High Energy X-rays: The Ultimate Tool For Operando Characterization of Electrochemical Systems.

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For future societal needs, the development of cost effective electrocatalytic devices is a key issue. In this contribution, I will discuss the use of high energy X-rays for obtaining comprehensive insights into the complex processes which occur inside such devices. This probe enables structural characterisation under operating conditions on all relevant length scales, from the atomic-scale interfaces to complete stacks and battery packs. This opens up possibilities to go beyond characterisation of the isolated components, towards an understanding of their interactions in the full system which determine the output, efficiency and degradation pathways in operational devices.

I will give various examples of state-of-the-art high energy X-ray techniques tailored particularly for characterisation of electrocatalytic and battery systems (Figure 1) and discuss the expected possibilities of new 4th generation synchrotron sources in this respect. Aspects of individual materials and device development will be examined, starting from the fundamentals of single crystal surfaces and finishing with operando characterisation of high performance devices where mass transport plays a decisive role. The future prospects and directions of using high energy X-rays in operando electrochemical experiments will be also discussed, including the high throughput pipelines and use of AI assisted materials discovery and device optimization.

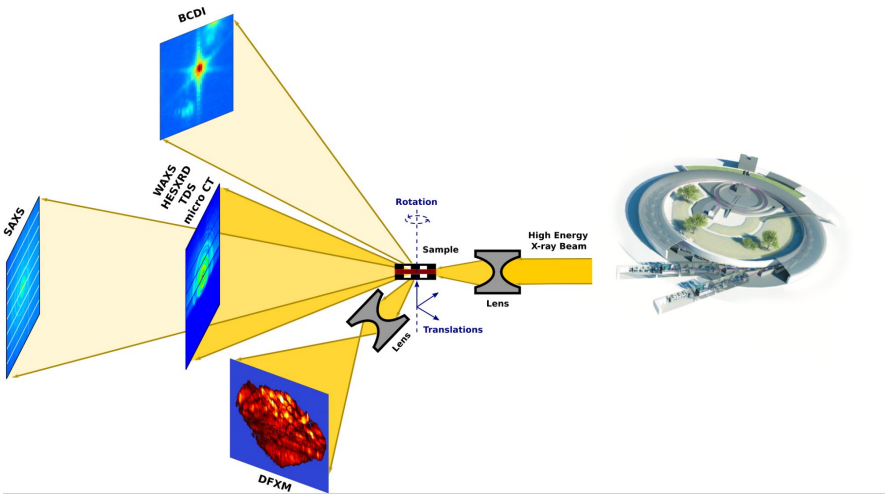

Figure 1. Application principles of high energy X-ray imaging and elastic scattering techniques. [1]

Literature:

[1] Martens *et al*, *J. Phys. Energy,* 3 **(2021),** 031003, 10.1088/2515-7655/abf43d