac.uk
* Correspondence: s.saharudin@rgu.ac.uk; Tel.: +44-(0)-1224-262-000 (ext. 4252)

1. Introduction

Advances in Sustainable Nanocomposites is a newly opened Special Issue of *Sustainability*, that aims to publish original and review papers on the new scientific development of sustainable nanocomposite materials that are accelerated by zero-carbon policy goals. As the world becomes increasingly aware of the environmental challenges posed by carbon emissions, the demand for sustainable nanocomposite materials has increased. Nanocomposites are emerging as promising alternatives to traditional materials because of their unique properties that make them suitable for use in environmentally friendly technological applications [1]. Nanocomposites are materials made from a combination of a matrix material and nanoparticles that are typically smaller than 100 nm in size [2]. The resulting materials have properties that are different from those of the individual components, allowing for the creation of materials with tailored properties.

One of the key advantages of nanocomposites, is their high specific strength, which is related to their strength-to-weight ratio. This property makes them ideal for use in lightweight structures, such as in aerospace and automotive applications, where weight reduction can lead to significant reductions in fuel consumption and carbon emissions [3]. Nanocomposites also exhibit excellent dimensional stability, meaning that they are less likely to deform or warp over time [4]. This property makes them well suited for use in precision manufacturing applications, such as in the electronics industry and electric vehicle structural elements. Another advantage of nanocomposites is their recyclability [5]. Unlike many traditional materials, nanocomposites can be broken down and reused, reducing waste and the need for new raw materials. This makes them an attractive option for manufacturers seeking to reduce their carbon footprint. Overall, the use of nanocomposites in environmentally friendly technological applications has the potential to contribute significantly to the transition towards a carbon-neutral society. By taking advantage of their unique properties, nanocomposites offer a promising alternative to traditional materials that can help reduce carbon emissions and promote sustainability. As research into these materials continues, it is likely that their applications will only continue to expand.

2. Challenges

The development of sustainable nanocomposites is a promising avenue for reducing carbon emissions and promoting sustainability. However, the creation of these materials

check for updates

Citation: Saharudin, M.S.; Ilyas, R.A.; Awang, N.; Hasbi, S.; Shyha, I.; Inam, F. Advances in Sustainable Nanocomposites. *Sustainability* **2023**, *15*, 5125. https://doi.org/10.3390/su15065125

Received: 7 March 2023
Revised: 9 March 2023
Accepted: 13 March 2023
Published: 14 March 2023

is not without its challenges. One of the main challenges of sustainable nanocomposites is cost. The production of nanoparticles and the incorporation of these particles into a matrix material can be expensive. This cost can be a barrier to the adoption of sustainable nanocomposites, particularly in industries where cost is a major consideration [6]. Finding ways to reduce the cost of production is an important area of research for the development of sustainable nanocomposites. Another challenge is performance. While nanocomposites offer unique properties, such as high specific strength and dimensional stability, their performance can be influenced by factors such as particle size, dispersion, and orientation [7]. Achieving consistent and predictable performance across a range of conditions is an ongoing challenge in the development of nanocomposites. Scalability is another important consideration for the development of sustainable nanocomposites [8]. While laboratory-scale production of nanocomposites is feasible, scaling up production to industrial levels can be difficult. Factors such as processing time, equipment requirements, and environmental impact must be considered in the scaling up process.

3. Opportunities

Despite these challenges, there are many opportunities for the development of sustainable nanocomposites. One key area of focus is life cycle assessment, which considers the environmental impact of a material from production to disposal. Understanding the environmental impact of nanocomposites can inform decisions about their use and help to identify areas for improvement. Nanocomposite manufacturing is another important area of research, as the manufacturing process can significantly impact the performance and properties of nanocomposites. Finding ways to optimize the manufacturing process can improve the quality and consistency of nanocomposites. One of the key applications of nanocomposites is in lightweight composites for electric vehicle structural elements, which can significantly reduce the weight of the vehicle and increase its energy efficiency. Additionally, nanocomposites can be used in the production of bioplastics and biocomposites, which are environmentally friendly alternatives to traditional plastics [9]. These materials can be used in a variety of applications, such as packaging and consumer goods, and have the potential to reduce the environmental impact of these industries.

Coating and thin film materials are also an area of focus for the development of sustainable nanocomposites. Coatings can enhance the properties of a material and protect it from environmental factors such as corrosion [10]. Thin film materials can be used to create high-performance devices such as sensors and transistors. Tribological analysis, which considers the wear and friction properties of a material, is also an important area of research for sustainable nanocomposites [11]. Understanding the tribological properties of nanocomposites can inform decisions about their use in applications such as bearings and gears. Finally, modelling and simulation can be used to predict the performance of nanocomposites under a range of conditions [12]. This can help to identify areas for improvement and optimize the properties of nanocomposites for specific applications. The development of sustainable nanocomposites offers many opportunities for reducing carbon emissions and promoting sustainability. While challenges such as cost, performance, and scalability must be addressed, ongoing research into areas such as life cycle assessment, composite manufacturing, coating and thin film materials, tribological analysis, and modelling and simulation are helping to overcome these challenges and pave the way for a more sustainable future.

4. Conclusions

In conclusion, the development of sustainable nanocomposites holds great promise for reducing carbon emissions and contributing to a more sustainable future. While challenges such as cost, performance, and scalability must be addressed, ongoing research and innovation in areas such as life cycle assessment, composite manufacturing, coating and thin film materials, tribological analysis, and modelling and simulation are helping to overcome these obstacles. Collaborative efforts across industries and disciplines will be crucial for

accelerating the development of sustainable nanocomposites and their adoption in environmentally friendly technological applications. The potential applications of nanocomposites, such as lightweight composites for electric vehicle structural elements, bioplastics, and biocomposites, further emphasize their importance in achieving a carbon-neutral society. With continued investment and focus on this promising field, sustainable nanocomposites have the potential to shape a more sustainable future for generations to come.

Author Contributions: Writing—original draft preparation, M.S.S., R.A.I., N.A. and S.H.; writing—review and editing, I.S. and F.I. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: We would like to extend our sincere gratitude and appreciation to the academic institutions that have contributed to the research and development of this article. Firstly, we express our thanks to the Robert Gordon University for providing the necessary support and resources for the research project. We would also like to thank Universiti Teknologi Malaysia, Universiti Kuala Lumpur, Edinburgh Napier University, and University of East London for their valuable contributions towards this research. Their expertise and collaboration have greatly enhanced the quality and significance of this article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Abdur Rahman, M.; Haque, S.; Athikesavan, M.M.; Kamaludeen, M.B. A Review of Environmental Friendly Green Composites: Production Methods, Current Progresses, and Challenges. *Environ. Sci. Pollut. Res.* **2023**, *30*, 16905–16929. [CrossRef] [PubMed]
2. Okolo, C.; Rafique, R.; Iqbal, S.S.; Saharudin, M.S.; Inam, F. Carbon Nanotube Reinforced High Density Polyethylene Materials for Offshore Sheathing Applications. *Molecules* **2020**, *25*, 2960. [CrossRef] [PubMed]
3. Das, O.; Babu, K.; Shanmugam, V.; Sykam, K.; Tebyetekerwa, M.; Neisiany, R.E.; Försth, M.; Sas, G.; Gonzalez-Libreros, J.; Capezza, A.J.; et al. Natural and Industrial Wastes for Sustainable and Renewable Polymer Composites. *Renew. Sustain. Energy Rev.* **2022**, *158*, 112054. [CrossRef]
4. Andrew, J.J.; Dhakal, H.N. Sustainable Biobased Composites for Advanced Applications: Recent Trends and Future Opportunities—A Critical Review. *Compos. Part C Open Access* **2022**, *7*, 100220. [CrossRef]
5. Sojobi, A.O.; Liew, K.M. Multi-Objective Optimization of High Performance Bio-Inspired Prefabricated Composites for Sustainable and Resilient Construction. *Compos. Struct.* **2022**, *279*, 114732. [CrossRef]
6. Valino, A.D.; Dizon, J.R.C.; Espera, A.H.; Chen, Q.; Messman, J.; Advincula, R.C. Advances in 3D Printing of Thermoplastic Polymer Composites and Nanocomposites. *Prog. Polym. Sci.* **2019**, *98*, 101162. [CrossRef]
7. Wei, J.; Vo, T.; Inam, F. Epoxy/Graphene Nanocomposites—Processing and Properties: A Review. *RSC Adv.* **2015**, *5*, 73510–73524. [CrossRef]
8. Griffin, A.; Guo, Y.; Hu, Z.; Zhang, J.; Chen, Y.; Qiang, Z. Scalable Methods for Directional Assembly of Fillers in Polymer Composites: Creating Pathways for Improving Material Properties. *Polym. Compos.* **2022**, *43*, 5747–5766. [CrossRef]
9. Arif, Z.U.; Khalid, M.Y.; Sheikh, M.F.; Zolfagharian, A.; Bodaghi, M. Biopolymeric Sustainable Materials and Their Emerging Applications. *J. Environ. Chem. Eng.* **2022**, *10*, 108159. [CrossRef]
10. Al-Maadeed, P.; Vijayan, P. Self-Repairing Composites for Corrosion Protection: A Review on Recent Strategies and Evaluation Methods. *Materials* **2019**, *12*, 2754. [CrossRef]
11. Sumithra, H.; Sidda Reddy, B. A Review on Tribological Behaviour of Natural Reinforced Composites. *J. Reinf. Plast. Compos.* **2018**, *37*, 349–353. [CrossRef]
12. Fu, G.; Huo, D.; Shyha, I.; Pancholi, K.; Saharudin, M.S. Experimental Investigation on Micro Milling of Polyester/Halloysite Nano-Clay Nanocomposites. *Nanomaterials* **2019**, *9*, 917. [CrossRef] [PubMed]