Nanomaterials at the edge: Emergent nanoparticles

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Abstract

Understanding and controlling the processes occurring at electrode/electrolyte interface are key factors in optimising fuel cells and electrolysers. Metal particles supported on oxide surfaces promote many of the reactions and processes that underpin the global chemical industry and are key to many emergent clean energy technologies. At present, particles are generally prepared by deposition or assembly methods which, although versatile, usually offer limited control over several key particle characteristics, including size, coverage, and especially metal-surface linkage. In a new approach, metal particles are grown directly from the oxide support though *in situ* redox exsolution. We demonstrate that by understanding and manipulating the surface chemistry of an oxide support with adequately designed bulk (non)stoichiometry, one can control the size, distribution and surface coverage of produced particles. We also reveal that exsolved particles are generally epitaxially socketed in the parent perovskite which appears to be the underlying origin of their remarkable stability, including unique resistance of Ni particles to agglomeration and to hydrocarbon coking, whilst retaining catalytic activity

We also present the growth of a finely dispersed array of anchored metal nanoparticles via electrochemical poling on an oxide electrode, yielding a sevenfold increase in fuel cell maximum power density. Both the nanostructures and corresponding electrochemical activity show no degradation over 150 hours of testing. These results not only prove that in operando treatments can yield emergent nanomaterials, which in turn deliver exceptional performance, but also provide proof of concept that electrolysis and fuel cells can be unified in a single, high performance, versatile and easily manufacturable device. This opens exciting new possibilities for simple, quasi-instantaneous production of highly active nanostructures for reinvigorating Solid oxide cells during operation.

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John Irvine FRSE, FRSC has made a unique and world-leading contribution to the science of energy materials, especially fuel cell and energy conversion technologies. This research has ranged from detailed fundamental to strategic and applied science and has had a major impact across academia, industry and government. Irvine's science is highly interdisciplinary extending from chemistry and materials through physics, bioenergy, geoscience, engineering, economics and policy.

The quality and impact of Irvine's research has been recognised by a number of national and international awards, including the Lord Kelvin Medal from the Royal Society of Edinburgh in 2018, the Schönbeim gold medal from the European Fuel Cell Forum in 2016, the RSC Sustainable Energy Award in 2015, with earlier RSC recognition via Materials Chemistry, Bacon and Beilby awards/medals.

Highlights of Irvine's activities include discovery of the Emergent nanomaterials phenomenon, establishing the field of oxide fuel electrodes, delivering high performance direct carbon fuel cells and demonstration of significant hydride ion conductivity. Other important achievements relate to photocatalysis, lithium ion batteries, non-stoichiometric oxides, structure/property/function, catalysis and electrocatalysis and bioenergy.