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EDITORIAL

Challenges and Trends for Multifunctional Materials

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1. Background

Materials science is the study of materials, their properties and their applications. As the rapid development of material science, materials tend to approach multifunctionality. Multifunctional materials are designed to perform multiple responsibilities through prudent combinations of different functional capabilities. Typically, each function contributes a distinct physical or chemical process that can deliver system-level improvements beyond the status quo. Even though some researchers have defined "smart material" as multifunctional materials (MFM), multifunctional composites (MFC), multifunctional structures (MFS), and multifunctional material systems (MFMS), the term "multifunctional materials" will be used to refer to all of these materials, composites, and structures in this paper [1]. One of the main advantages of multifunctional materials is their capacity to simultaneously accomplish multiple functions, which can decrease the need for various materials and components in the system. This benefit can result in reduced weight, higher efficiency, and superior properties and the development of multifunctional materials enables technologies that were previously impossible. The properties of multifunctional materials could vary substantially based on the applications and demands of the material. For example, the materials may respond to heat (thermal), stress & strain (mechanical), electrical, magnetic, pH, moisture, light (photonic), and molecular or biomolecular substances, and others. By incorporating these materials into composites, numerous functionality, including self-healing, self-sensing, self-cleaning, electric conductive, thermal conductive, membrane, shape memory, and actuation, can be achieved. Therefore, multifunctional materials can improve processes and products, create several avenues to increase sustain-

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ability, and have a direct and positive impact on economic growth, environment, and quality of life.

2. Challenges

To unlock the full potential of multifunctional materials, several challenges need to be addressed. These challenges include the needs for 1) multi-disciplinary collaboration, 2) a suitable balance of the different properties of the material, 3) development of environmentally sustainable materials, 4) cost-effective manufacturing and implementation methods, and 5) high durability of the materials to enable them to withstand environmental conditions and allow them to be used in real-world applications. The first major challenge in developing multifunctional materials is the requirement for multi-disciplinary approaches. The key to the success of multifunctional materials is the integration of various properties into a single material, which involves knowledge of materials science, physics, chemistry, and engineering. This challenge creates difficulties in terms of collaboration and communication among experts from several scientific fields. Secondly, the ideal development of multifunctional materials can only be accomplished by combining multiple properties without sacrificing any of them. Until now, optimizing multi-functions often require a trade-off between them, and achieving the right balance can be challenging. In addition, manufacturing multifunctional materials might be complicated and require specific equipment and experience. Frequently, the manufacturing of multifunctional materials includes complicated and time-consuming procedures that demand high precision and control and this can raise manufacturing expenses and restrict application to large-scale usage. Finally, the performance of multifunctional materials can be affected by environmental factors such as mechanical damage, chemical exposure, temperature, humidity, UV irradiation, and others; therefore, developing materials that can survive these environments is a major challenge.

3. Trends

Despite the challenges stated previously, the development of multifunctional materials is an attractive field of study, motivated by the potential to develop novel products that can meet the diverse demands of society. Future trends in this subject include the invention of environmentally sustainable materials that can be manufactured using sustainable processes. As the world progressively focuses on sustainability and lowering carbon emissions, future research on multifunctional materials will need to address the environmental impact. This research strategy involves the use of biodegradable materials, materials derived from renewable sources, and recyclable or reusable materials. This also brings the demands of developing multifunctional materials that can address specific sustainability challenges, such as air/water purification or green energy generation.

All cutting-edge technologies and materials will eventually be evolved through more efficient and cost-effective procedures, enabling them to be widely implemented in civil society and improving how people live and work. Even though the area of multifunctional materials is still in its beginnings, the ultimate goal is to develop materials with practical applications. Hence, continuous research about how multifunctional materials could be incorporated into real-world systems, such as electronics, aerospace engineering, and healthcare devices, will be essential for promoting innovation and generating new markets [2]. Moreover, future civil engineering structures will undoubtedly integrate and consist of multifunctional materials. Aside from the attractive functions and properties such as self-monitoring, self-healing, high UV and chemical resistance, color-changing, temperature regulation, air-cleaning, and energy harvesting, it is anticipated that multifunctional materials with properties such as sustainability, cost-savings, and enhanced durability will have the potential to be utilized on a global scale.

Conflict of Interest

There is no conflict of interest.

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