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Biomimetic Approaches and Engineered Living Materials (ELMs) in Surface Engineering: Utilizing Common, Biodegradable Materials for Functional Structures

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Surface engineering, a critical sub-discipline of materials science, plays a pivotal role in enhancing the performance and functionality of materials across various industries. While high-tech materials offer impressive capabilities, the principle of “good enough” as observed in Nature suggests that various functionalities can be achieved using simpler, more accessible materials. This approach reduces costs and environmental impact and opens avenues for sustainable innovation. The keynote address explores biomimetic strategies to develop functional structures from common chemical elements that are bio-based and biodegradable.

Nature offers several exemplary models: the micro- and nanostructured scales of butterflies, composed of chitin, exhibit remarkable optical properties and hydrophobicity, enabling beautiful coloration, self-cleaning surfaces and potentially passive radiative cooling. Similarly, the triangular chitin hairs of Saharan silver ants provide efficient radiative cooling, allowing these ants to forage during extreme heat. Keratin structures, such as those found in horns, hooves and porcupine quills, demonstrate durability and resilience. Additionally, the hollow chitin hairs of Akhal-Teke horses from Central Asia, which provide thermal regulation, showcase the multifunctionality achievable with natural materials.

These examples underscore the “good enough” principle, where living Nature balances material properties with longevity, repairability and environmental compatibility. Engineered Living Materials (ELMs) further illustrate the potential of bio-inspired solutions, such as bacteria-infused concrete that self-heals and living root bridges as are found in the northeastern Indian state of Meghalaya that grow and strengthen over time.

This paper discusses the integration of these natural principles into surface engineering, emphasizing the benefits of using biodegradable, bio-based materials. By adopting biomimetic approaches, we can develop innovative surface treatments and coatings that meet industrial and strategic needs while promoting sustainability and reducing our reliance on rare and costly resources.

Keywords: Surface engineering, biomimetics, biodegradable materials, functional structures, good enough principle, chitin, keratin, thermal regulation, sustainable innovation.