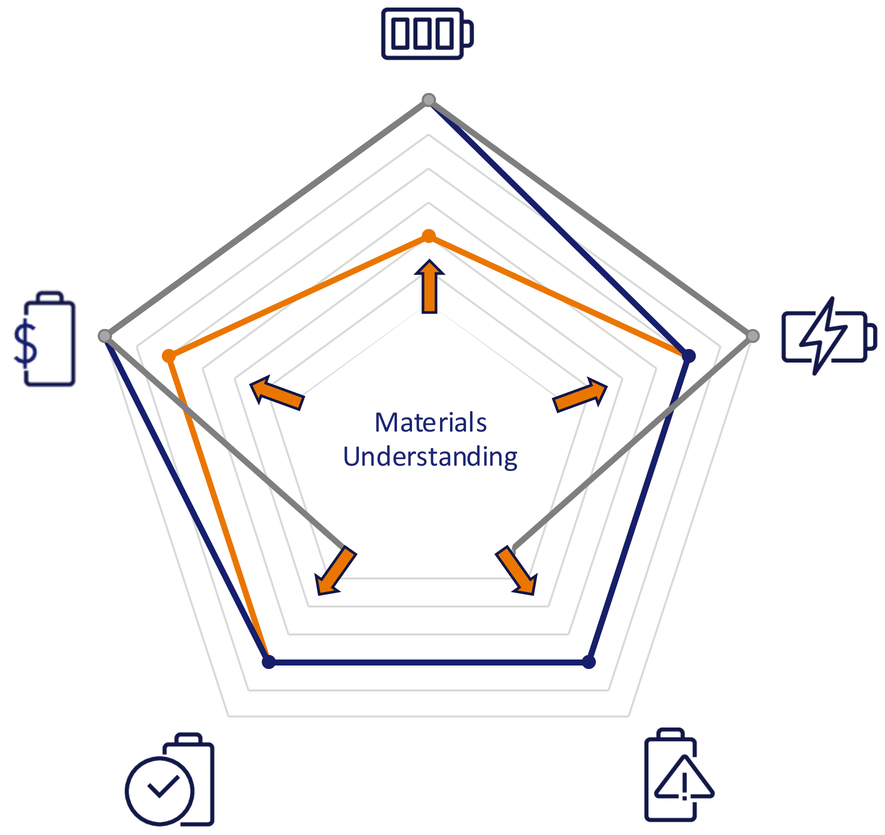
Solutions for Battery Materials Analysis

Enabling your battery development through materials understanding

Desirable battery properties

	Today	2035
Energy Density (how much charge can be stored)	**250** Wh/kg	**500** Wh/kg
Power Density (how quickly charge can be used)	**3** kW/kg	**12** kW/kg
Safety	-	Eliminate thermal runaway
Lifespan	**8** years	**15** years
Cost	**100** $/kWh	**50** $/kWh



Enabling battery development through materials understanding

MINING & EXTRACTION

- EDS — Yield optimisation
- SPECTROSCOPY — Mineral liberation analysis

RECYCLING

- EDS — Black mass composition
- NMR — Electrolyte identification

FAILURE ANALYSIS

- RAMAN — Separator degradation
- EBSD — Post cycling electrode structure

MATERIALS PROCESSING

- EDS — Precursor powder purity
- RAMAN — Graphite orientation consistency
- SPECTROSCOPY — Trace element analysis

RESEARCH & DEVELOPMENT

- NMR — Ion mobility & electrolyte conductivity
- AFM — SEI formation processes

MANUFACTURING

- EDS — Electrode compositional uniformity
- NMR — Electrolyte quality and purity

Solutions for Materials Understanding

NMR

Analysis of structure, chemical and physiochemical properties in liquids and solids

AFM

3D characterisation of surface nanoscale structure, mechanical and electrical properties

Raman

Surface and subsurface chemical structure and microscopy of organic and inorganic materials

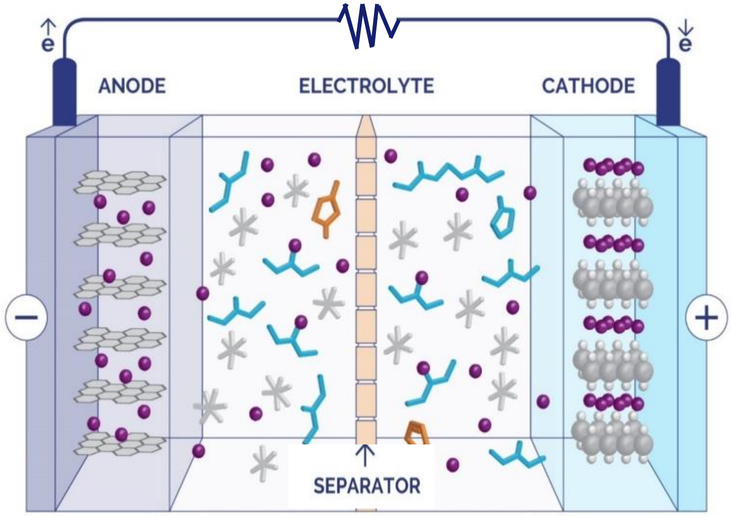
EDS/WDS/EBSD

Nano scale elemental and structural characterisation and classification of key materials using SEM

- Correlative microscopy solutions include Raman Imaging and Scanning Electron Microscopy (RISE)

Characterising critical battery components

Electrolyte Characterisation	Techniques	Property
Concentration and purity	NMR	
Ionic conductivity	NMR	
Breakdown & degradation	NMR	
Impact on electrode SEI formation	AFM	



Anode Characterisation	Techniques	Property
Lithium content	SEM, Raman	
Interfacial roughness	AFM	
Carbon material quality	Raman	
Characterise SEI formation	AFM	

Cathode Characterisation	Techniques	Property
Particle size	EDS	
Chemical consistency	EDS, Raman	
Powder purity	EDS	
Cycling effect on chemistry	Raman, RISE	

Separator Characterisation	Techniques	Property
Structure deterioration during cycling	Raman, RISE	
Nanoscale structure	AFM	
Porosity & permeability	NMR	

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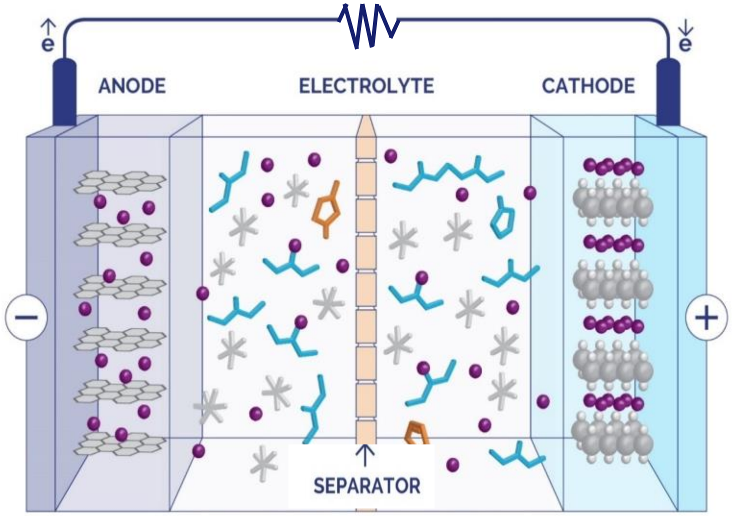

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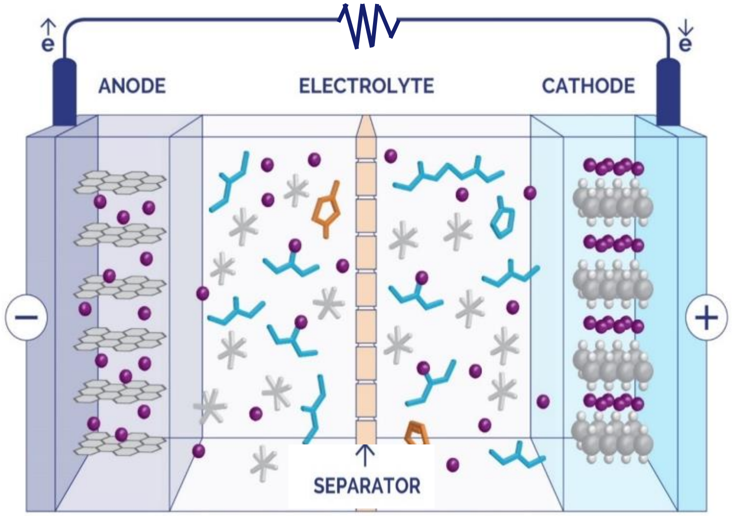

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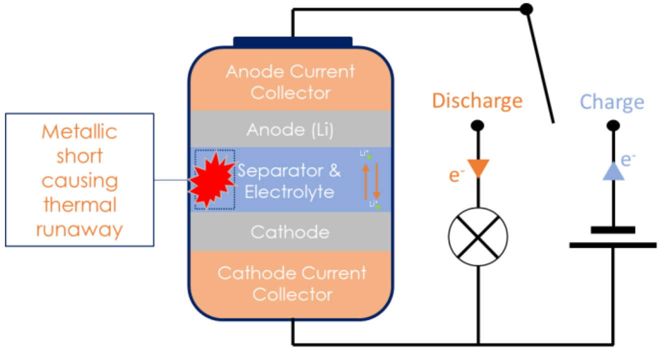
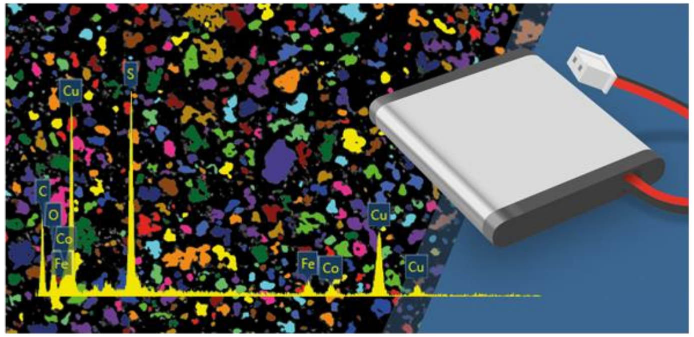
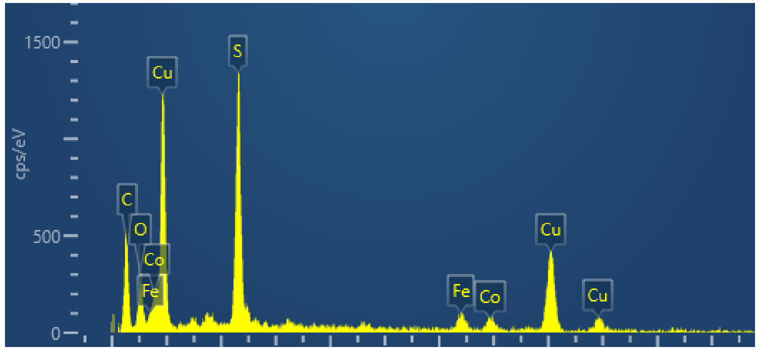
How clean is my electrode precursor material?

Application: Battery safety

Technique: EDS







The Problem

Identification of metallic contaminants introduced during the mining and subsequent manufacturing of Li-ion batteries can cause short circuits

The Analysis

AZtecBattery provides high speed automated software analyses of EDS spectra identifying and classifying elements in contaminants and their morphology

The Solution

Quantifying levels of unwanted Fe, Cu, and other metallic contaminants in manufacturing plant filters identified stainless steel pipes as the source and now enables ongoing QC monitoring

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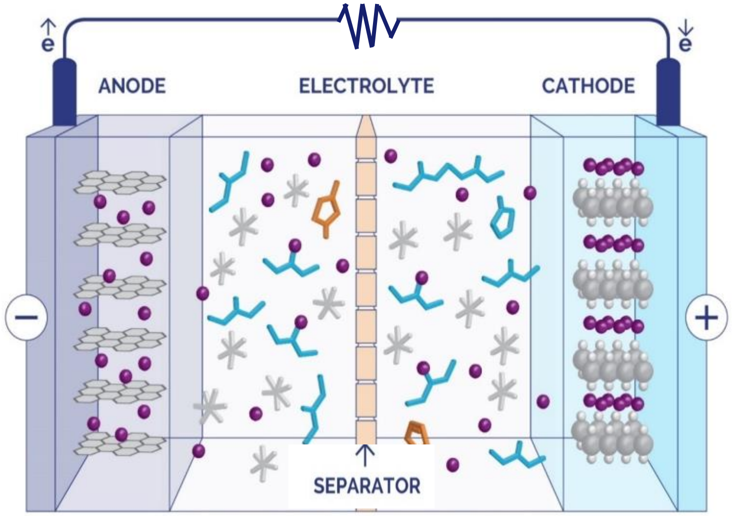

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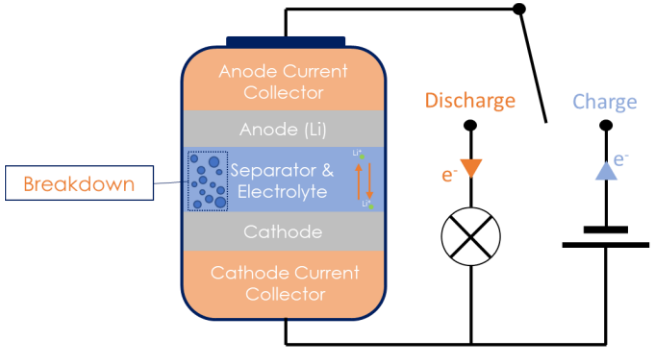
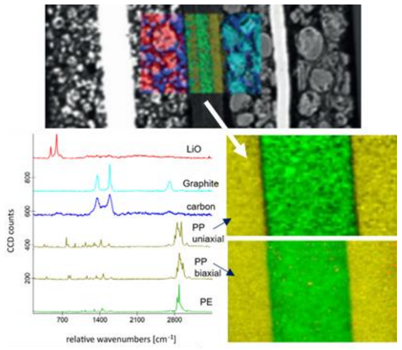
Does my separator degrade during cycling?

Application: Battery lifespan

Technique: Raman





The Problem

Separator polymers undergo molecular deterioration with cycling. Changes in separator composition and their ability to suppress dendrite growth affect the performance of Li-ion batteries.

The Analysis

Raman Imaging Scanning Electron Microscopy (RISE) maps high resolution microstructure, chemical and elemental composition and atomic/molecular bonding to understand separators and electrodes before and after cycling

The Solution

The outer uniaxial polypropylene layers of the separator deteriorate, appearing as biaxial in the cycled battery. These structural changes can be correlated to observed cell performance degradation

Characterising critical battery components

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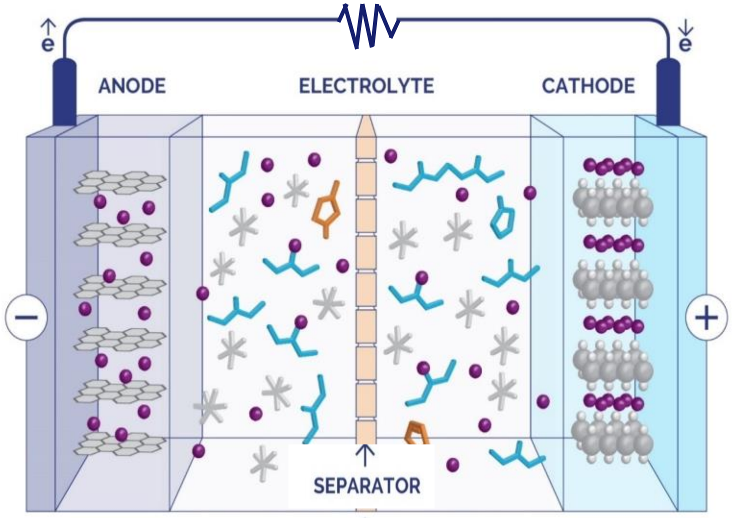

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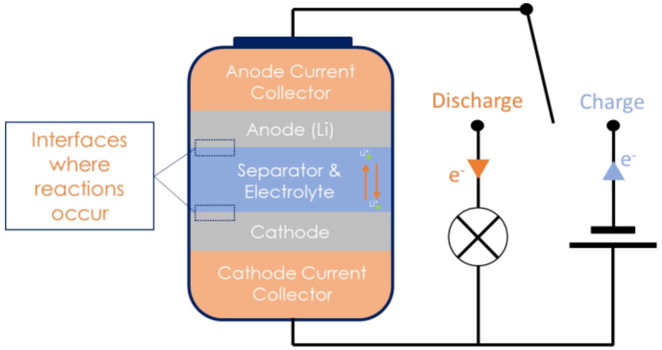
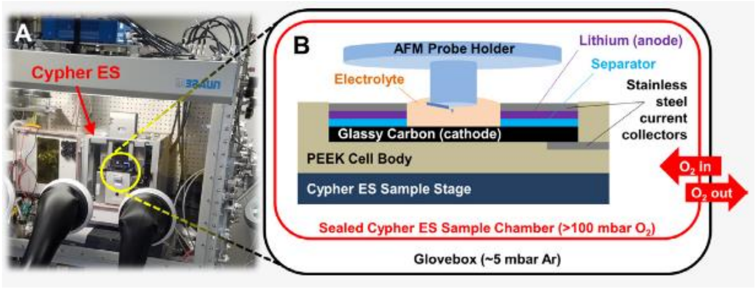
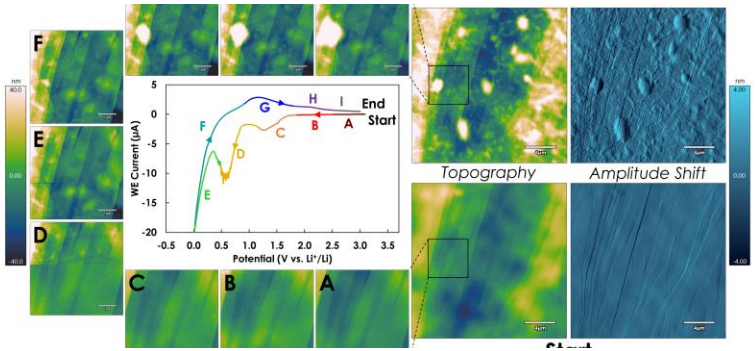
How does my SEI form?

Application: Battery lifespan

Technique: AFM







The Problem

Formation of a stable anode Solid Electrolyte Interphase (SEI) is critical for reliable battery performance. During cycling this SEI can degrade deteriorating capacity, or ultimately form dendrites which cause short circuits.

The Analysis

Using a Cypher AFM an integrated electrochemical cell inside a glove box, the anode surface morphology is imaged during the charge and discharge cycle.

The Solution

As the SEI forms on different electrode designs, AFM quantifies its uniformity. One electrode undergoes unwanted blistering at high charge potentials as intercalated water molecules split. Roughness increases dramatically during cycling.

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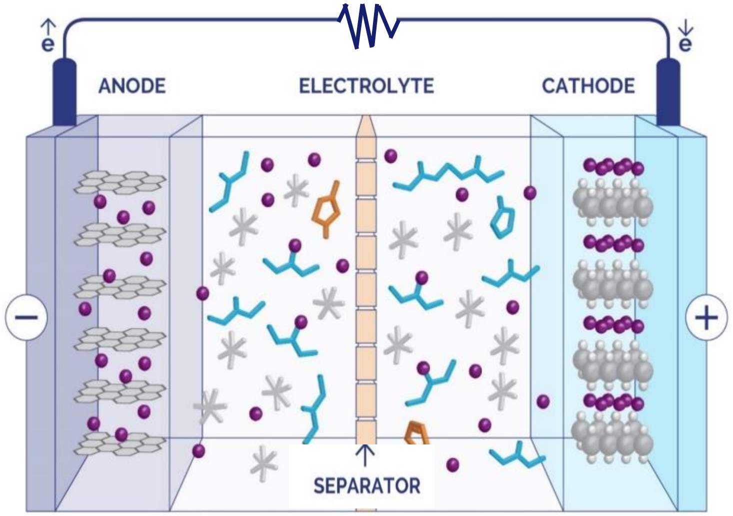

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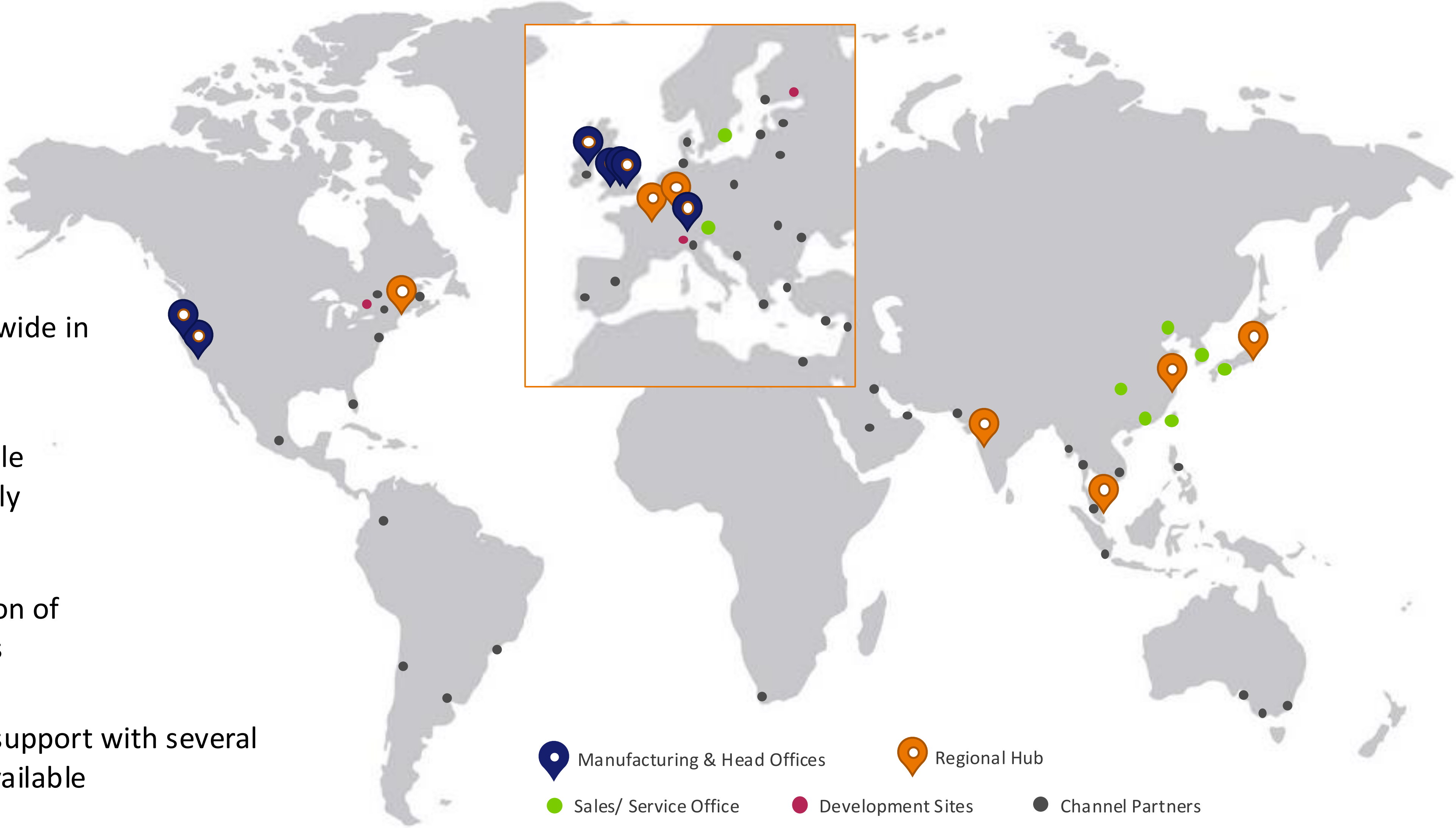
Global Footprint

28 offices worldwide in 18 countries

Over **1,850** people employed globally

Global distribution of technical centres

24 hour service support with several support levels available



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Summary

Oxford Instruments can help battery development with a broad variety of techniques.

- Of which only a small number has been showcased here:
  - Electrolyte property optimisation
  - QA/QC (cathode precursor powders, electrolyte)
  - Analysis of separator degradation with cycling
  - Imaging and monitoring of SEI formation
- We can also help with:
  - **Failure analysis** (electrodes, electrolyte, full battery, failure mechanisms)
  - **Materials research** (formulation testing, new materials development, light and trace element analysis, high resolution analysis)
  - **Recycling** (black mass analysis)
  - **Correlative microscopy**

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