Corrosion, Electrocatalysis, Biofilms: The Role of Local Electrochemistry in Materials Science

Sanjin J. Gutić

University of Sarajevo – Faculty of Science, Zmaja od Bosne 33-35 71000 Sarajevo, Bosnia and Herzegovina
E-mail: sgutic@pmf.unsa.ba

The development and engineering of materials rely on a detailed understanding of their intrinsic properties, which are commonly determined under vacuum or ambient conditions. However, when materials operate in liquid environments, such properties often fail to correlate directly with their behavior or performance, as assessed, for example, by bulk electrochemical methods, and may even be altered to some extent. To overcome this limitation, a range of advanced techniques now enables direct probing of local electrochemical performance. These methods provide high-resolution spatial mapping of regions with distinct properties, which is particularly valuable in fundamental studies of corrosion, electrocatalysis, and biofilms. An additional advantage is the ability to probe materials without external polarization, as well as materials that are non-conductive or electrochemically inactive.

With their current spatial resolution, scanning electrochemical techniques allow rapid screening of electrode surfaces, revealing the distribution of zones with varying electrochemical activity. Among these, scanning electrochemical microscopy, electrochemical atomic force microscopy, and scanning electrochemical cell microscopy have proven especially effective in studying corrosion and protection mechanisms, including systems with conductive and insulating films. In electrocatalysis, localized methods provide insight into reaction intermediates, mechanisms across different electrode regions, and processes at three-phase boundaries such as gas bubble nucleation, growth, and detachment. These techniques have also been successfully applied to investigate the formation and stability of solid electrolyte interphases in batteries and side reactions at supercapacitor electrodes, offering perspectives beyond routine characterization and revealing key processes responsible for performance degradation.