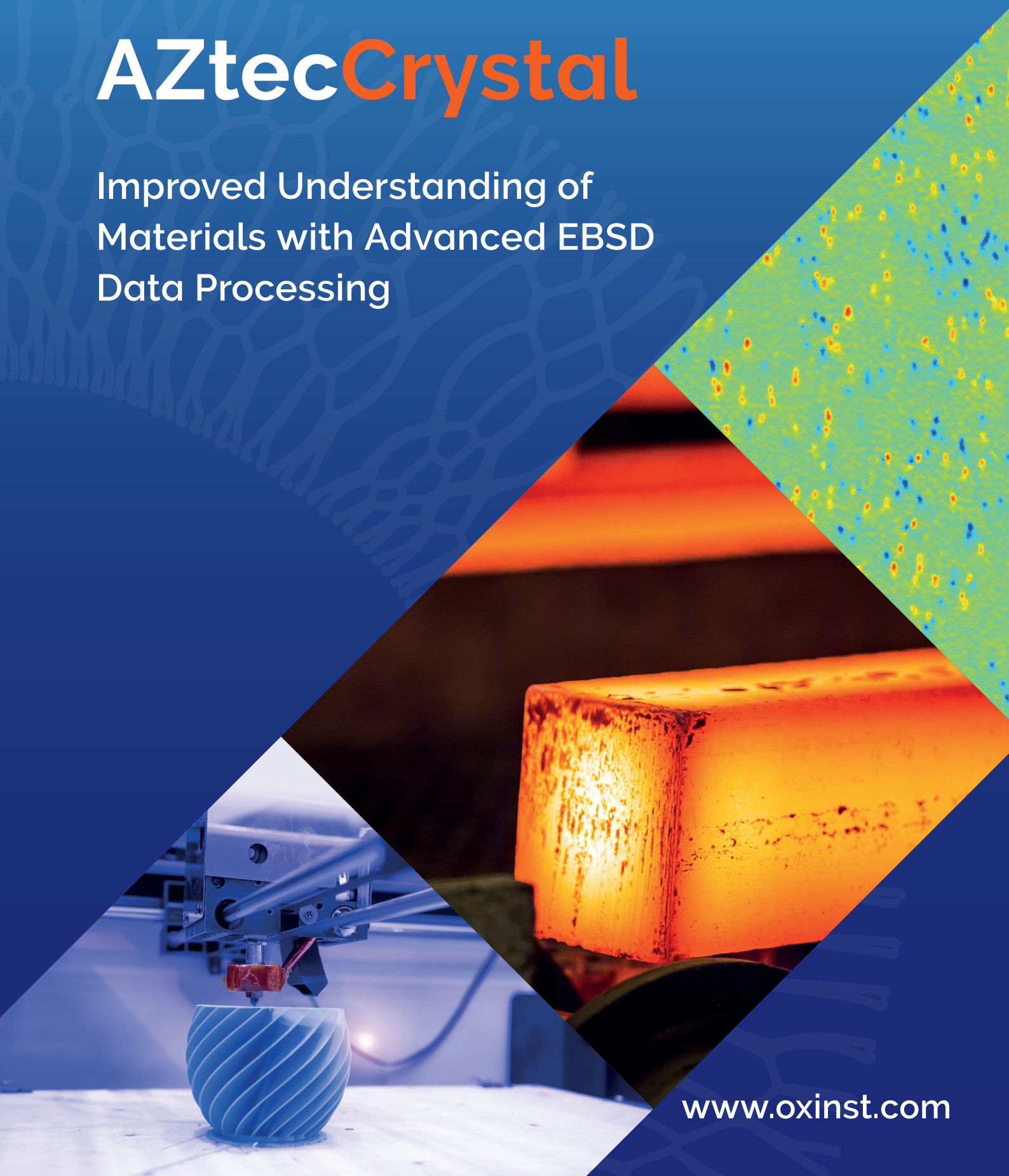
OXFORD INSTRUMENTS

AZtecCrystal

Improved Understanding of Materials with Advanced EBSD Data Processing



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AZtecCrystal

Next Generation EBSD Data Processing

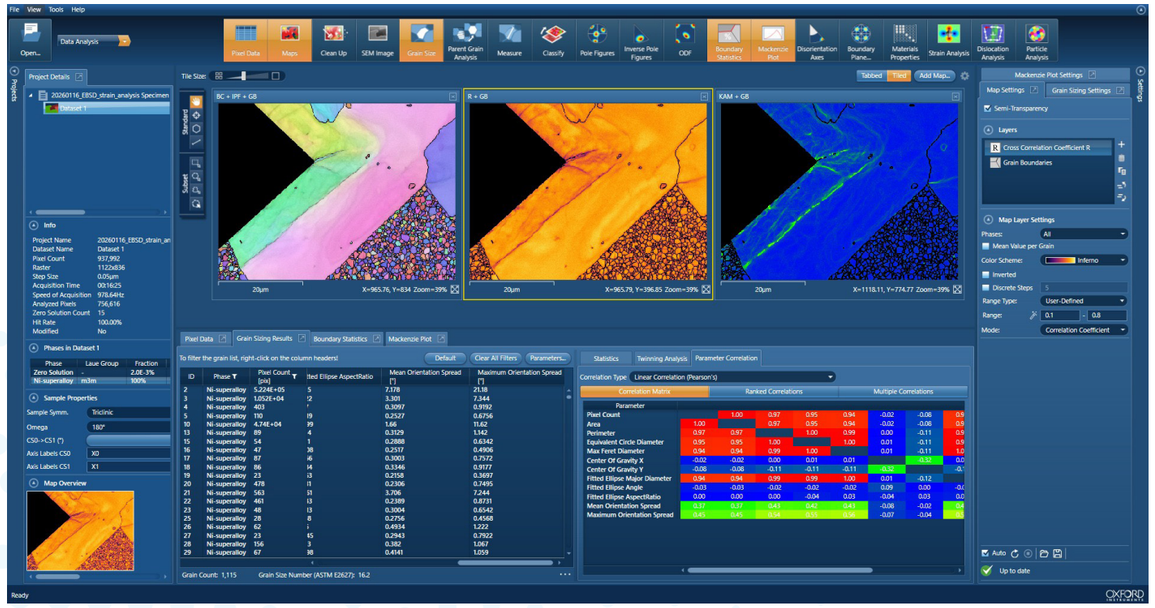
Every electron backscatter diffraction (EBSD) analysis starts at the microscope, requiring a high-quality EBSD detector coupled with reliable acquisition and indexing software. However, the measurement workflow does not stop there – it is the offline processing of EBSD datasets that truly reveals a sample's physical properties and microstructural characteristics.

AZtecCrystal is Oxford Instruments' modern and innovative EBSD data processing software, designed for the new era of high-speed EBSD detectors and ever-expanding EBSD applications. First launched in 2019, AZtecCrystal has been continually developed ever since and now offers the accessibility and functionality to satisfy the novice and expert alike.

Designed for Every User

Interrogating EBSD datasets has never been easier. AZtecCrystal has an accessible user interface that is both intuitive and flexible. Whether you are an occasional EBSD user, requiring instant access to routine functionality, or an EBSD expert wanting to extract detailed microstructural information from your sample, AZtecCrystal is designed for you.

- AZtec-inspired interface with user-configurable settings and layouts
- Multiple Data Analysis modes that provide instant access to key functionality



Increasing Productivity

Modern CMOS-based EBSD detectors can collect EBSD data at speeds in excess of 20 million analyses per hour. AZtecCrystal is designed to handle such large datasets with ease and incorporates smart functionality to enhance your data throughput.

- High-speed quaternion based data manipulation
- Intelligent saving of processed data and customised displays
- Customisable templates and batch processing for quick, routine analysis tasks

Your Results, Your Data

AZtecCrystal stores data in an open-access hierarchical data format (HDF5). All relevant results, including stored EBSD patterns, chemical information from energy dispersive X-ray spectrometry (EDS), processed data and calculated results are saved in our bespoke *.h5oina format.

- Access to all your data in an open format
- Full data format details available at github.com/oinanoanalysis/h5oina

Key features and benefits of AZtecCrystal post-processing software

Feature	Description	Standard	Advanced	Expert
Data Clean Up	Removal of indexing errors and improve dataset hit rates	✓	✓	✓
Map Display	Plot and customise maps to display any EBSD data	✓	✓	✓
SEM Image	View electron images with EBSD data and correct drift/distortion	✓	✓	✓
Grain Analysis	Comprehensive grain measurement and analysis	✓	✓	✓
Texture Analysis	Analyse textures using (inverse) pole figures and ODFs	✓	✓	✓
Measure Tool	Plot changes along user-defined transects	✓	✓	✓
Boundary Analysis	Comprehensive analysis of boundary properties and lengths	✓	✓	✓
Subsets	Partition data into constituent subsets for further analysis	✓	✓	✓
Templates/Batch processing	Set up repeatable processing across all calculations/displays	✓	✓	✓
Classification Tool	Machine-learning classification of microstructure constituents	✓	✓	✓
Physical Properties	Calculate and view the elastic properties of samples	✓	✓	✓
Parent Grain Analysis	Reconstruct and analyse parent grain microstructures	option	✓	✓
Dislocation Analysis	Detailed dislocation analysis using Weighted Burgers vectors	option	✓	✓
Particle Analysis	Analysis and classification of particulate microstructures	option	✓	✓
Crystal Batch & Compare	Create & visualise data stacks, add external parameters and Batch process	option	✓	✓
MapSweeper - Pattern Matching	Dataset enhancement using simulated pattern matching indexing on stored EBSPs	option	option	✓
Strain Analysis	Calculate deviatoric strain from stored patterns using MapSweeper	option*	option*	✓

*requires MapSweeper licence

Standard

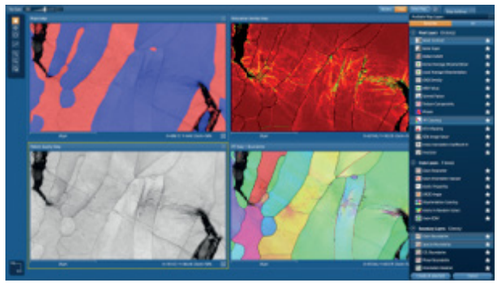
For all of your routine EBSD data processing needs

Many EBSD data processing tasks are standard, such as plotting phase or orientation maps, determining the texture and characterising the boundary populations. AZtecCrystal has all the tools required for these everyday tasks as part of the Standard processing package, as well as many more advanced features for dataset cleaning, subset creation and analysis and flexible data outputs.

Create the Maps You Need

Map display is at the heart of almost every EBSD analysis, whether it is for showing the distribution of phases or for visualising strain and deformation. AZtecCrystal has unlimited flexibility in map creation and display, allowing you to view the key features in every microstructure.

- Over 30 basic, customisable map components
- No limits to the number of components that can be combined in a single map

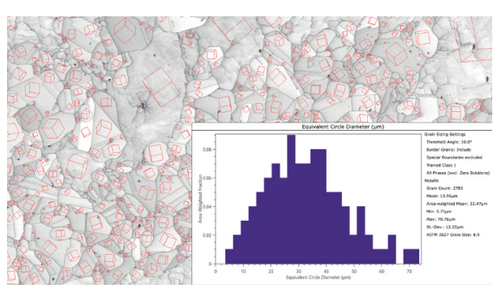


Standard screenshot showing the flexibility in map creation and display

Instantaneous Grain Measurements

EBSD is a highly effective technique for all grainbased analyses, including grain size measurements to international standards and rigorous grain morphology determination. AZtecCrystal automatically calculates grain data for every dataset, with multiple data outputs and visualisation tools.

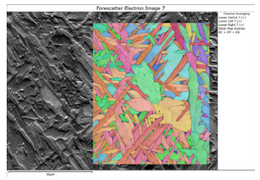
- Grain size measurements to ISO and ASTM standards
- Calculation of >30 user-defined grain parameters



Grain size and grain orientation displays for a Ni Superalloy sample

Perfect Image Correlation

AZtecCrystal enables effective correlation between EBSD maps and any accompanying electron images, enhancing your understanding of every microstructure.



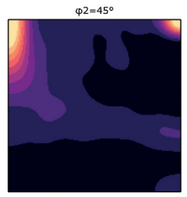
- Full distortion correction to ensure perfect correlation

An orientation map superimposed on a forescatter electron image for a dataset from a Ti64 alloy

Complete Texture Analysis

The measurement of texture (or crystallographic preferred orientation) is a fundamental output of any EBSD analysis. AZtecCrystal has all the tools needed for rigorous texture analyses:

- Fully configurable pole and inverse pole figure calculation and display
- Full orientation distribution function (ODF) determination using spherical harmonics
- Extensive range of texture display options in maps

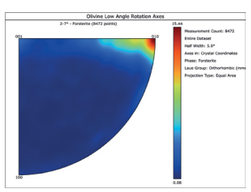


Example ODF section from a rolled steel sheet

Full Boundary Characterisation

Many key physical properties are linked to the characteristics of inter- and intra-granular boundaries. AZtecCrystal gives access to a wide range of boundary analysis tools, enhancing your understanding of both material processing and the subsequent properties.

- Full boundary misorientation analysis
- Detailed boundary length statistics, including for twin and special boundary types
- Boundary trace analysis and full 5-parameter boundary population analysis

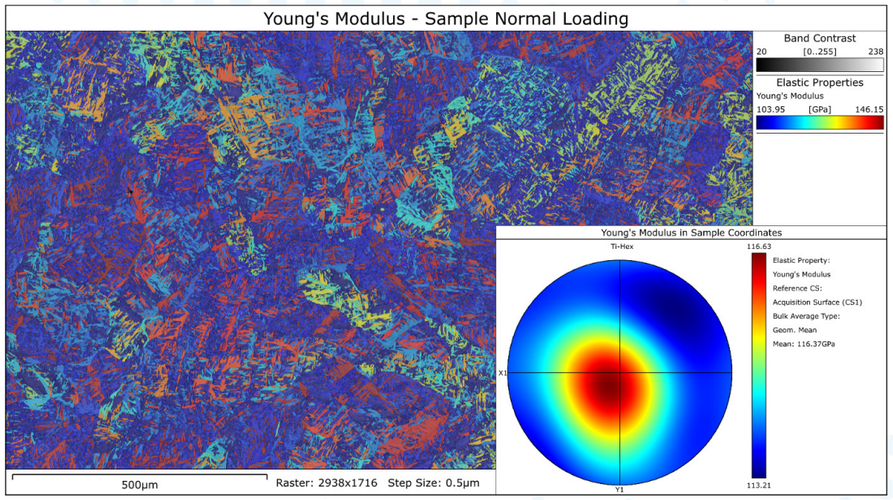


Inverse pole figure showing the orientation of low angle boundary rotation axes in a deformed olivine sample

Predict Your Sample's Properties

Many elastic properties of materials are linked to the crystallographic orientation of individual grains. AZtecCrystal combines the orientation data with elastic coefficients to predict the grain-scale and bulk elastic properties of samples.

- Calculation of 5 different elastic properties for every grain in each dataset
- Bulk averages indicate sample-scale elastic properties

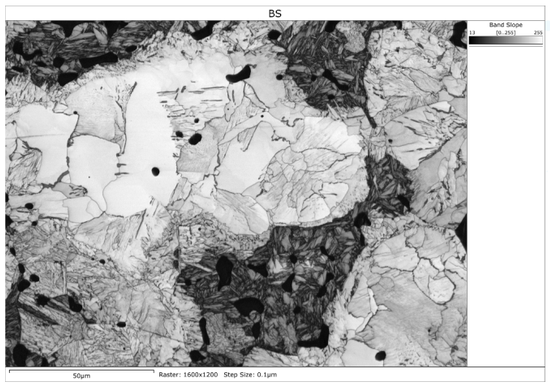


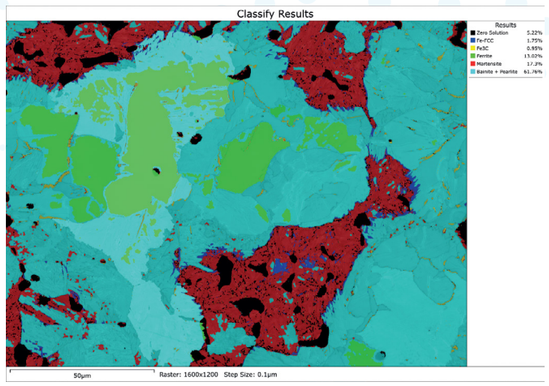
Young's Modulus map for an additively manufactured Ti64 alloy (loading parallel to the build direction), with the pole figure showing the variation in Young's Modulus for different loading directions.

Advanced Microstructure Classification

The Classify Tool in AZtecCrystal combines user training with machine learning intelligence to classify structures and phases within datasets. This allows rigorous, repeatable identification of microstructural components in steels (e.g. martensite and bainite) or the separation of deformed and recrystallised grains.

- Utilises multiple parameters for rigorous classification
- Classification recipes can be stored for repeatable results on multiple samples





Pattern quality and phase classification maps from a complex structural steel, showing ferrite (green), bainite (light blue) and martensite (red). Sample courtesy of Höganäs AB, Sweden.

Advanced

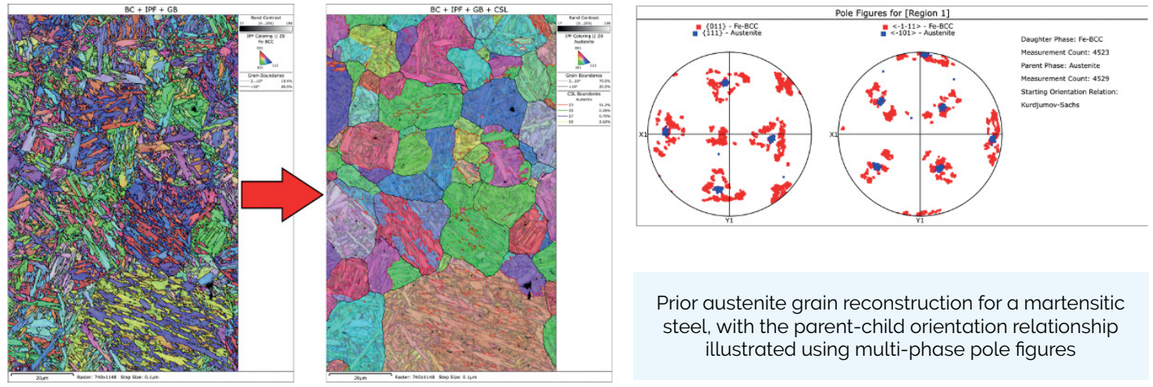
Deepen your understanding of every sample

The Advanced package of AZtecCrystal includes multiple high-end data analysis tools that have been developed using the latest advances in EBSD research.

Parent Grain Reconstruction

For samples that have undergone displacive phase transformations, AZtecCrystal's Parent Grain Analysis tool enables rapid and robust reconstruction of the parent phase microstructure.

- Highly flexible settings, working for any phase system (including steels and Ti/Zr alloys)
- Orientation relationship refinement tool ensures accurate reconstruction for any sample

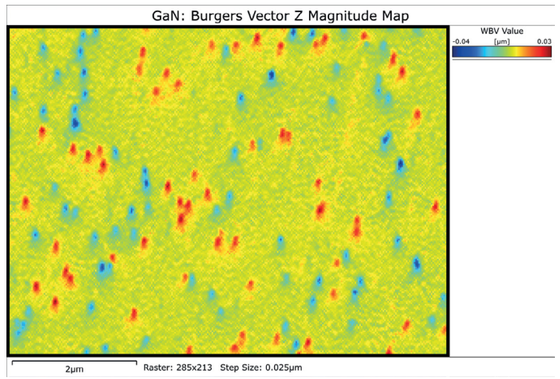


Prior austenite grain reconstruction for a martensitic steel, with the parent-child orientation relationship illustrated using multi-phase pole figures

Advanced Dislocation Analysis

EBSD is a powerful tool for examining dislocation structures and densities in a wide range of materials. The dislocation analysis tool in AZtecCrystal enables the rapid interrogation of dislocation types and densities with unprecedented detail.

- Calculation of dislocation densities using a unique integral loop method (patent pending)
- Weighted Burgers vector orientation analysis to assist in dislocation type analysis and slip system determination

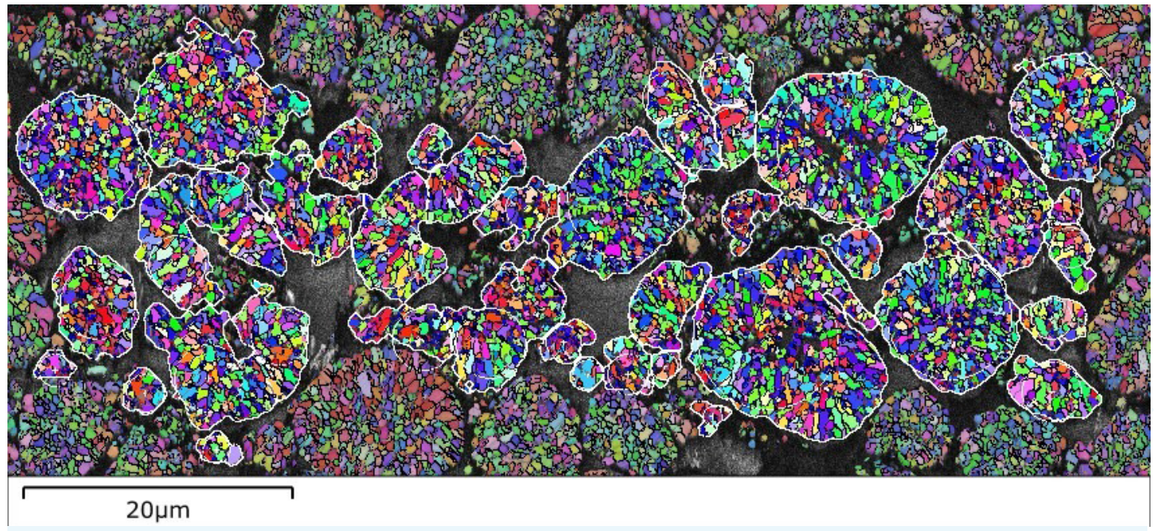


Weighted Burgers vector z-magnitude map from a GaN thin film, showing screw dislocations with +<c> (red) and -<c> (blue) Burgers vectors

Particle Analysis

The Particle Analysis tool in AZtecCrystal enables a robust characterisation and classification of particulate microstructures, such as is typical for battery electrodes, additive manufacturing powders and biomaterials.

- Automated detection and separation of particles
- Texture analysis within each particle's reference frame
- User-driven classification of particles using machine learning



IPF texture Map of battery electrode material Li (NiO_2), showing Radial texture for each individual particle.

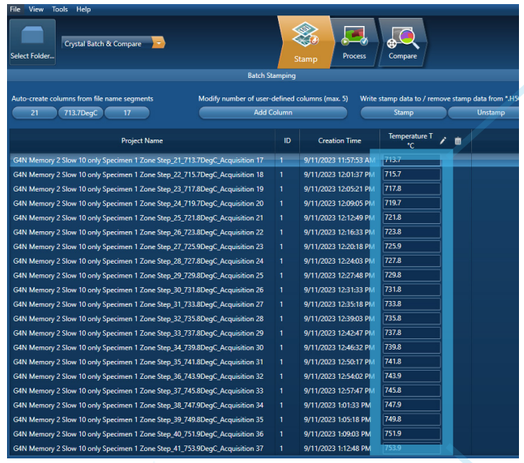
Advanced

Crystal Batch & Compare

Crystal Batch & Compare is a licenced mode within AZtecCrystal that is designed to load, edit and evaluate data stacks. It allows users to import multiple EBSD data sets into a single data stack, combine it with external experimental parameters and batch process each one in a consistent and reproducible way. This workflow enables users to:

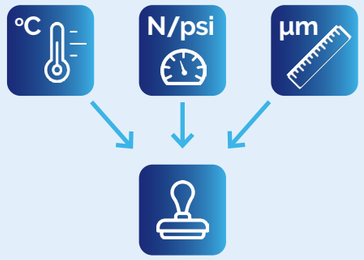
- Consistently clean & process hundreds of data sets in one easy step
- Manage and process in-situ experimental data
- Link experimental parameters to EBSD metrics
- Track the evolution of key experimental parameters over time
- Visualise timelapse data and export as a media output

Enrich your EBSD with in-situ experimental parameters using the **NEW** data 'STAMP' tool.



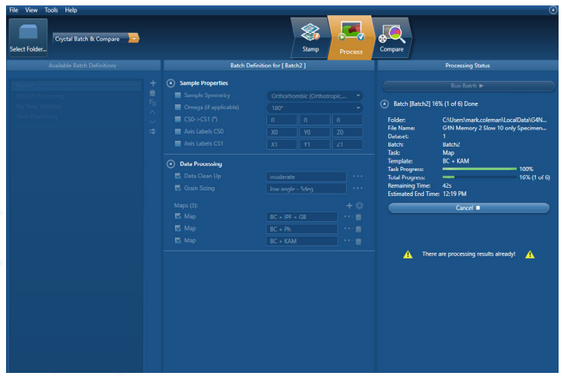
STAMP Tool

- Data 'Stamp' tool allows third party data to be added to the corresponding H5OINA file.
- This can be done automatically using AZtec Project naming strategies.
- Or manually add temp/load/extension data from external sources via .csv import tool.



Batch

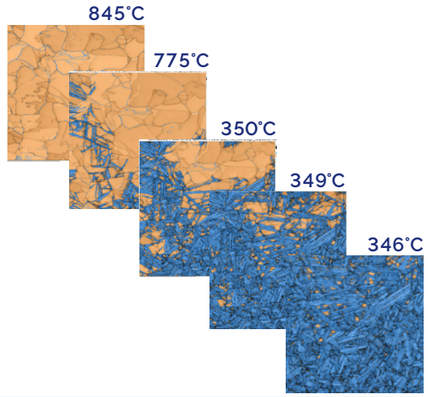
- Batch process hundreds of files in one easy step
- Automatically clean all map layers in minutes
- Load processing templates directly from AZtecCrystal
- Make quality control easy by consistently comparing hundreds of results

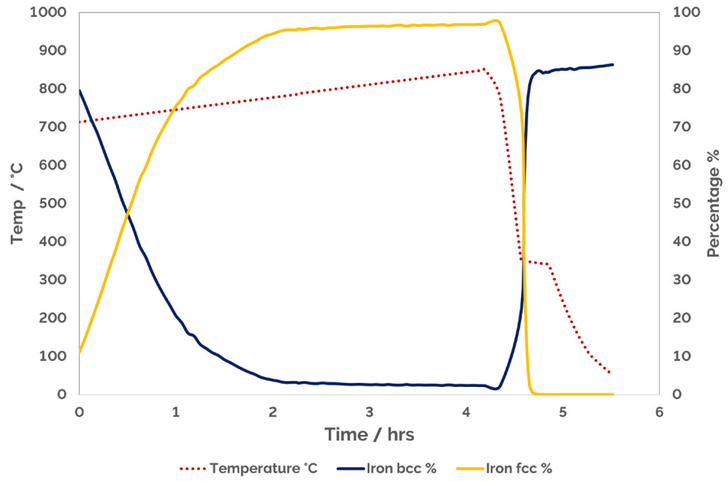


Compare

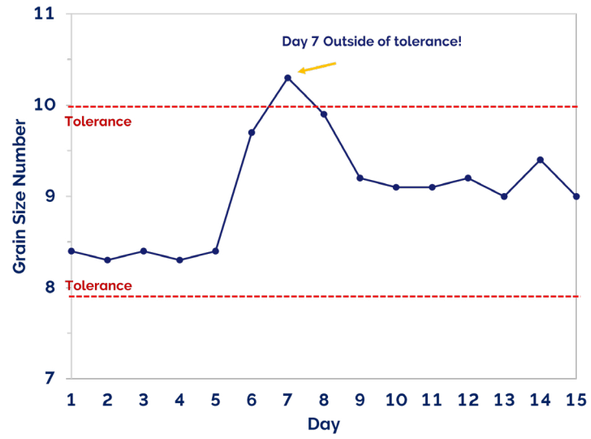
Track key experimental parameters with Compare

- Track and plot key experimental parameters from your data stack and directly link exported experimental data to map layer
- Zoom in and relate maps to Histogram data points
- Edit stacked data and manually remove map layers
- Export all map data in one easy step
- Seamlessly link between Crystal Batch & Compare with full AZtecCrystal Data Analysis

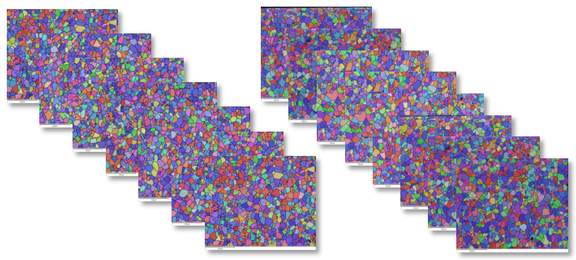




Data courtesy of Mark Taylor[1], Albert Smith[2], Jack Donoghue[1] and Ed Pickering[1].
1. University of Manchester and Henry Royce Institute. 2. TESCAN UK



- Ideal for quality control
- Standardise processing for consistent measurements
- Track key metrics and identify out of tolerance samples in minutes



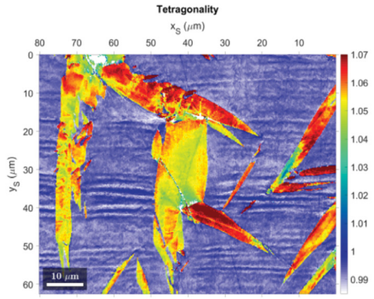
Expert

AZtecCrystal MapSweeper

Intelligent Hybrid Analysis

AZtecCrystal MapSweeper utilises a smart hybrid approach to dataset reanalysis, incorporating the initial indexing results wherever possible. Simple to set up, MapSweeper's on-the-fly pattern matching method delivers flexibility, power and speed.

- Full dynamical pattern simulation
- Refine Sweep – extract more from your data:
  - improve angular precision to <0.01˚
  - resolve crystal pseudosymmetries
  - discriminate between similar phases
  - determine crystal polarity or chirality
  - measurement of lattice distortion
- Repair Sweep - filling in the gaps in your data:
  - fix isolated indexing errors
  - increase indexing hit rates

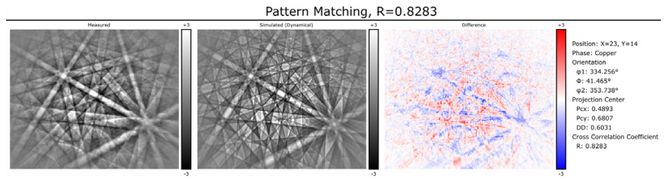


Apparent tetragonality variations in the austenite (blue). The observed tetragonality in the martensite is significantly larger (yellow/red) and shows tetragonality features which are not correlated with the scratch/deformation features. Improved angular precision allows for accurate measurement of lattice distortion so that tetragonality can be used to determine Martensite.

Dynamic Template Indexing

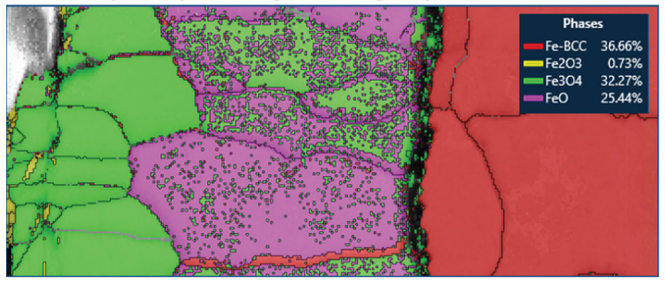
For datasets where reliable indexing was impossible at the microscope, AZtecCrystal MapSweeper enables full indexing using Dynamic Template Matching (DTM), enabling high quality data from the most challenging samples, such as highly deformed or nanocrystalline materials.

- Index Sweep - indexing using on-the-fly DTM:
  - extract valid data from poor patterns
  - no requirement to generate a library of EBSP simulations
  - dynamic geometry calibration – effective at all magnifications

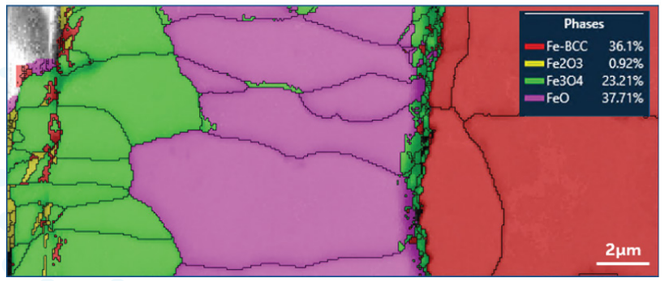


EBSD Pattern Matching analysis, showing the correlation between an experimental Cu EBSP (left) with a dynamical simulation (centre), with the pattern differences shown to the right. Weighting has been applied to focus the pattern matching on the pattern area with the strongest signal.

Before MapSweeper - Hough Indexing only



After MapSweeper

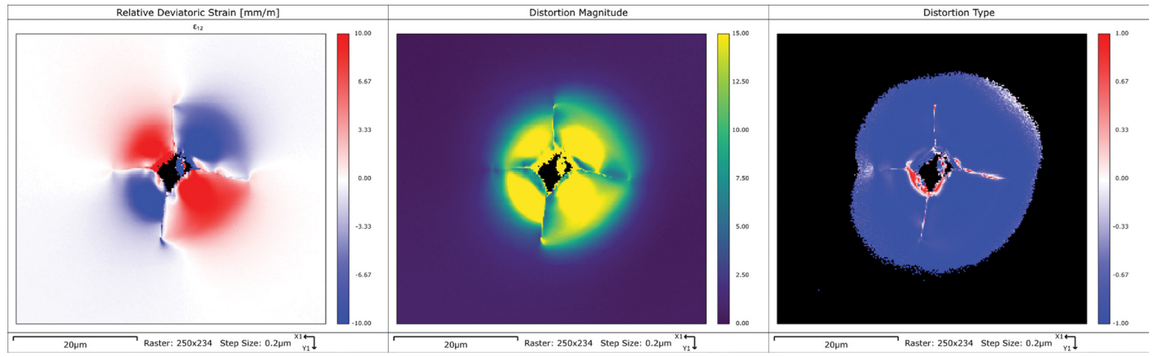


Phase map of an oxide scale on a ferritic steel, following a hybrid reanalysis with AZtecCrystal MapSweeper, showing reliable separation of the cubic Fe (red) , FeO (lilac) and Fe_3O_4 (green) structures. Sample courtesy of Onur Meydan, MSc, Metallurgy Engineer, Turkey

Strain Analysis

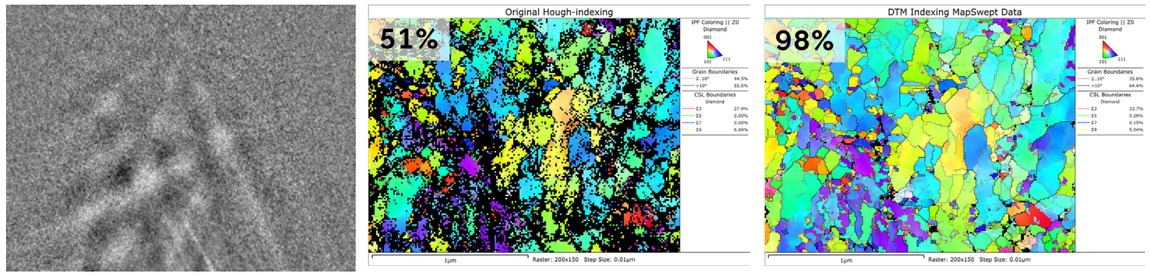
The improved precision of MapSweeper enables the calculation of relative deviatoric strains, allowing users to measure the effects of elastic and plastic deformations as seen by local lattice parameter changes in crystalline materials.

- Calculate strain tensors
- Visualise distortion magnitudes
- Determine distortion type - tension, compression or pure shear
- Calculate rotation



Left - Relative Deviatoric strain ε_{12}, Centre - Distortion Magnitude and Right - Distortion Typemap showing compression, tension or pure shear type distortion of an indent in pure Si.

- Highly deformed microstructures can be very challenging to analyse effectively using EBSD due to poor pattern quality
- Standard Hough indexing gives low hit rates (51%)
- Re-analysis using MapSweeper (Dynamic Template Matching "Indexing Sweep" – 15 minute reanalysis) results in 98% indexing, revealing nanostructures and complex twinning



From left to right: Diamond TKD pattern. Hough indexing (51%). Mapsweeper (98%)

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