coatings

Editorial

Recent Advancements in Biological Microelectromechanical Systems (BioMEMS) and Biomimetic Coatings

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Biomimetic micro- and nanotechnology have substantially grown in recent years, contributing to significant progress in the pharmaceutical and biomedical domains [1]. The advancement of such technologies has led to the development of improved and new materials, tools, and devices, with various applications. Biological microelectromechanical systems (BioMEMS) are devices or systems built by micro- and/or nano-scale manufacturing processes that are utilized for the processing, delivery, alteration, analysis, or synthesis of biological and chemical units [2]. The interdisciplinary nature of BioMEMS have various applications from the biomedical sector to electrical engineering, such as genomics [3], molecular diagnostics, point-of-care diagnostics [4], tissue engineering [5], single cell analysis [6], and implantable microdevices [6]. BioMEMS provide several benefits over traditional approaches that are worth investigating, with compact device size, mobility, replication reliability, high-throughput performance, multi-functionality, and potential automation. The smaller dimension provides apparent benefits since these devices can be miniaturized with reduced manufacturing costs for devices [7]. Furthermore, BioMEMS devices offer multi-functionality, allowing separate tools to be incorporated into a single device. This, in turn, promotes automation analysis with minimal human participation, which is a critical aspect of such devices. This is critical, especially when dealing with unknown or newly discovered severe disorders. Because of their mobility and light weight, such devices are ideal in distant and/or rural locations wherever centralized laboratories are unavailable [8]. At present, BioMEMS are one of the world's fastest developing technologies; owing to the ramifications, they might be utilized in a variety of industries, comprising the health sector, particularly in healthcare facilities and hospitals [9]. Since the term BioMEMS was first used in the 1990s, there has been a steady growth of publications in this subject [10]. As per Clarivate Analytics, citations each year, including 'BioMEMS' as a keyword, have scaled from fewer than 100 in the late 1900s to over 2400 in 2021 [11]. BioMEMS are classified into two broad categories established by their applications: those designed for biomedical applications, such as inertial sensors, and those that incorporate micromachining [12] and microelectronics methods to gain, sense, or manipulate chemical or biological things [13].

The biological materials are frequently used for the fabrication of BioMEMS. They are composed of biominerals (sustain loading) and organic materials (provide the ability to undergo deformation). Most of them are composites that are continuously bathed with body fluids, and their properties and structures are defined by the physical and chemical nature of the constituents present and their relative amounts [14]. Self-organization, self-healing capability, complex structure, and multifunctionality are fundamental features that inspire scientists to design novel biological materials. They can be synthesized by applying the concept of computer modeling and realizing the by-design [15]. The major obstacle of applying engineering concepts is the underlying obscure mechanism, particularly, how molecules are arranged during different time scales and lengths at the macroscopic level.

BioMEMS are used for the production of microspheres to deliver biological materials, spot synthesis of peptides, microprinting of biodegradable polymers for proliferation, and spot deposition for DNA, protein, and antibody arrays [16]. The biological integration of MEMS can be improved using microfabrication technology. The biological materials discover applications in BioMEMS ranging from surgical tools to gene sequencing chips. BioMEMS find applications in the treatment of medical conditions, cell biology, and the diagnosis of diseases [2].

BioMEMS are prominent in biological applications, including detection and diagnostics for monitoring and controlling food quality for accurate, rapid, and easy-to-handle devices for care detection. The high level of synergism that occurs between microelectronic processing, nanotechnology, and microbiology has great potential for the analysis and rapid detection of food-borne pathogens. The fundamental understanding of wear, friction, adhesion, and surface contamination of biological materials is compulsory because they are primary parameters for rapid and accurate detection methods. MEMS biomaterials should exhibit excellent tribological and mechanical properties at microscales. Therefore, new lubricants and lubrication methods are required for suitable BioMEMS to enhance the adhesivity between substrates and biomolecules [17]. There is a great need to systemize the observations and underlying principles of mechanics in a unified manner to design novel biological materials for BioMEMS applications. Biodegradable and nonbiodegradable surfaces are made more bioactive for osseointegration by developing a bone-like apatite coating using biomimetic techniques [18]. The bioactivity of materials, i.e., calcium phosphate, can be combined with the excellent mechanical properties of the substrate [19].

There has always been a considerable amount of interest in advanced BioMEMS and biomimetic coatings because of the tremendous and unexpected progress in their synthesis, characterization, and properties. A variety of different fields have also utilized them, such as biomimetic organic hybrid coatings used for the replacement and repair of biomedical devices [20], including certain types of metal [21], glass ceramic [22], and polymer materials [19]. Furthermore, advanced organic and biological coatings are applied in bioelectronics, biosensors, and tissue engineering. Numerous excellent reviews and research articles have addressed many topics in this area, namely, lab-on-a-chip (LOC) [23], microfluidic devices [24,25], the micrototal analysis system (µTAS) [26], organic materials and device coatings [27], self-assembly hybrid-material coatings [28], bio-interfaces [29], bioelectronics and biosensors [30], electrospinning coatings [31], and plasma treatment [32,33]. Advanced BioMEMS and biomimetic coatings play a crucial role in their interaction with environmental factors. Yet, sophisticated, fundamental knowledge, processes, characterization, and modeling are required to achieve a comprehensive understanding of these coatings.

This Special Issue provides a platform to share the knowledge concerning unsurpassed networking and relationship-building opportunities by presenting and discussing the research results, to date, and to promote further research into advanced BioMEMS and biomimetic coatings.

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

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