Hybrid materials engineering in biology, chemistry and physics
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Modern technologies have made their way into all areas of today’s life. Cell phones, fast internet, modern airplanes, or medical diagnostics have simplified many aspects of our lives and will continue to change the way we live in the future. None of these developments are, however, possible without the concomitant development of new advanced materials that are able to perform the tasks necessary for the proper function of a specific device. Telecommunication, health and environment, energy and transportation, and sustainability are just a few examples where new materials have been key for technological advancement.

As many modern technologies require the combination of several properties in one material, hybrid materials have become the focus of an ever-growing research community worldwide. A particularly interesting and useful development is the blurring of the boundaries between the classical disciplines; nowadays, for example, the combination of chemical synthesis and bioengineering approaches is a well-accepted and highly successful strategy for the development of advanced materials with a variety of tunable chemical, biological, and physical properties.

Accordingly, the number of conferences on the subject has rapidly grown, covering all aspects of materials synthesis, characterization, and application. Starting in 2010, the European Materials Research Society has held three successful symposia on hybrid materials. At the E-MRS Spring Meeting 2014 in Lille, the third symposium of the series, “Symposium Q: Hybrid materials engineering in biology, chemistry and physics”, took place. With over 240 abstracts received, the symposium was among the four largest symposia at the meeting. The organizers, Fabrice Leroux (Clermont-Ferrand, France), Pierre Rabu (Strasbourg, France), Nico Sommerdijk (Eindhoven, The Netherlands), and Andreas Taubert (Potsdam, Germany) therefore had a large selection of excellent abstracts to consider for oral and poster contributions, no easy task given the tight schedule of the meeting. Certainly the key challenge in selecting the oral contributions was the fact that there were about 2.5 times more applications for oral contributions than available slots.

The abstracts submitted to the symposium covered a wide range of topics from synthesis, high-end characterization, theory, and simulation, to a widespread set of applications. As the main goal of the symposium was to connect researchers active in different subfields of the hybrid materials field, the organizers also invited a set of speakers to highlight the different aspects, to inspire the community into new and promising directions. The symposium opener provided an in-depth overview of materials design using sol–gel approaches towards hybrid materials for plenty of applications. Two lectures highlighted new developments in biologically inspired hybrid materials: one focused on the synthesis, mainly using calcium carbonate as the inorganic component and various organic matrices and inclusions, and the other on the applications of biomineralization-inspired chemistry, presenting new insights into the formation and tuning of calcium phosphate cements. Advanced materials based on graphene and inorganic components constitute an important topic in hybrid materials, which was emphasized by the large set of applications from biology to energy that were presented. The aspect of magnetic materials received attention with lectures on new stimuli-responsive magnetic materials and the coupling of magnetic and electrical properties with appropriate surfaces. The synthesis of nanoparticles also focused on two widely differing...
Fabrice Leroux graduated from Nantes University and obtained his Ph.D. in 1995 at the Jean Rouxel Materials Institute, Nantes, France (supervisors Dr. Dominique Guyomard and Yves Piffard). After a postdoctoral fellowship at Waterloo University, Canada, between 1995 and 1998 under the guidance of Prof. Linda Nazar, he was appointed to a CNRS junior research position at the Inorganic Materials Laboratory in 1998 and joined the layered double hydroxide (LDH) research team managed by Dr. Jean-Pierre Besse. His research has focused on the fundamental and applicative aspects of lamellar inorganic materials and polymer nanocomposite derivatives. His research interests also include solid-state kinetics and ion diffusion in open and/or porous complex frameworks such as ionogels, hybrid geopolymers, and so on. More specifically, and of relevance to this Cluster Issue, he developed LDH-type materials as multifunctionalized layered containers, electrochemical supercapacitors using carbon replica derivatives as well as adaptive fillers for different applications (biocides, corrosion inhibition, anti-UV, etc.). Indeed he is keen on developing materials associated with (nano)technology that can bridge the laboratory-scale research with a possible industrial reality. He got a CNRS senior position in 2007 and became the general manager of the Inorganic Materials Laboratory at the Chemical Institute of Clermont-Ferrand (ICCF) in 2012. He received the 2010 award of the Solid-State Chemistry Division of the French Chemical Society. Since 2011, he is the President of the Advisory Board of the International Symposium on InterCalation Compounds (ISIC).

Pierre Rabu obtained his Ph.D. in solid-state chemistry from the University of Nantes, France, in 1990. He then became CNRS researcher at IPCMS to work on low-dimensional magnetic materials. He was short-term research fellow at the Institute for Fundamental Organic Chemistry, Kyushu University, Fukuoka, Japan, in 1996 and visiting fellow of the Advanced Materials Research Institute, University of New Orleans, USA, in 2001. He received the 1998 prize of the Solid-State Chemistry division of the French Chemical Society. Since 2005, Pierre Rabu is director of research in CNRS and focuses his activities on the design of molecular, inorganic, or hybrid organic—inorganic solids, with special emphasis on synthesis, structure—property relationships, modeling, and analysis of the magnetic behavior of low-dimensional systems. His current activities include especially layered organic—inorganic magnetic and multifunctional materials, multifunctional hybrid materials, magnetic, photoactive, chiral, or bioinorganic nanostructures, and magnetic mesoporous structures. From 2005 to 2008, he was director of the CNRS national group of research on Multifunctional Hybrid Materials. Pierre Rabu is now research director at IPCMS, Strasbourg, France, where he is head of the Department of Chemistry of Inorganic Materials and president of the regional section (Alsace) of the French Chemical Society.

Andreas Taubert is Professor of Supramolecular Chemistry at the University of Potsdam. He holds a DiplomChemiker degree from the University of Basel and completed his doctoral studies at the Max Planck Institute for Polymer Research and the University of Mainz. After a postdoctoral stay at the University of Pennsylvania, he returned to the University of Basel, where he became an independent group leader. In 2006 he became Assistant Professor at the University of Potsdam and the Max Planck Institute of Colloids and Interfaces before accepting his current position in 2011. His interests encompass the field of biominerization and biominerization-inspired materials chemistry, materials chemistry using ionic liquids, and, more recently, hybrid materials for water treatment.

Nico Sommerdijk is full professor in Bioinspired and Multiscale Materials in the Laboratory of Materials and Interface Chemistry at Eindhoven University of Technology. He studied chemistry at the University of Nijmegen, where he specialized in Organic Chemistry and obtained his degree in September 1988. In 1995 he obtained his Ph.D. (Cum Laude) from the University of Nijmegen for his work on the synthesis and aggregation of chiral surfactant molecules, under the supervision of Prof. Dr. R. J. M. Nolte and Prof. Dr. B. Zwanenburg, described in his thesis “Tuning the Molecular Organization of Amphiphilic Molecules”. From 1995 to 1997, he was an ERC Human Capital and Mobility Fellow at the University of Kent (UK), where he worked on sol—gel-based silicates and subsequently received a research grant from ICI to work on bioinspired crystallization with Prof. B. Heywood at Keele University (UK). He returned to Nijmegen to work on (macro)molecular self-assembly and bioinspired mineralization, and in 1999 he moved to Eindhoven to work on bioinspired hybrid materials through biomimetic mineralization and self-organization. He studies these processes by combining (macro)molecular self-assembly and advanced electron microscopy with the aim to apply them in the synthesis of advanced functional materials. Prof. Sommerdijk’s work has been supported by several personal grants including VIDI and VICI Awards from the Netherlands Science Foundation. Currently, he is scientific director of the Soft Matter CryoTEM Unit, core member of the Institute for Complex Molecular Systems, member of the Eindhoven Polymer Laboratories, and the Eindhoven Multiscale Institute.
aspects: the design of metal alloy nanoparticles and how nanoparticles can be assembled into functional hybrid structures with high order. On the topic of materials analysis, the use of scanning probe techniques for in-depth characterization of perovskite surfaces was discussed.

In addition to the above, some invited lectures are represented in this issue. Verónica de Zea Bermudez (Vila Real, Portugal) and a very collaborative team present the synthesis of sol–gel self-assembly-driven hybrid materials, and Guido Kickelbick and Tom Engel (Saarbrücken, Germany) report on new self-healing materials based on silsesquioxane nanoarchitectures. The invited lecture that concluded the symposium showed how bioinspiration can lead to specific highly successful applications, focusing on the example of how surfaces can be modified with hybrid materials to dramatically reduce biofouling on ship hulls and other surfaces. Besides the invited speakers, the symposium also hosted high-quality contributed talks and two very large and successful poster sessions, resulting in many discussions and a number of new collaborations.

To carry the impact of the symposium even further, the symposium organizers and the European Journal of Inorganic Chemistry joined forces to produce a Cluster Issue on the general subject of hybrid materials highlighting the power of these materials for all aspects of modern technology. To that end, all contributors of Symposium Q were invited to submit an article to the Cluster Issue, but to provide an even broader view of the field the invitation was extended to eminent scientists around the world. As a result, the Cluster Issue that is now in your hands covers many aspects of hybrid materials research and development.

For reasons of space, we cannot introduce every article in the Cluster Issue but would like to select some examples that, together with the invited lectures, illustrate the breadth of the topics. Garcia and coworkers describe the synthesis of a coordination polymer that can be transformed into nickel nanoparticles, a true materials-by-design approach. Walter and Zahn describe how bismuth oxide nuclei form and how the formation of the nuclei is affected by nitrate ions; this study provides useful information for experimentalists trying to control particle formation processes. Neira-Carrillo and colleagues describe a new additive for calcium oxalate precipitation, a study that could be useful for medical applications. On an entirely different topic, Xie and Su review recent developments on how to use ionic liquids for tailoring the structure and properties of carbon-based materials. Rocha and colleagues evaluate methods to calculate optical properties of a set of lanthanide-based materials, illustrating the useful additional information or independent confirmation of experimental data that calculations often provide. Hwang and colleagues introduce interesting inorganic–inorganic hybrid materials for CO₂ adsorption, showing that the term “hybrid material” is quite broad and extends beyond organic–inorganic hybrid materials.

These are just a few examples highlighting the creativity and imagination of chemists when it comes to the development of new advanced materials. Before concluding, the symposium organizers and guest editors of this issue would like to state that such a symposium and therefore also this Cluster Issue is only possible through cooperation and scientific exchange: “Japan in Motion”, a parallel symposium at the E-MRS Meeting, assembled a large group of high-profile contributions from Japan. Two of these contributions were hosted by Symposium Q. Finally, funding is always a key issue, and the guest editors are happy to acknowledge financial support from COST MP1202, which enabled some of the participants to attend this highly successful symposium.

As the guest editors, we would like to thank all contributors to Symposium Q and to the Cluster Issue for making both a success. We also invite all readers to browse the Cluster Issue, set up collaborations with the authors, and advance the field by actively contributing new research.

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