Correlative Electrochemical Multi-Microscopy: How Nanoscale Measurements Facilitate a Multiscale Understanding of Electrochemical Processes and Interfaces

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Electrodes of practical importance are usually complex on a range of length scales, from the nanoscale to the device level. To address this complexity, we have introduced new approaches, whereby nanoscale information on electrode activity is obtained by electrochemical microscopy in the form of activity maps and activity movies [1-10] and these rich datasets are mapped onto co-located electrode structure and properties from complementary high-resolution microscopy and spectroscopy techniques. The figure below shows the pairing of our key electrochemical imaging technique – scanning electrochemical cell microscopy (SECCM) – with examples of some of the complementary microscopy techniques used. With this approach, complex electrode surfaces are studied as sets of “single entities” (e.g., individual steps, terraces, defects, crystal facets, grain boundaries, single particles). With this detailed microscopic information, an interesting question is: can we predict the behaviour of electrodes on larger length scales? And what do we learn about electrochemical systems from a multiscale approach?
A wide range of illustrative examples of this general philosophy includes investigations of 1D and 2D materials, single particles and ensembles of particles on electrode supports, as well as structurally and/or compositionally heterogeneous surfaces, such as polycrystalline metals and polymer composite electrodes. Applications include electrocatalysis, battery electrodes, next generation membranes and corrosion. Ultimately, the approaches we advocate provide a roadmap to facilitate the rational design of functional (electro)materials. The techniques and ideas can also be translated to other areas, from crystallisation to studies of living cells at the nanoscale.

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References