

## Editorial overview

### Hot Topic – Colloid & Interfacial Phenomena in Electrochemical Systems

Gabriel Loget and Yann Leroux

Electrochemistry is an interfacial science by nature, not only because it concerns the study of interfaces (most of the time solid/liquid or liquid/liquid), but also because this subfield of physical chemistry lies at the interface of at least two and sometimes three disciplines. As never before, electrochemistry is in the spotlight.<sup>1,2</sup> Indeed, it sits at the center of many crucial technologies since the discipline is at the basis of major fields such as renewable energy conversion and storage, material processing, or biomedical analysis. Electrochemical systems are employed for several aims, mainly for analysis (e.g., biosensing), material design (e.g., electrodeposition), material protection (e.g., anodization), and energy (e.g., batteries). Beyond these well-established applications, concepts studied by electrochemistry are also crucial in other fields such as photochemistry or triboelectricity. In recent years, new frontiers have emerged in the various fields of electrochemistry. In this Article Collection, selected research has been gathered to offer the reader a glimpse into recent advances in established and emerging electrochemical systems.

In Nature, chirality plays an important role in many recognition events, and two enantiomers can have opposite properties. This particularity has inspired many researchers to develop complex systems that enable the synthesis or the detection of specific enantiomers. Electrochemical charge transfer at the solid/liquid interface also depends on the surface state of the solid as well as the structure of the redox species dissolved in the solution. S. Arnaboldi *et al.* present how chirality-sensitive electrodes can be prepared, discuss how molecular chirality can affect the electrochemical response, and describe different transduction mechanisms. Another important and interdisciplinary aspect of electrochemistry is electrochemiluminescence (ECL). ECL is the production of light triggered by reactions on the surface of an electrode. This very sensitive phenomenon is the basis of many biomedical detection systems that are marketed and used routinely for the diagnosis of various pathologies.<sup>3</sup> In their article, G. Valenti *et al.* report how diverse nanomaterials can affect the features of ECL emission, in particular through the mechanisms of metal-enhanced fluorescence and resonance energy transfer.

One of the biggest trends nowadays is the development of electrochemistry of individual entities, such as colloids or cells, in solution or on surfaces.<sup>4</sup> This obviously may find applications as ultimate sensing devices; however, it also presents considerable fundamental challenges. While electrochemistry at ultramicroelectrode (UME) has been largely described, with the continuous development of technologies, researchers can now have access to nanoelectrodes. In their contribution, S. Lemay *et al.* discuss the recent advances in using nanoscale electrodes in electrochemical impedance spectroscopy. They first provide a

theoretical background, but also place particular attention on the experimental challenges. They report recent advances and discuss current challenges in this field.

To gain insight into interfacial reactions, electrochemical methods can also be coupled with other techniques. This has led to the development of new and very specific equipment or techniques. For instance, Raman spectroscopy is often used to probe interfacial phenomena and material states and thus is often used as a spectroscopy technique to probe interfacial reactions. More specifically, a few years ago, the group of J. Feng-Li developed the so-called shell-isolated nanoparticle-enhanced Raman spectroscopy (SHINERS) which offers a powerful technique to probe interfacial reactions down to the molecular level. In their contribution, Jian Feng-Li *et al.* review the recent advances in SHINERS and SHINERS-satellites strategy for practical (nano)catalysts investigation and propose future directions for SHINERS. In the same spirit, as the field of electrocatalysis is receiving attention from a growing scientific community *in-situ* and *operando* studies are now becoming essential to elucidate electrocatalytic mechanisms. Benedikt Lassalle-Kaiser has been involved in many X-ray absorption (XAS) investigations of electrocatalysts. In its paper, his team reviews the state-of-the-art and discusses the perspectives concerning the coupling between X-ray spectroscopy and electrocatalysis for the specific field of carbon dioxide reduction.

From the materials science side, corrosion has often been an important subfield of electrochemistry, with strong and direct consequences as corrosion is often seen as a severe industrial issue that represents considerable maintenance costs. J. Mauzeroll and L. Grandy review the recent literature on corrosion fatigue mechanism with a particular focus on the use of localized electrochemical techniques, such as scanning electrochemical microscopy (SECM) or scanning electrochemical cell microscopy (SECCM), to probe metal damage simultaneously exposed to corrosion and mechanical stress. In his contribution, L. Santinacci introduces atomic layer deposition, a powerful coating method allowing the growth of thin films monolayer-by-monolayer. He proposes it as a promising tool for corrosion protection and presents successful examples. In contrast to well-known electrochemical dissolution, which can be provoked by undesired corrosion, anodic electrochemical processes can also be employed for the preparation of substrates with a remarkable organization at the micro- or the nanoscale. In their article K. Lee and J. Yoo report the recent development of a promising anodization method based on a molten salt to produce self-organized titanium dioxide nanotubes on titanium metal foils. They discuss the structuration mechanism and review the applications of these nanostructured substrates.

Electrochemistry and energy are intimately related and this is particularly true in the development of devices for renewable energy storage. Even if the development of such systems and devices has already attracted the attention of many researchers and industries, electrochemical energy storage devices are experiencing a new, very strong resurgence of interest due to the global worldwide rise of energy consumption and global warming. In this special issue, F. Geneste *et al.* review the use of anthraquinone derivatives in aqueous redox flow batteries (AORFBs) with particular emphasis on their integration into industrial

processes as this technology is about to reach the required performances for industrial development. While the use of aqueous electrolytes appears appealing to produce safe and environmental-friendly electrolytes, many other promising electrolytes have been studied and developed recently, including water-in-salt, deep eutectic solvents (DES) or room temperature ionic liquids (RTILs) for instance. In their review, O. Fontaine *et al.* focus on a special class of RTILs, the redox ionic liquids, and suggest a classification for them. They discuss the electrochemical fundamental aspects and their applications in energy storage devices such as lithium-ion batteries (LIB) and supercapacitors.

Last but not least, the two last contributions intend to demonstrate how electrochemistry has implications far beyond its classical forms. On the one hand, Ciampi *et al.* discuss how surface modification can affect the direct current generated by the motion of two charged interfaces. These systems, referred to as triboelectric generators, may emerge in the future as portable current sources. On the other hand and in strong link with the article of B. Lassalle-Kaiser, N. T. Nguyen and C. Perdomo report recent advances in semiconductor-based nanocatalysts for the reduction of carbon dioxide. These systems, where electrochemical interfacial charge transfers are triggered by incident light, are promising for converting CO<sub>2</sub> into valuable chemicals through the action of incident photons such as those produced by solar illumination.

As guest editors for this Article Collection of Current Opinion in Colloid & Interface Science, we assembled articles that highlight the broad range of scientific fields where electrochemical processes are involved and the importance of this discipline in the actual and future challenges that our current society has to face. We would like to warmly thank all the authors for their contributions ranging from fundamental research to applied ones, in themes closely related to contemporary issues. We hope that readers of the journal will find it interesting and valuable to their own research and understanding of the areas covered in this issue.

Bio:

Gabriel Loget is a physical chemist. In 2015, he joined the CNRS where he works on material sciences and photoelectrochemistry. His current research includes energy conversion, detection, and electrogenerated luminescence. He has published more than 65 papers.

Yann R. Leroux is a researcher working at the CNRS and located at the Institute des Sciences Chimiques de Rennes (ISCR) in France. His current research interests focus on the functionalization of carbon and other surfaces by (electro) chemical means and localized electrochemistry. He received the young electrochemist award from the French Chemical Society.

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<sup>1</sup> Castelvechi D., Stoye E: **Chemistry Nobel honours world-changing batteries.** *Nature* 2019, 574:308.

<sup>2</sup> Ganiyu S O, Martínez-Huitle C A: **The use of renewable energies driving electrochemical technologies for environmental applications** *Curr. Opin. Colloid Interface Sci.* 2020, 22:211-220.

<sup>3</sup> Knezevic S, Bouffier L, Liu B, Jiang D, Sojic N: **Electrochemiluminescence microscopy: From single objects to living cells** *Curr. Opin. Electrochem.* 2022, 35:101096.

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<sup>4</sup> Fan Y, Barlow S T, Zhang B : **Single-molecule electrochemistry** *Frontiers of Nanoscience* 2021, 18:253-293.