Cite this article
Guigo N (2024)
Editorial.
Green Materials **12(4)**: 223–224,
https://doi.org/10.1680/jgrma.2024.12.4.223

Editorial

Green Materials

Editorial

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Composites, by definition, are materials made from two or more constituent elements with significantly different physical or chemical properties. When combined, they produce a material with characteristics different from the individual components. The synergy between the matrix and reinforcement is the key to their exceptional performance. The journey of composites dates to ancient civilizations, with, for instance, the Egyptians using straw-reinforced clay bricks.

Leonardo da Vinci, the renowned Renaissance polymath, made significant contributions to the field of materials science and engineering that continue to influence modern material design. While composite materials as we know them today did not exist in da Vinci's time, his innovative approach to materials and structures laid important groundwork for future developments. Da Vinci recognized the importance of understanding material properties and their behavior under different conditions. He designed and proposed machines for tensile testing and impact testing of materials, which were revolutionary concepts for his era. These ideas are fundamental to modern materials characterization techniques used in composite material development.

"*Go take your lessons in nature*". This advice underscores Leonardo da Vinci's belief that nature is the ultimate source of inspiration for artists, scientists, and inventors alike. It encourages a direct, experiential approach to learning from the natural world, which was a cornerstone of da Vinci's own methodology in his diverse pursuits.

Furthermore, da Vinci is considered a pioneer of bio-inspired design, an approach that is highly relevant to contemporary composite materials research. His keen observations of nature and its structures informed his designs and inventions. This bio-inspired approach is now a significant aspect of advanced composite material development, where researchers often look to natural structures for inspiration in creating strong, lightweight, and multifunctional materials. Da Vinci's work on structural design, particularly his studies on the strength and behavior of different geometries, has indirect implications for composite material design. His understanding of how shape and structure contribute to overall strength and performance is a principle that underpins much of modern composite material engineering.

Today, as we face unprecedented environmental challenges, the focus of composite materials has shifted to sustainable alternatives. Bio-based composites offer a solution by utilizing renewable resources, reducing our dependence on fossil fuels, and potentially lowering carbon footprints. The challenge now lies in scaling up production and optimizing performance to match or exceed that of conventional composites. With ongoing research and development, bio-based composites are not just an eco-friendly alternative – they represent the next frontier in materials science.

In an era where environmental concerns are paramount, the SUSPENS[1] project, granted by the European Commission under the Horizon Europe research and innovation programme (Grant Agreement No. 101091906), aims to revolutionize the composite industry by developing eco-friendly alternatives to traditional petroleum-based products. The SUSPENS consortium is pushing the boundaries of material science by developing up to 95% bio-sourced epoxy and polyester resins. These resins are derived from sustainable sources like flax formulated to match or exceed the performance of conventional fossil-based composites. Complementing the bio-sourced resins, SUSPENS is exploring sustainable reinforcements that include natural cellulose fibers, lignin-based carbon fibers and recycled carbon and glass fibers. This holistic approach ensures that both the matrix and reinforcement components of the composites are environmentally conscious, significantly enhancing their sustainability profile. SUSPENS aims to demonstrate the practical applications of these sustainable composites through the manufacturing of several key products such as an automotive battery pack, a leisure boat hull and deck or an aircraft winglet. SUSPENS goes beyond merely creating sustainable materials; it also addresses end-of-life concerns. The project is developing innovative recycling solutions, including a matrix pyrolysis process that utilizes waste heat from carbon fiber production, significantly reducing energy consumption. Additionally, a solvolysis process for bio-sourced resins will enable the recovery of matrix constituents. A comprehensive life cycle analysis will measure the environmental impact of these materials, with an ambitious goal of reducing CO_2 equivalent emissions by 40–50%.

In this line of shifting to more sustainable composite materials, this issue of Green Materials includes several papers that demonstrate some key advances in this field.

The first paper[2] presents a pathway to create lightweight composites by combining a geopolymer made from fly ash bricks and wheat straw fibers. Composites with higher strength are obtained when wheat straw is pretreated with sodium hydroxide as the consequence of higher bonding strength between the geopolymer matrix and the fibers.

Plastic packaging represents the predominant use of petroleum-based plastics, and their absence of biodegradability poses serious environmental concerns. Therefore, the second paper[3] proposes a new edible biocomposites made pectin-alginate films reinforced with orange peel powder – a food residue. The films are fully biodegradable and orange peel powder can be incorporated in significant amount (up to 30 wt%) without sacrificing the flexibility. Morphological, thermal and barrier properties of these reinforced films are also very promising for developing applications.

Metal-organic framework and in particular Zeolitic imidazolate framework-8 (ZIF-8) is a class of materials that have interesting applications in pollutant adsorption and photocatalytic degradation. However, their immobilization is still a challenge. Therefore, the third paper[4] showcases an original investigation that utilize polydopamine-covered wood sponge to attach ZIF-8. The resulting composite was effective in adsorbing toluene contaminants from water.

To address the construction industry's high non-renewable energy use and carbon dioxide emissions, phase-change material energy-storage heating systems (PCMEHSs) can be sustainable solutions for building heating. In this line, the fourth paper[5] presents a new composite phase change material with enhanced properties that was prepared with a hydrated inorganic salt mixture combined with extended graphite. The presence of extended graphite lead to a phase change material with high thermal conductivity thus favoring the heat-transfer rates.

Altogether, this issue of *Green Materials* demonstrates that green composites can have a pivotal role in redefining industrial applications such as in construction, packaging, energy storage, and many more. Other articles in this issue present innovative solutions for the emergence of greener materials.

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