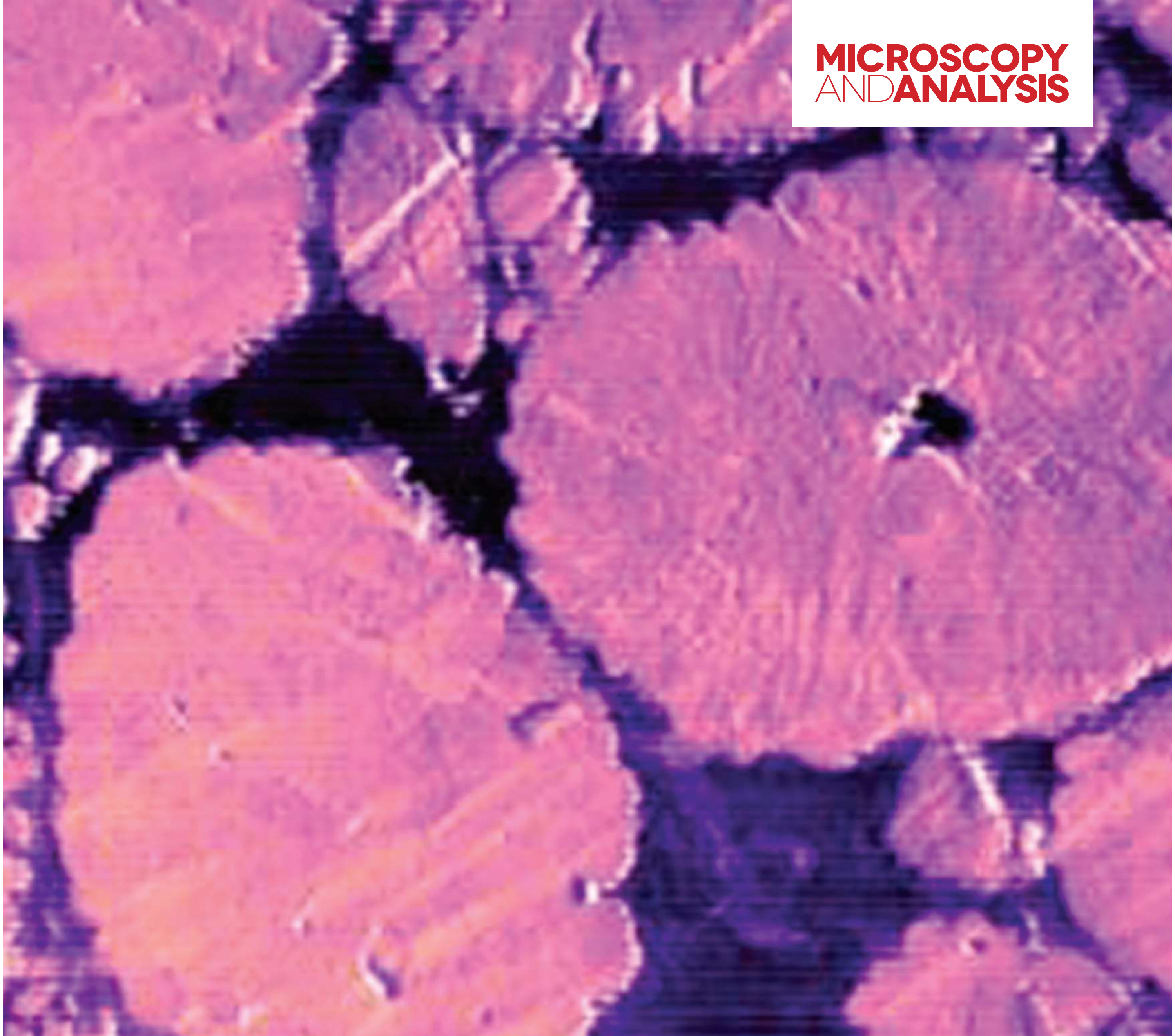
MICROSCOPY AND ANALYSIS



Battery Research: Characterizing the Future

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BRUKER

Front cover: atomic force microscopy image of a cross-sectioned cathode with lithium metal oxide, carbon and polymer filler. 15x15μm scan. Image © Bruker.

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Essential Knowledge Briefings, published by John Wiley & Sons, comprise a series of short guides to the latest techniques, applications and equipment used in analytical science. Revised and updated annually, EKBs are an essential resource for scientists working in both academia and industry looking to update their understanding of key developments within each specialty. Free to download in a range of electronic formats, the EKB range is available at www.essentialknowledgebriefings.com

INTRODUCTION

Dramatic changes in the world of batteries over recent decades have helped usher in our modern technological world. Today, many of our electronic devices, from laptops to smartphones, are powered by rechargeable lithium-ion (Li-ion) batteries, and they could soon extend into many other areas as well. This includes transport, through the ongoing development and adoption of electric vehicles.

As the metal with the lowest density and a very high electrochemical potential – and therefore the highest energy-to-weight ratio – lithium is an ideal material for batteries. The first lithium batteries were developed in the 1970s, powered by a metallic lithium anode. Although more powerful and longer lasting than the alkaline battery, these first lithium batteries were non-rechargeable, limiting their use.

Adoption of a lithium cobalt oxide cathode and a graphite anode led to the first rechargeable Li-ion battery, which was commercialized in 1991. Li-ion batteries are now the gold standard for rechargeable batteries, hence their ubiquity in portable electronic devices.

Yet there is significant room for improvement. Although less susceptible than other battery types, Li-ion batteries still suffer from 'self-discharge', whereby chemical reactions inside the battery reduce its stored charge (by up to 3% per month). Li-ion batteries also exhibit limited capacity, inaccurate estimates of remaining charge, and are notoriously expensive to produce. Furthermore, they can suffer from the growth of crystalline needles of lithium, known as dendrites, from the anode. If these dendrites grow to reach the cathode, they can short-circuit the battery, potentially causing it to catch fire or even explode.

Scientists are actively investigating various ways to overcome these issues – from producing improved Li-ion batteries by synthesizing better battery materials to developing next-generation battery technologies that might one day replace Li-ion batteries as the gold standard. But doing this requires precise, sensitive techniques for analyzing and characterizing these materials and technologies.

This EKB will introduce the main analytical techniques used to characterize Li-ion battery materials. In particular, it will focus on nanoindentation, a very common method for measuring the mechanical properties of materials, and atomic force microscopy (AFM) characterization, which works by 'touching' the surface of materials with a mechanical probe to map their topography and properties with nanoscale resolution. The EKB will explain how these techniques and their various modes work, and will detail how they are used for analyzing battery materials and what kind of information they can produce. It will also present two case studies to illustrate how the techniques are being applied by working scientists in the laboratory.

Looking to the future, it will explore what new lithium-based battery technologies are in the pipeline – including metal, sulfur and air-based technologies – and the specific challenges associated with their characterization. It will look at novel characterization approaches that may overcome these challenges, and explore the ultimate applications of more powerful batteries, from powering electric vehicles to storing renewable energy.