Innovision in ecotribology: Biomimetic approaches

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ABSTRACT – The approach to innovation in tribology needs to be strongly connected to strategic long-term planning. Approaches based on biomimetic inspiration can steer the field into a very profitable future, combined with benefits for the whole biosphere. In the future there will be more money than ever spent on energy, but it is up to the "innovision" in the field how much of these funds will actually flow into tribology and contribute to an improvement of the human condition. In this respect the future of technological development strongly depends on properly analyzing emerging trends and issues.

1. INTRODUCTION

Tribology is all about optimization of friction, adhesion, lubrication and wear. Traditionally, main concern was put on technological optimization. With the emergence of ecotribology, i.e. tribology that is concerned with environmentally acceptable practices, the approach in the field widened its focus by including societal issues [1,2].

2. METHODOLOGY

Based on the specific example of biomimetics [3,4], which is an emerging new field that deals with the abstraction of good design from living nature for applications in science and technology, the author takes the path from innovation to innovision, characterized by a new framework of thinking that is the prerequisite for the provision of solutions.

3. RESULTS AND DISCUSSION

Transdisciplinary knowledge transfer from living nature to tribology provides new approaches concerning materials, structures and processes, the three main areas that tribology is concerned with.

3.1 Materials

Traditionally, metals are of high importance in engineering. In living nature, this is not the case. Organisms only use metals when they are chemically necessary, for example as the center atom of chlorophyll, magnesium, and as the center atom of hemoglobin, iron. Mechanical strength, structural support, and further functional properties in organisms are provided rather by highly functional structures of benign materials than by metals. Until we are at such a high stage with our technological materials, we will still utilize metals. However, it is not necessary to obtain metals in the environmentally unsustainable way as we currently obtain them. Various plants mine the soil and the water bodies in ways that are contrary to conventional human mining approaches. With their roots they take up metals from the ground, and accumulate them in their bodies. In some cases, various percent of the dry body mass of the plants is metal [5]. This mining with plants takes place at ambient conditions, with little or no waste produced, and at no negative effects for the biosphere. Learning from plants how to mine could potentially revolutionize our way to obtain base materials for our technological devices. In the future, however, a nearly complete replacement of metals by functional structures made from benign materials can be envisaged.

3.2 Structures

Nachtigall [6] identified general biomimetic principles that can be applied by engineers who are not at all involved in biology. One of these principles is "integration instead of additive construction". As opposed to the plenitude of different materials currently used in technological approaches, organisms use only a small amount of different materials, however slightly chemically varied in different applications, and greatly varied structurally. One example for the realization of "structure rather than material" in organisms is the way that colors are produced in some microorganisms and tropical plants [7,8]. Minuscule structures on the order of the wavelength of the visible light (in some cases, of the light visible to other animals, such as the ultraviolet light visible for some insects and birds) interact with the light in similar ways as the water droplets do in the generation of a rainbow, or the thin film of oil does on water when generating iridescent colors that change with the viewing angle, resulting in brilliant coloration that does not bleach, and that does not employ any potentially toxic chemicals but just contains structures from benign materials. A central aspect of structural colors and structure-based functions in organisms in general that makes them interesting for tribology is their multifunctionality. "Multi-functionality instead of mono-functionality" is a further general biomimetic principle identified by Nachtigall [6]. Structures in and on beetles, butterfly wings, tropical plants and microorganisms also control wetting behavior as well as frictional and adhesion properties. One example is the nanostructured silica hinges and interlocking devices in diatoms [9] that can serve as inspiration for optimized tribology in microelectromechanical systems (MEMS).

3.3 Processes

The third category in which tribology can learn from living nature is in the large and important area of processes. Materials and structures in living nature are produced via completely different approaches than currently applied in manufacturing by man. One intriguing example for the exquisite processes employed in living nature is the protein-based biomineralization of more than 70 different minerals by living organisms [10].

Such materials comprise carbonates such as $CaCO_3$ shells in mollusks, phosphates such as hydroxyapatite in bones, oxides such as magnetite Fe_3O_4 in bacteria, sulfates such as celestite $SrSO_4$ in radiolarians, sulfides such as pyrite FeS_2 and greigite Fe_3S_4 in magnetotactic bacteria, arsenites such as oripiment As_2S_3 in bacteria, native elements such as Gold nanoparticles in yeast, silica $SiO_2 \cdot nH_2O$ in diatoms, halides such as fluorite CaF_2 in fish, and organic minerals such as guanine in fish scales, providing the beautiful fish silver.

Biomineralization is characterized by chemical reactions involving proteins, the creation of perfect crystals, the control of crystal growth and inhibition depending on the crystallographic axis, as well as the production of composite materials with properties that are of high value to engineering.

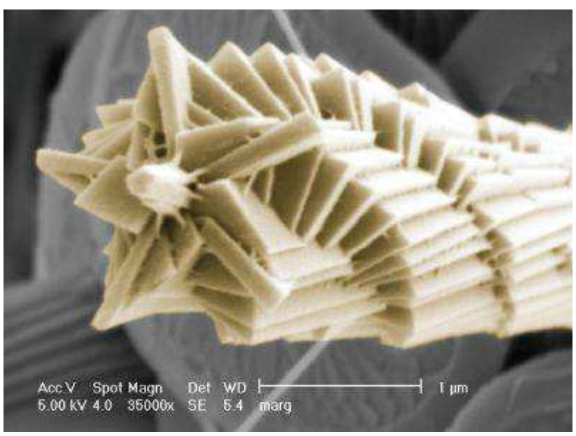

Figure 1 Spine tip of the microorganism *Rhabdosphaera clavigera*. Material: Calcite, $CaCO_3$. Structure: spiral formed from consistently aligned crystal units with rhombic faces. Process: Biomineralized in cool seawater, with the help of proteins, at ambient conditions. Scale bar 1 μm = 0.001 mm. [11]

4. CONCLUSIONS

Current tribology is still employing various hazardous materials and processes. On the way towards full establishment of modern tribology that is concerned with environmentally acceptable practices (ecotribology), inspiration from living nature can give valuable inputs regarding materials, structures and processes that provide environmental sustainability with optimized tribological functions.

5. REFERENCES

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