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Editorial

Green Materials

Editorial: Advancement in sustainable green manufacturing techniques for plant-based natural fiber composites

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Residents' awareness of the environmental effects of industrial manufacturing has grown dramatically in recent years. As a result of this shift, a number of organizations have realized how critical it is to implement sustainable practices that simultaneously benefit the environment and the economic. For scholars, business executives, policymakers, and students who want to understand the driving forces behind the shift to more environmentally friendly production methods, this special issue is a priceless resource. Research on plant fiber–reinforced composites has significantly increased as a result of the need for sustainable innovation. People usually praise synthetic fiber composites for their remarkable mechanical strength, but questions remain about their biological compatibility and environmental durability. On the other hand, natural fiber composites made from plants and made from renewable and biodegradable materials are a good choice for the environment. It is crucial to keep developing material science and production techniques to solve the current problems with mechanical performance and durability.

Punia *et al*.[1] examined the rationale for corporations' adoption of additive manufacturing (AM), emphasizing the technology's advantages for environmental sustainability and material efficiency. This examines how AM's layer-by-layer manufacture significantly reduces material waste compared to traditional subtractive processes, while also enabling lightweight designs that utilize less resources. The study examines trade-offs; for instance, although AM can significantly decrease the amount of raw materials required, high-intensity instruments such as lasers and powder atomization may occasionally need greater energy consumption along with classification of AM as shown in Figure 1. Moreover, metal AM powders may require additional constituents, complicating their utilization in a closed-loop system and recycling processes. The paper examines the primary motivations for firms to adopt AM and highlights its attractive features. A significant aspect of the research examines AM's recycling systems and demonstrates their contribution to enhancing environmentally sustainable production. Classifying AM processes by material type enhances our comprehension of the relationship between material efficiency and environmental objectives. The study examines how AM may improve operating efficiency, increase customization options, and attain superior design precision relative to conventional production methods. The assessment indicates that insufficient long-term, empirical data exists about the environmental impact of AM; hence, further research is necessary to explore its practical use and the recycling of technological advancements. The study employs many life-cycle assessments to compare AM with traditional production across various sizes and forms. The research indicates that AM is most effective for components that are either limited in quantity or very complex non-solid geometries. In these instances, its design adaptability and material efficiency compensate for its energy deficiencies.

In their paper, Xu J *et al*.[2] examined novel aerogel made of graphene oxide and glutamine-modified chitosan, or GCG. This aerogel is intended to remove both the anionic color methyl orange and copper (Cu^{2+}) ions from water at the same time. According to the study, GCG performs noticeably better than an unaltered grapheme–chitosan composite. At a pH of 3 and a temperature of 25°C, it may retain up to 261.8 mg of methyl orange per gram. At pH 6 at the equivalent temperature, the concentration of copper ions reaches around 74.8 mg/g. The Langmuir isotherm model well describes the adsorption process, which adheres to a pseudo-second-order kinetic framework. Aerogel exhibits significant reusability, which is crucial. Following six sorption–desorption cycles, it retains over 85% of its original adsorption effectiveness. By integrating the extensive surface area of graphene with the many functional groups found in chitosan and including glutamine functionalization, GCG produces a versatile and sustainable nano-adsorbent very effective in eliminating dyes and heavy metals. This work by Chahar *et al*.[3] investigated the influence of varying fiber weight percentages on the mechanical and wear characteristics of eco-friendly hybrid composites formed by incorporating hemp, jute, and bamboo fibers into an epoxy resin matrix. Specimens were fabricated using a manual lay-up technique by amalgamating fibers in different proportions (up to 15 weight percent) with epoxy resin to produce panels for evaluation. The mechanical properties included tensile strength, flexural stiffness, impact resistance, and frictional wear. In contrast to pure epoxy, the use of natural fibers significantly enhanced mechanical performance in all formulations. The composite with 15 weight percent fiber content exhibited optimal properties: a specific wear rate of approximately $1.824 \times 10^{-8}\ m^3/N \cdot m$, a tensile strength of roughly 54.3 MPa, a flexural strength of around 158.5 MPa, and

Figure 1. Classification of additive manufacturing[1]

an impact energy absorption of approximately 11.85 kJ/m^2. Finite element analysis simulations were conducted and juxtaposed with experimental data to validate these findings. The study indicates a distinct trend: at the optimal 15 weight percent level, advantages tend to stabilize, however augmenting fiber content generally enhances tensile and flexural strength, impact resistance, and wear rate. These improvements are attributed to the natural fibers' ability to strengthen and the effective stress transfer facilitated by the fiber matrix interface. A multipurpose nano-fiber membrane that can concurrently capture volatile organic compounds (VOCs) and fine particulate matter (PM) is shown by Sun J *et al*.[4] Without the use of hazardous solvents, the membrane is produced from a bio-based polymer matrix by physical cross-linking and an environmentally benign electrospinning process. Figure 2 shows the synthesis and application of Pt/Co_3O_4-CeO_2@PI. For PM1.0, the filter's particle removal efficiency exceeds 99%, guaranteeing excellent filtration performance. In addition, it maintains a small pressure drop (about 35 Pa), which makes airflow movement easy. Mechanistic study indicates that the use of tannic acid enhances mechanical strength and pollutant adsorption by establishing extensive hydrogen bonds with polymer chains, hence facilitating structural stability and prolonged filtration capacity.

Kumawat *et al*.[5] reinforced aluminum using silicon carbide (SiC) particles and banana stem fibers to create a sustainable metal–matrix composite. The researchers want to use ceramic

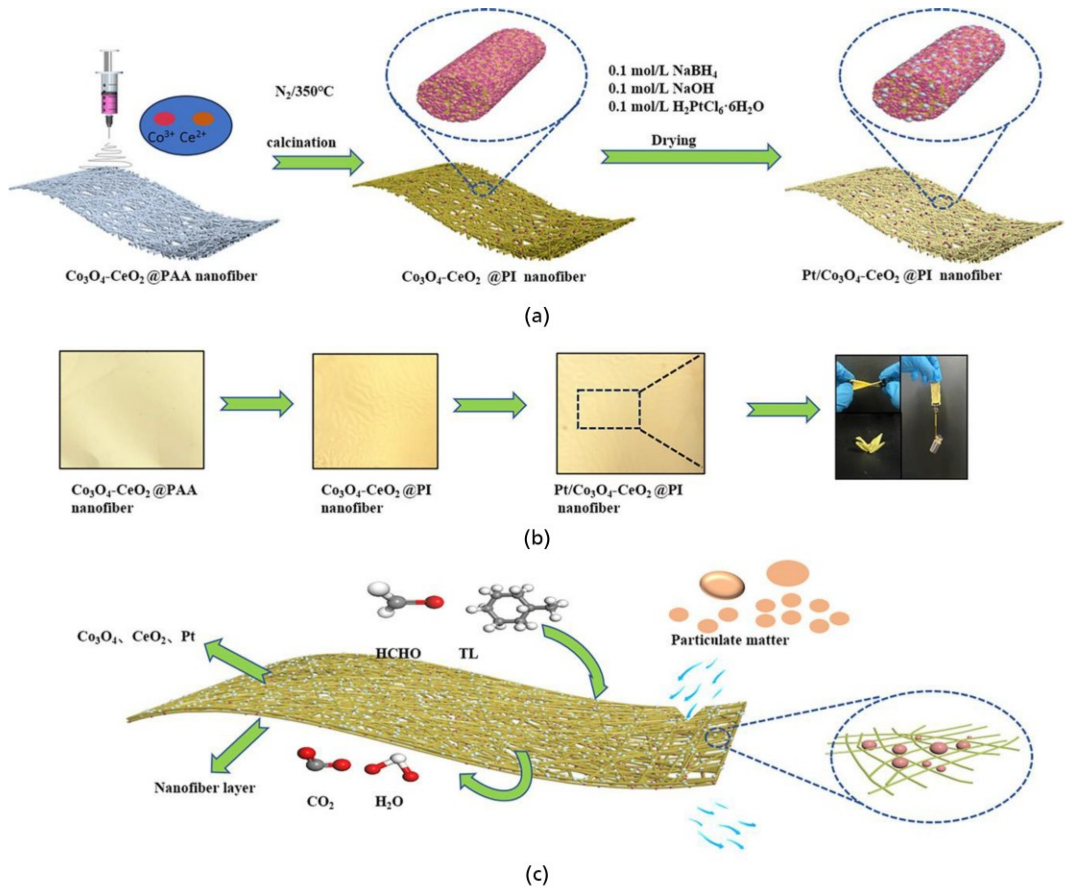

Figure 2. Synthesis and application of Pt/Co_3O_4-CeO_2@PI

SiC and banana fibers from agro-waste to create lightweight, mechanically strong composites with improved thermal and structural qualities. Banana stem fibers and SiC were integrated into an aluminum matrix by casting methods. The resulting attributes were subsequently assessed by mechanical testing and microscopic analysis. Experimental findings indicate that hybrids including both banana fiber and SiC exhibit much greater stiffness and strength compared to pure aluminum. Microstructural investigations demonstrated enhanced interfacial bonding and uniform dispersion, which contributed to increased load-transfer efficiency. Favorable impacts were seen in thermal behavior; nevertheless, the abstract lacked specific data. The composite exhibited several performance enhancements relative to the unreinforced matrix alloy. This study emphasizes the significance of combining ceramic and natural fiber reinforcement in aluminum-based materials to enhance mechanical and environmental performance. The composite provides an eco-friendly alternative that maintains strength and durability by replacing synthetic or purely metallic fillers with biodegradable banana stem fibers and inorganic SiC. The authors indicate that it can be utilized in many applications where cost-effectiveness, sustainability, and lightweight strength are desired. The study introduces a hybrid aluminum composite that efficiently integrates ceramic reinforcement with agricultural waste. It presents a promising combination of sustainability potential, structural integrity, and mechanical enhancement, facilitating the development of more eco-friendly, high-performance materials in industrial applications.

To promote sustainable industrial production in accordance with Sustainable Development Goal 9 (industry, innovation, infrastructure), Sharma *et al.*[6] examined the integration of three-dimensional (3D) printing technologies, composite fiber manufacturing, and Internet of Things (IoT) systems within the context of a circular economy. The authors illustrate how IoT, by way of networked sensors, provides manufacturers with real-time monitoring capabilities that enable proactive maintenance, defect detection, and predictive analytics. These qualities facilitate the production of composite fibers by optimizing resource use, reducing waste, and decreasing energy consumption. By incorporating IoT into AM processes, operators may enhance their control over material flow, energy usage, and quality assurance. This will also promote a transition to reuse-oriented production methods. A significant element is the integration of IoT with circular economy frameworks, which diminish environmental impacts by recovering and reconstructing composite materials using closed-loop technologies and renewable or recycled fiber feedstocks. The paper consolidates recent advancements in IoT-enhanced composite printers to establish more intelligent and sustainable production networks, encompassing systems that monitor deposition precision, material efficiency, thermal regulation, and machinery performance. Interoperability across diverse IoT systems, cybersecurity vulnerabilities, scalability challenges, and the necessity for effective industry-wide standards are significant concerns that have been addressed. The evaluation recommends artificial intelligence–powered analytics, machine learning for predictive diagnostics, and modular IoT architecture to enhance material efficiency and system robustness. The author proposes further research focused on standardizing IoT-enabled frameworks, exploring bio-based and recycled composite materials, and validating real-world deployment outcomes. The objective is to enhance supply chain reliability, foster energy-efficient practices, and reduce waste in the production of 3D-printed composite fibers, therefore advancing industrial innovation and sustainability. This paper offers a valuable framework for integrating IoT and circular economy principles in additive composite manufacturing, demonstrating how these intelligent, interconnected systems may foster innovation and sustainable industrialization in alignment with SDG 9. Kumar A *et al.*[7] examined the impact of antioxidant chemicals on the dielectric properties of a plant-derived insulating oil, namely, the natural ester Envirotemp, as a sustainable substitute for traditional mineral oil in transformers. Despite their prevalent use, mineral oils pose environmental and fire risks, prompting research in renewable and biodegradable substitutes. The study used statistical models, namely, the normal and Weibull distributions, to evaluate the impact of two antioxidants, butylated hydroxytoluene (BHT) and citric acid (CA), on the AC breakdown voltage of the ester at varying risk levels (1%, 25%, and 50%). The results indicate that the use of antioxidants significantly enhances dielectric strength; BHT yields the most substantial enhancement (~32%), while CA results in an improvement of around 24%. The integrity of the data set was validated by the strong conformity of all breakdown voltage values to both normal and Weibull statistical distributions. The study underscores the need of meticulously regulating antioxidant levels, since exceeding recommended thresholds (about 0.3 wt%) may diminish insulating efficacy and elevate conductivity or dielectric loss.

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