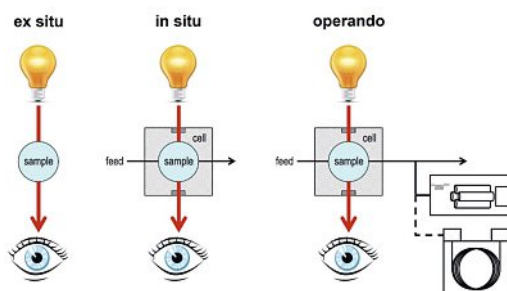


# Editorial



Maarten Nachtegaal and Davide Ferri

*Operando* is a term introduced in chemistry indicating that functional material characterization is performed under reaction conditions and is combined with simultaneous measurements of its performance (activity, selectivity, etc.). This, in contrast to the *in situ* methodology where materials are measured under operating conditions but without simultaneous performance measurements, allows the structure-activity or structure-selectivity relationships to be determined. These structure-performance relationships are essential for the rational design or optimization of functional materials such as catalysts or battery materials.



Since the introduction of the term *operando* in 2002, Swiss research groups have been actively shaping this research field, by developing *operando* physico-chemical (spectroscopy) methods that allow the analysis of the structure of the material with increased sensitivity and time resolution and of analytics to improve chemical speciation. Many of these developments were made at Switzerland's large research facilities such as the Swiss Light Source, the Swiss Spallation Neutron Source or the Swiss Norwegian Beamlines at the European Synchrotron Radiation Facility. This issue of *CHIMIA* is devoted to highlighting the research activities and available facilities related to the *operando* methodology in Switzerland. Scientific contributions from various Swiss groups showcase the different approaches used to tackle identification of active structures within solid catalysts using one or more spectroscopy-diffraction-imaging techniques and to correlate this with kinetic parameters such as for example reaction rates.

**Sarma and Grunwaldt** (KIT) introduce *operando* spectroscopy, giving an account of early contributions of Swiss researchers to this field and show some examples from their own research including emission control, oxidation catalysis in chemical industry, future power-to-X processes and non-oxidative conversion of methane. In their mini-review, **Abdala and Müller** (ETH Zurich) show advances in the understanding of the structure of active sites and its evolution using synchrotron X-ray based methods, XAS, XRD and PDF for the case of catalytic CO<sub>2</sub> valorization. **Nachtegaal et al.** (PSI) demonstrate the powerful *operando* and *in situ* X-ray spectroscopy capabilities of the SuperXAS beamline at the Swiss Light Source. **Ferri et al.** (PSI) show their approach to obtain detailed information on the structure of active sites by combining benefits of various *operando* characterization techniques and the modulated excitation methodology. **Fabbri et al.** (PSI) discuss recent advances in the understanding of oxygen evolution catalysts based on transition metal oxides using X-ray absorption spectroscopy. **Jeschke et al.** (ETH Zurich) report on the opportunities and challenges of electron paramagnetic resonance spectroscopy for *in situ/operando* experiments. **Borgschulte** (Empa), **Boillat** (PSI), **Trtik** (PSI) *et al.* present case studies of neutron imaging to demonstrate the potential of this emerging technique for understanding processes related to energy production. **Tileli** (EPFL) reviews electron microscopy studies of solid-liquid interfaces present for example in electrochemical processes. **Arenz et al.** (University of Bern) describes an *operando* cell for electrochemical studies of the oxygen evolution reaction (OER) that exploits total X-ray scattering.

We thank all authors for their contributions and hope these publications inspire new collaborations and applications of the *operando* methodology in your research. We wish you an enjoyable read!

Davide Ferri and Maarten Nachtegaal

The CHIMIA Editorial is very grateful to Drs. Davide Ferri and Maarten Nachtegaal for their great efforts in organizing this issue on *Operando Spectroscopy in Switzerland* showcasing the broad range of facilities and research activities in this topic in Switzerland.

The front cover represents the adapted logo of the Center for *Operando* Spectroscopy Studies (COSS) recently launched at PSI (<https://www.psi.ch/en/operando>) and shows pictorials of various *operando* techniques which are described in this themed issue. The image was realized by D. Aegerter, F. Buttignol, D. Ferri, R. J. G. Nuguid, M. Roger, I. Sadykov and A. Zabiliska.