Editorial Corner

Advanced Materials and Technologies for Engineering Applications

Indran Suyambulingam, Sanjay Mavinkere Rangappa* and Suchart Siengchin
Natural Composites Research Group Lab, Department of Materials and Production Engineering, The Sirindhorn International Thai-German School of Engineering (TGGS), King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

* Corresponding author. E-mail: mavinkere.r.s@op.kmutnb.ac.th DOI: 10.14416/j.asep.2023.01.008

Historical roots in metallurgy and solid-state physics have given way to a more expansive field known as materials science, which supports many branches of physical and engineering science [1]–[3]. These days, it also includes the mechanical behaviour of sophisticated manufactured products in extreme conditions, as well as computations and measurements of the nature of bonding in materials. Businesses across the world have shifted from supplying raw materials like metals, polymers, and ceramics to supplying finished products like components and systems to sectors like healthcare, energy, aerospace, and others that rely on innovatively integrating new materials [4]. Three primary industrial and societal needs will shape the development of novel materials in the years to come: 1) sustainability and materials security; 2) materials for energy; and 3) high value markets [5]–[7]. This is in contrast to looking at different types of materials. In order to stay up with the rapid pace set by modern materials, research and development (R&D) and engineering departments must exert extraordinary effort. A company or a competitor can always come out with a new product or service that helps them gain market share, customer needs, boost profits, or comply with regulations. Using thermoplastics and high-tech materials, businesses can now print out fully functional product components using 3-D or 4-D printers. These parts can be made in limited quantities and supplied to customers directly or refined for use in the mass production of specialized, high-quality products [8], [9].

Manufacturers may use polymer matrix composites to create products that are not only more robust and long-lasting, but also more manageable and portable [10]. Electronics, aerospace, automobiles, paints and coatings, energy storage, and other fields may all profit from graphene because of its remarkable and unusual mix of properties [11]. Industries and engineering fields can discover the state-of-the-art resources they require in areas such as composite and nanomaterials, polymer and concrete, metal and alloy, hybrid ceramic materials, electrical materials, and biomaterials [11]–[13].

Multiple machines are now on the market, suggesting that the number of businesses using additive manufacturing is on the rise. Porous graded membranes have potential game-changing uses in filtration and energy conversion devices, anisotropic metamaterials, and active biomaterial implants [14]. A small number of materials are currently amenable to these methods of production, and their ultimate qualities are on par with those of materials manufactured using more traditional means. One explanation for this is that our fundamental understanding of materials science has progressed much faster than additive manufacturing's mechanical capabilities (software, positioning actuators and controllers, lasers, etc.) [15]. This adds to the occurrence of the phenomenon in question because of the micro-structural and residual stress evolution, defects, geometrical control of the new materials [16], [17]. When compared to well-established subtractive technologies like machining, the production tools and control used in additive manufacturing are less sophisticated. Similarly, the development lag has slowed the incorporation of novel materials into the additive process. The reasons why companies spend money on discovering and vetting new applications for cutting-edge materials. Following are a few typical cases for the importance of advanced materials and technologies for various Engineering applications:

- **Reduced costs and increased profitability**: Newer, more technologically advanced materials can outlast their less advanced counterparts, saving manufacturers and consumers money in the long run by reducing the frequency with which components need to be replaced.

- **Increased customer satisfaction and loyalty**: Advanced materials, by virtue of their superior qualities, can result in finished goods that better meet client needs and have fewer flaws, all of which contribute to higher competitiveness.
- **Regulatory compliance and sustainability**: Manufacturing and production are becoming increasingly difficult as a result of new and stricter laws. Companies can use cutting-edge materials to meet regulatory requirements without compromising on performance.

Metal matrix composites (MMCs) and ceramic matrix composites (CMCs) are both playing significant roles in the development of cutting-edge materials and technologies that can be applied in a wide variety of engineering specializations. The mechanical properties of MMCs are superior to those of their monolithic equivalents, particularly in terms of specific strength and specific elastic modulus. Additionally, with careful compositional control, they may exhibit remarkable thermal conductivity, electric conductivity, dimensional stability, damping capacity, and wear resistance [18], [19]. Matrix metal matrix composites have been studied for over 40 years, and in that time, significant technological obstacles have been overcome [20]. Therefore MMCs are being used more and more frequently in fields like as security, transportation, aircraft, electronics, and even leisure and entertainment. The widespread use of MMCs has also motivated researchers to dig further into the best ways to make and put these tools to work [21]–[23].

Hybrid reinforcing is an alternative and essential method for designing and constructing improved MMCs. The goal of this approach is to increase the overall performance of the system by adding numerous types of hybrid reinforcements into a metal matrix and banking on the synergistic effects resulting from the specific strengths of the hybrid reinforcements [24], [25]. Since the hybrid reinforcement strategy is based on selecting the most appropriate type, content, and ratio of the hybrid reinforcements to achieve optimal performance, it provides greater convenience and promise than the construction of bioinspired structures when it comes to building MMCs in large quantities. Therefore, similar methods to those presently employed in the production of MMCs can be used to synthesize hybrid MMCs. Selecting the right hybrid reinforcements also allows for a nice compromise between excellent mechanical capabilities, wear resistance, and other desirable physical attributes. As a result, the development of hybrid composites has the potential to greatly expand the range of present MMC uses [22], [26].

Composite materials having a ceramic matrix are known as ceramic matrix composites. The ceramic matrix is reinforced with another polymer or metal phase and various reinforcements like fibers, whiskers, CNTs, graphene, particles, and so on (CMCs) [27]. These composites have a number of beneficial features, including increased strength and toughness and wear behaviour, good impact resistance, excellent thermal stability, and excellent temperature resistance. CMCs are a widely used material class with applications in a variety of fields, including the military and transportation, energy and power, electronics and electricals, chemistry and medical. The exceptional mechanical and physical qualities that CMCs possess are the reason for their widespread use. Because of the uses of ceramic matrix composites, there is an increasing need for them. The global market for CMCs is expected to grow from USD 8.1 billion in 2018 to USD 20.7 billion in 2026, representing a Compound Annual Growth Rate (CAGR) of almost 19% over the past several years [2], [3].

The Emerging Technologies Awareness Committee (ETAC) of ASM International conducted a survey of three hundred ASM members and compiled a list of technological and process breakthroughs based on the results of the survey [28], [29]. The new developments are expected to have a major impact on materials science and engineering soon. If you're interested in staying abreast of the latest advances in the field of materials science and engineering, a great resource for learning about new research and technical breakthroughs is research articles published in academic journals. Organizations will need to adjust their approaches to product design, development, and production to stay up with the revolutionary changes that modern materials are bringing to the commercial world. Unquestionably, fresh perspectives and opportunities will become available; the most successful companies will be those that assist their R&D and engineering experts in recognizing and making the most of these opportunities.

References

[1] R. Hsissou, R. Seghiri, Z. Benzekri, M. Hilali, M. Rafik, and A. Elharfi, "Polymer composite materials: A comprehensive review," *Composite Structures*, vol. 262, 2021, doi: 10.1016/j.compstruct.2021.113640.

[2] J. Sun, D. Ye, J. Zou, X. Chen, Y. Wang, J, Yuan, H. Liang, H. Qu, J. Binner, and J. Bai, "A review on additive manufacturing of ceramic matrix composites," *Journal of Materials Science & Technology*, vol. 138, pp. 1–16, 2023, doi: 10.1016/j.jmst.2022.06.039.

[3] Y. Hu and W. Cong, "A review on laser deposition-additive manufacturing of ceramics and ceramic reinforced metal matrix composites," *Ceramics International*, vol. 44, pp. 20599–20612, 2018, doi: 10.1016/j.ceramint.2018.08.083.

[4] T. M. Loganathan, M. T. H. Sultan, and M. K. Gobalakrishnan, "Ultrasonic inspection of natural fiber-reinforced composites," *Sustainable Composites for Aerospace Applications*, pp. 227–251. doi: 10.1016/B978-0-08-102131-6.00011-6.

[5] K. Rohit and S. Dixit, "A review-future aspect of natural fiber reinforced composite, *Polymers from Renewable Resources*, vol. 7 no. 2, 2016, doi: 10.1177/204124791600700202.

[6] S. D. S. Kopparthy and A. N. Netravali, "Review: Green composites for structural applications," *Composites Part C: Open Access*, vol. 6, 2021, Art. no. 100169, doi: 10.1016/j.jcomc.2021.100169.

[7] N. Hiremath, J. Mays, and G. Bhat, "Recent developments in carbon fibers and carbon nanotube-based fibers: A review," *Polymer Reviews*, vol. 57, pp. 339–368, 2017, doi: 10.1080/15583724.2016.1169546.

[8] Y. W. D. Tay, B. Panda, S. C. Paul, N. A. N. Mohamed, M. J. Tan, and K. F. Leong, "3D printing trends in building and construction industry: A review," *Virtual and Physical Prototyping*, vol. 12, pp. 261–276, 2017, doi: 10.1080/17452759.2017.1326724.

[9] A. L. Duigou, D. Correa, M. Ueda, R. Matsuzaki, and M. Castro, "A review of 3D and 4D printing of natural fibre biocomposites," *Materials and Design*, vol. 194, 2020, Art. no. 108911. doi: 10.1016/j.matdes.2020.108911.

[10] M. Chanes de Souza, I. Moroz, I. Cesarino, A. L. Leão, M. Jawaid, and O. A. T. Dias, "A review of natural fibers reinforced composites for railroad applications," *Applied Science and Engineering Progress*, vol. 15, no. 2, 2022, doi: 10.14416/J.ASEP.2022.03.001.

[11] H. Nakajima, P. Dijkstra, and K. Loos, "The recent developments in biobased polymers toward general and engineering applications: Polymers that are upgraded from biodegradable polymers, analogous to petroleum-derived polymers, and newly developed," *Polymers (Basel)*, vol. 9, pp. 1–26, 2007, doi: 10.3390/polym9100523.

[12] S. Gul, A. Kausar, B. Muhammad, and S. Jabeen, "Research progress on properties and applications of polymer/clay nanocomposite," *Polymer - Plastics Technology and Engineering*, vol. 55, pp. 684–703, 2016, doi: 10.1080/03602559.2015.1098699.

[13] T. Iwata, "Biodegradable and bio-based polymers: Future prospects of eco-friendly plastics," *Angewandte Chemie International Edition*, vol. 54, pp. 3210–3215, 2015, doi: 10.1002/anie.201410770.

[14] R. Seemann, M. Marincola, D. Seay, C. Perisanidis, N. Barger, and R. Ewers, "Preliminary results of fixed, fiber-reinforced resin bridges on four 4- × 5-mm ultrashort implants in compromised bony sites: A pilot study," *Journal of Oral and Maxillofacial Surgery*, vol. 73, pp. 630–640, 2015, doi: 10.1016/j.joms.2014.10.031.

[15] L. Ciccarelli, F. Cloppenburg, S. Ramaswamy, S. V. Lomov, A. V. Vuure, N. V. Hong, T. C. Thanh, N. M. Tri, and G. Thomas, "Sustainable composites: Processing of coir fibres and application in hybrid-fibre composites," *Journal of Composite Materials*, vol. 54, pp. 1947–1960, 2020, doi: 10.1177/0021998319886108.

[16] D. Jose, N. Kitiborwornkul, M. Sriariyanun, K. Keerthi, "A review on chemical pretreatment methods of lignocellulosic biomass: Recent advances and progress," *Applied Science and Engineering Progress*, vol. 15, no. 4, 2022, doi: 10.14416/j.asep.2022.08.001.

[17] A. Verma, "A perspective on the potential

material candidate for railway sector applications: PVA based functionalized graphene reinforced composite," *Applied Science and Engineering Progress*, vol. 15, no. 2, 2022, doi: 10.14416/j.asep.2022.03.009.

[18] E. M. Uygur, "Production of metal matrix alumina-ceramic composites," *International Journal of Machine Tools and Manufacture*, vol. 37, pp. 1539–1553, 1997, doi: 10.1016/0890-6955(95)00093-3.

[19] M. H. Kumar, S. M. Rangappa, and S. Siengchin, "A comprehensive review on metal matrix composites for railway applications," *Applied Science and Engineering Progress*, vol. 15, no. 2, 2022, doi: 10.14416/j.asep.2022.03.003.

[20] A. A. Adediran and M. Sriariyanun, "Applicability of agro-waste materials in the development of aluminium matrix composites for transport structures," *Applied Science and Engineering Progress*, vol. 16, no. 2, 2022, Art. no. 6634, doi: 10.14416/j.asep.2022.12.003.

[21] J. F. Flores, A. Neville, N. Kapur, and A. Gnanavelu, "Assessing the resistance of metal matrix composites and their microstructural integrity under erosion-corrosion," *Wear*, vol. 271, pp. 1331–1340, 2011, doi: 10.1016/j.wear.2010.12.027.

[22] T. Rajmohan and K. Palanikumar, "Application of the central composite design in optimization of machining parameters in drilling hybrid metal matrix composites," *Measurement (Lond)*, vol. 46, pp. 1470–1481, 2013, doi: 10.1016/j.measurement.2012.11.034.

[23] A. Rajeswari, E. J. S. Christy, S. Gopi , K. Jayaraj, and A. Pius, *Characterization Studies of Polymer-Based Composites Related to Functionalized Filler-Matrix Interface*. Amsterdam, Netherlands: Elsevier, 2019.

[24] M. M. Ahmed, H. N. Dhakal, Z. Y. Zhang, A. Barouni, and R. Zahari, "Enhancement of impact toughness and damage behaviour of natural fibre reinforced composites and their hybrids through novel improvement techniques: A critical review," *Composite Structures*, vol. 259, 2021, Art. no. 113496, doi: 10.1016/j.compstruct.2020.113496.

[25] M. K. Gupta, M. Ramesh, and S. Thomas, "Effect of hybridization on properties of natural and synthetic fiber-reinforced polymer composites (2001–2020): A review," *Polymer Composites*, vol. 42, pp. 4981–5010, 2021, doi: 10.1002/PC.26244.

[26] G. Carra, D. Formaggioni, M. S. Johnson, P. J. Mistry, A. Bernasconi, and S. Bruni, "Optimization of a filament wound hybrid metal composite railway axle design concept," *Applied Science and Engineering Progress*, vol. 15, no. 2, 2022, Art. no. 5791, doi: 10.14416/j.asep.2022.03.006.

[27] R. Kumar, R. K. Singh, and D. P. Singh, "Natural and waste hydrocarbon precursors for the synthesis of carbon based nanomaterials: Graphene and CNTs," *Renewable and Sustainable Energy Reviews*, vol. 58, pp. 976–1006, 2016, doi: 10.1016/j.rser.2015.12.120.

[28] B. Mansfield, S. Torres, T. Yu, and D. Wu, "A review on additive manufacturing of ceramics," in *ASME 2019 14th International Manufacturing Science and Engineering Conference*, 2019, pp. 36–53, doi: 10.1115/msec2019-2886.

[29] E. Asmatulu, J. Twomey, and M. Overcash, "Recycling of fiber-reinforced composites and direct structural composite recycling concept," *Journal of Composite Materials*, vol. 48, pp. 593–608, 2014, doi: 10.1177/0021998313476325.

Assoc. Prof. Dr. Sanjay Mavinkere Rangappa, Editor (Left),
Prof. Dr. -Ing. Habil. Suchart Siengchin, Editor-in-Chief (Middle)
Dr. Indran Suyambulingam (Right)