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# Bioinspired surfaces and materials

Romana Schirhagl,[a] Christoph Weder,[b] Jiang Lei,[c] Carsten Werner[d] and Hans Marcus Textor*[e]

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[a] *Groningen University, University Medical Center Groningen, Antonius Deusinglaan 1, 9713 AV Groningen, Netherlands. E-mail: romana.schirhagl@gmail.com*

[b] *University of Fribourg, Adolphe Merkle Institute, Chemin des Verdiers 4, CH-1700 Fribourg, Switzerland. E-mail: christoph.weder@unifr.ch*

[c] *Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Zhongguancun East Road 29, 100190, Beijing, China. E-mail: jianglei@iccas.ac.cn*

[d] *Leibniz Institute of Polymer Research Dresden (IPF), Max Bergmann Center of Biomaterials Dresden (MBC), 01069 Dresden, Germany. E-mail: carsten.werner@tu-dresden.de*

[e] *ETH-Zurich, Department of Materials, Wolfgang-Pauli-Str. 10, 8093 Zürich, Switzerland. E-mail: marcus.textor@mat.ethz.ch*

Over millions of years evolution has optimized the properties of materials *via* natural selection for many specific purposes. Indeed, natural materials have unique properties which come very close to perfection. Cells, for instance, are able to carry out intricate sequences of chemical reactions that are difficult or impossible to carry out *ex vivo*, cell membranes are the most complex selective and responsive semipermeable membranes that exist, and animal shells exhibit a clever nanostructure that renders them hard and tough at the same time. In short, materials scientists can learn a lot from nature's materials. The perfection and performance of nature's materials not only spark fascination, but also trigger the question as to why certain structures or surfaces exhibit outstanding properties and inspire research towards new materials. While the materials of living nature impressively serve dedicated purposes, they are formed under restricted conditions. For instance, they have to be designed to function under a narrowly defined set of physiological conditions, and can only be composed of building blocks an organism has available. Without these restrictions, material scientists can design entirely new materials or surfaces. Taking the design and function of natural materials as

**Romana Schirhagl**

*Romana Schirhagl (born 1984) is a chemist by training who studied at Vienna University. After that she moved on to do postdocs at Stanford University (Zare group) and ETH Zurich (Degen group) before she finally ended up as an Assistant Professor at Groningen University where she currently leads the Bioimaging and Bioanalysis group. She has already been awarded several prestigious awards including the most recent German Fachgruppenpreis for analytical chemistry, a Rosalind Franklin Fellowship, and a Theodor Koerner Prize. Her research interests include diamond magnetometry for bioapplications, optics, molecular imprinting as well as biomimetic antibodies or viruses.*


**Christoph Weder**

*Christoph (Chris) Weder is Professor for Polymer Chemistry and Materials at the Adolphe Merkle Institute of the University of Fribourg (Switzerland). He also serves as Director of this center for fundamental and applied research on soft nanomaterials and heads the Swiss National Competence Center in Research Bio-Inspired Materials. He has mentored about 70 PhD students and postdoctoral researchers and co-authored about 200 papers and book chapters. His main research interests are the design, synthesis, investigation, and exploitation of novel functional polymer systems, in particular stimuli-responsive polymers, bio-inspired materials, and polymer nanocomposites.*

inspiration, they are able to widen the range of physicochemical boundary conditions such as the choice of elements, building blocks or temperature. This can improve these materials or add new properties, for instance better robustness, stimuli responsiveness or fracture resistance. This themed issue of *Chem Soc Rev* provides a collection of papers that aims to give an overview of this exciting topic, describe the current state and trends of the field, and sketch the limitations of current bioinspired materials design. We emphasize that research on bioinspired surfaces and materials is a vast and diverse domain, and therefore the present collection can hardly provide more than a glimpse of a selection of topics.

Heinzmann *et al.* (DOI: 10.1039/c5cs00477b) review the field of supramolecular polymer adhesives. These materials are inspired mostly by the dynamic nature of non-covalent binding mechanisms found in nature. Artificial materials have been designed which show, for instance, stimuli responsiveness, bonding and debonding on demand, or surface selectivity or recyclability.

Phillips *et al.* (DOI: 10.1039/c5cs00533g) discuss colloid-based porous materials which resemble self-assembling natural hierarchical structures. These materials have inspired the design of materials for optics, wetting, sensing, catalysis, and electrodes. The authors describe the demands of these materials as well as trends and future directions for development.

Hensel *et al.* (DOI: 10.1039/c5cs00438a) review the current understanding of omniphobic surfaces found in nature, for example in the water- and oil-repellent cuticle of springtails, summarize the knowledge of the underlying principles, and discuss approaches to their technological implementation.

Wu *et al.* (DOI: 10.1039/c5cs00514k) contribute an article about micro- and nano-fabricated structures to spatially separate and confine bacteria. Such structures are expected to lead to synthetic microbial societies.

Palivan *et al.* (DOI: 10.1039/c5cs00569h) review bioinspired polymer vesicles and membranes. Their natural counterparts play a key role in living organisms by providing stable and functional compartments, and preserving cell architecture, while supporting signaling and selective transport. However, they also inspired hybrid or purely synthetic materials for many biomedical applications.

Meng *et al.* (DOI: 10.1039/c5cs00459d) summarize the field of abrasion resistant materials. Of particular interest are the natural design principles for lightweight and flexible materials.

Fratzl *et al.* (DOI: 10.1039/c5cs00598a) discuss clever geometric arrangements in

**Jiang Lei**

*Lei Jiang received his BS degree in solid state physics (1987), and MS degree in physical chemistry (1990) from Jilin University in China. From 1992 to 1994, he studied at the University of Tokyo in Japan as a China-Japan joint course PhD student. Then, he worked as a postdoctoral fellow in Prof. Akira Fujishima's group. In 1999, he joined the Institute of Chemistry, Chinese Academy of Sciences (CAS). In 2015, he moved to the Technological Institute of Physics and Chemistry, CAS. Since 2008, he has also served as the dean of the School of Chemistry and Environment in Beihang University.*

**Carsten Werner**

*Carsten Werner is Professor for Biofunctional Polymer Materials at TU Dresden and deputy director of the Leibniz Institute for Polymer Research, Dresden, Germany (IPF). His research interests include electrosurface phenomena, hemocompatible materials, cell-instructive polymer matrices for regenerative therapies and biomimicry concepts in materials science. Carsten Werner holds an Adjunct Full Professorship at the Institute of Biomaterials and Biomedical Engineering of the University of Toronto, Ontario, Canada, and serves as an Associate Editor of Biomaterials and Section Editor of Current Opinion in Colloid and Interface Science. He has authored or co-authored more than 250 publications and filed more than 30 patents.*

**Hans Marcus Textor**

*Trained in chemistry at the University of Zurich, Marcus Textor spent two years as a postdoctoral fellow at the School of Molecular Sciences, University of Sussex, UK. In 1978 he took up a position at Alusuisse-Lonza, Switzerland, as head of the R&D department on aluminum metallurgy and surface technology. In 1994 he joined ETH Zurich, Department of Materials, establishing an interdisciplinary research group on biointerface science, micro/nanotechnology and advanced cell culture platforms. His teaching activities until 2014 covered the area of surfaces and interfaces in the field of light metals, biomaterials and nanobiotechnology.*

nature to avoid mechanical trade-offs in stiffness, strength and flexibility and their use to avoid fraction in synthetic materials.

Heinz *et al.* (DOI: 10.1039/c5cs00890e) cover the theoretical perspectives of designing bionanomaterials. The aim is to provide fundamental understanding and guidance to solve current problems and accelerate the discovery of better performing materials.

Finally, Studart (DOI: 10.1039/c5cs00836k) reviews additive manufacturing technologies which represent bioinspired fabrication pathways for functional materials with complex heterogeneous architectures.

As guest editors of this themed issue, we hope that this collection of outstanding papers conveys that the potential impact of bioinspired materials and surfaces extends far beyond the examples discussed herein. Indeed, the general research approach is broadly useful and can be applied to virtually all domains of surface and materials science.