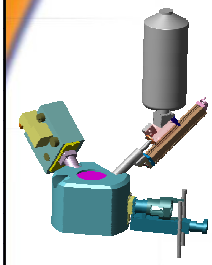
Introduction to OIM Analysis



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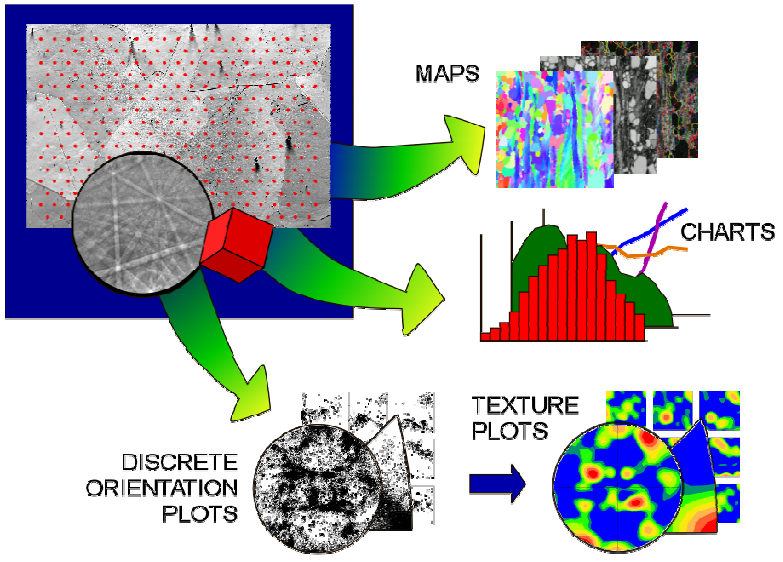
advanced microanalysis solutions
AMETEK

OIM Analysis



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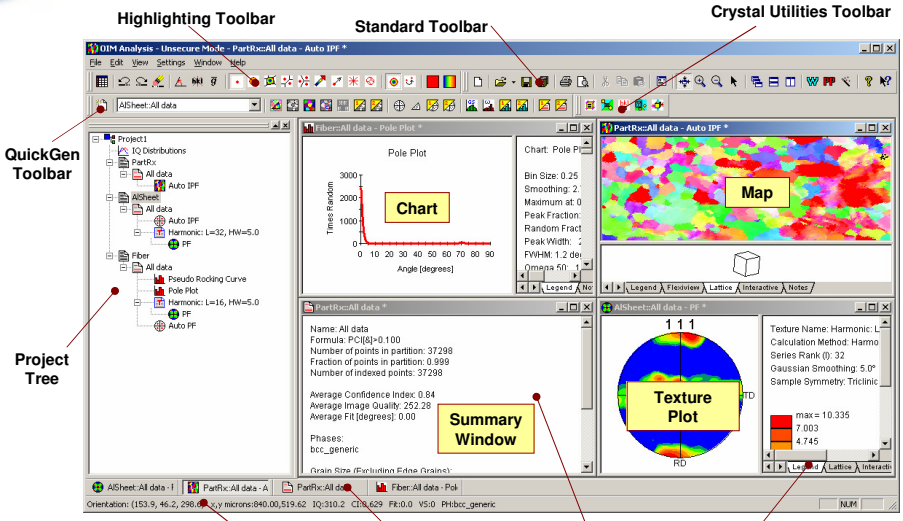
OIM Analysis



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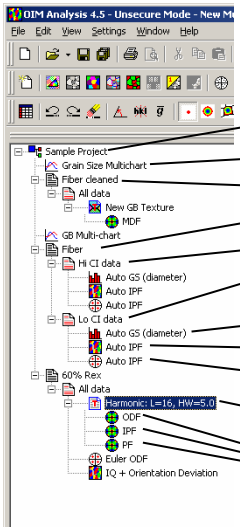
Project tree



In OIM a project contains all of the documents created during an analysis session.

Project

A chart that combines results from any partition in the project

OIM Datasets

Partitions. Essentially subsets of the data that meet some user prescribed criteria.

A "Chart" – e.g. grain size distribution, IQ distribution…

A map

A discrete orientation plot such as a pole figure or an "ODF" – I.e. discrete points plotted in Euler space.

A "Texture" – this contains all of the results for a given calculations. I.e. for a user prescribed set of parameters.

Texture plots (of intensities) such as a Pole Figures or ODFs.

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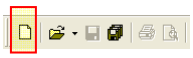
Practice session – OIM Analysis

- Create a project
  - File Menu or use icon on toolbar



- Right mouse click on project icon in project tree and select New>Dataset.
- Open “Dual Phase Titanium.osc”
- Right mouse click on “All Data” partition in the project tree and select New>Map
- Press the “OK” button in the Map Properties Dialog
- Switch to the “Lattice” pane in the Map Window

- Move the cursor around the map and note the rotating crystal
- Note the structure of the project tree

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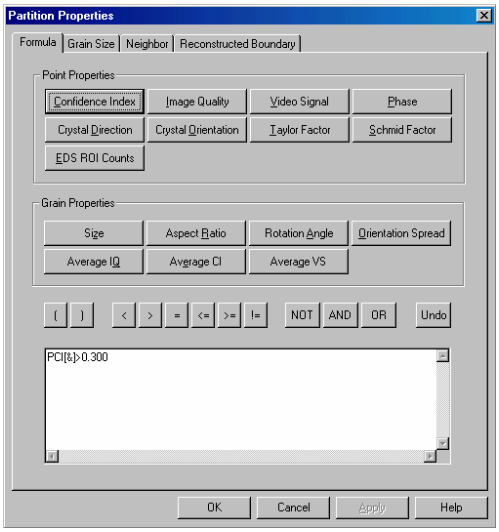
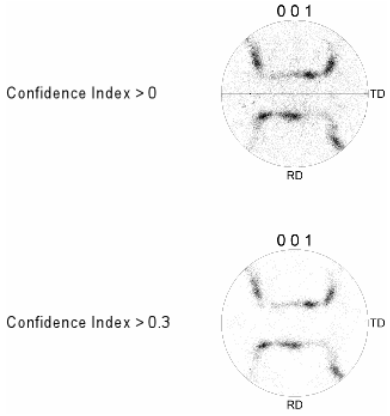
Partitions





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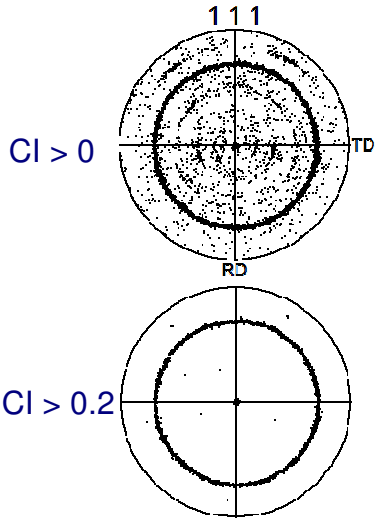
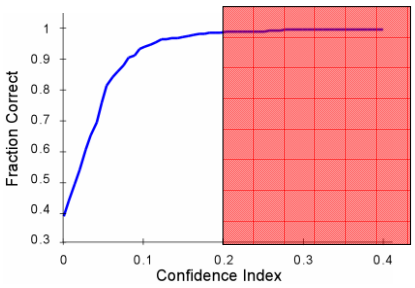
Partitions



The data can be filtered based on any variety of parameters. In this case the confidence index.



Aluminum Thin Film

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"Grains" in OIM

While the concept of a grain in conventional metallography is commonly understood, the definition of a grain in an OIM scan is slightly different .

Grains in OIM are formed by an algorithm that groups sets of connected and similarly oriented points into "grains".

For each point in the OIM scan, the neighbors of this point are checked to see if they are within the Grain Tolerance Angle of the given point.

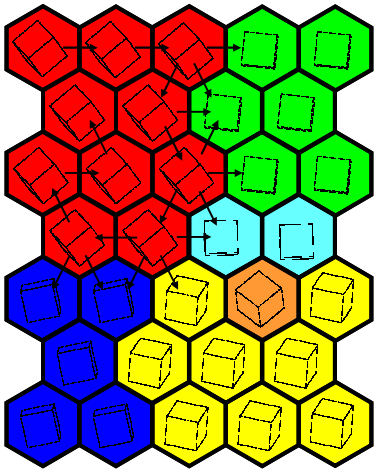
If a neighboring point is found to be within the tolerance angle then the neighbors of this point are checked to see if they are within the tolerance angle of this point.

The procedure is repeated over and over again until the set of connected grains is bounded by points which exceed the tolerance angle.

Using this approach, the point to point misorientation in a "grain" will be quite small but the spread of orientation among all points in the "grain" can be relatively large.

The number of points required to decide whether a given group of points should be considered a "grain" group (the Minimum Grain Size) can be specified by the user along with the Grain Tolerance Angle.

Thus, the definition of a grain in OIM can vary depending on user-specified values. These parameters are set using the Grain tab in the partition dialog.



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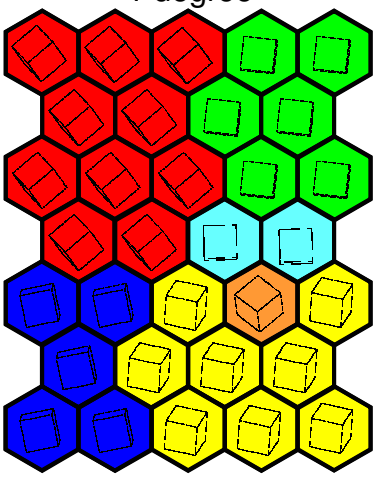
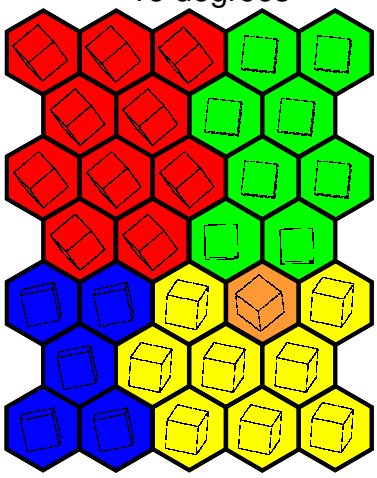
Grain size parameters – tolerance angle

1 degree



15 degrees



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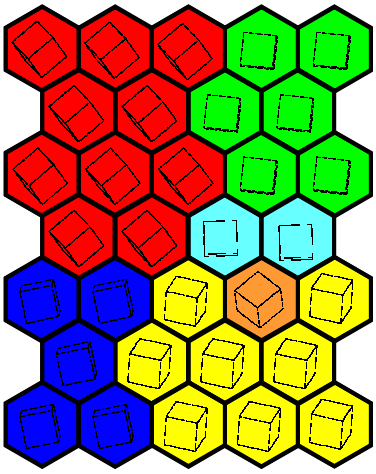
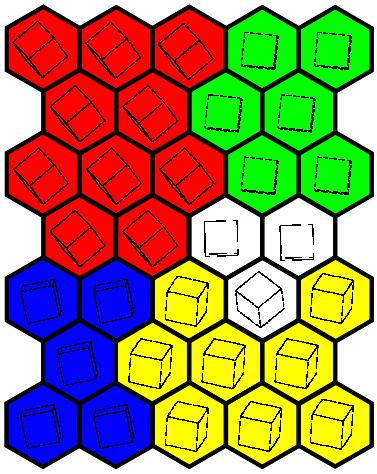
Grain size parameters – min grain size

1 “Pixel”



3 “Pixels”



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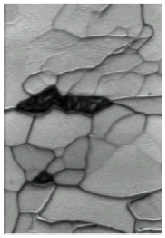
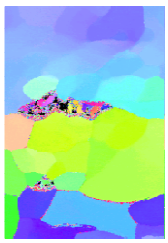
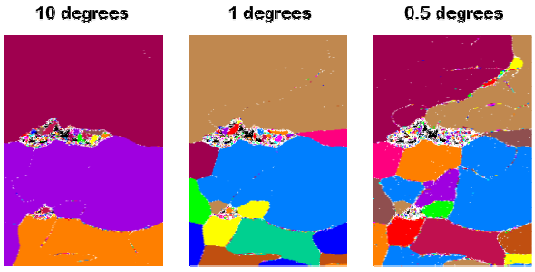
"Grains" in OIM





Effect of Grain Tolerance Angle



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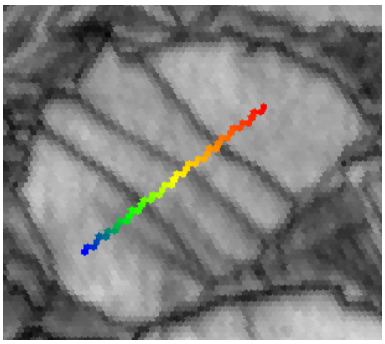
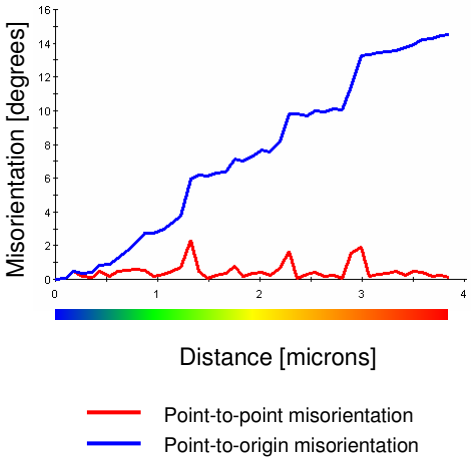
Grain size - misorientations

The grain grouping algorithm focuses only on neighbor-to-neighbor misorientations. Thus, while the pixel-to-pixel misorientations will be less than the tolerance angle; the misorientation from one side of the grain to the other can be quite large. This is particularly evident in deformed materials.





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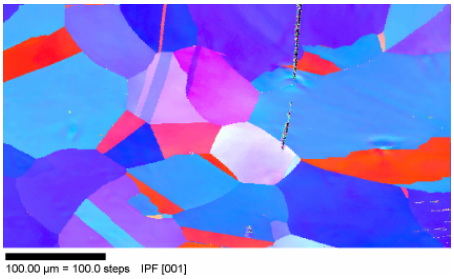
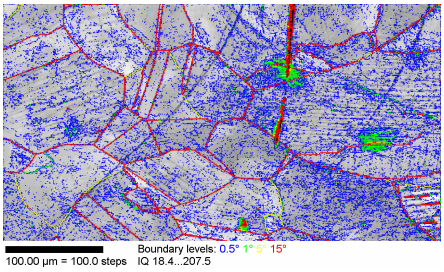
“Grains” in OIM

Choosing a cut-off value is not always obvious – in fact, the choice of cutoff value is often best selected by visual inspection. In the case shown here of choice of 5 degrees seems quite reasonable.

OIM gives a more precise meaning to the term boundary. However, there is obviously a great deal of literature in materials science that uses the definition from conventional metallography. It is not always an easy comparison between OIM and conventional metallography.





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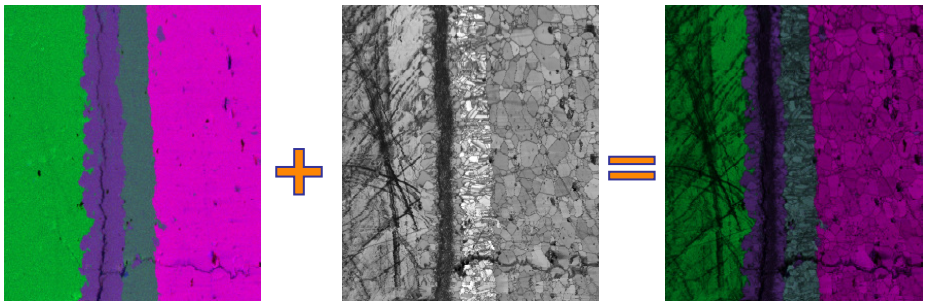
Maps



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Map types

- Orientation based maps
  - Inverse Pole Figure
  - Crystal Direction
  - Crystal Orientation
- Misorientation based maps
  - Kernel Average Misorientation
  - Grain Orientation Spread
  - Grain Average Misorientation
  - Grain Reference Orientation Deviation
  - Local Average Misorientation
  - Local Orientation Spread
- Non-orientation scalar maps
  - Image Quality
  - Confidence Index
  - Fit
  - Detector Signal
  - Phase
  - EDS
  - EDS Blended Color
- Grain based maps
  - Unique Grain Color
  - Grain Size
  - Grain Shape Orientation
  - Grain Shape Aspect Ratio
  - Grain Shape Major Axis
  - Grain Shape Minor Axis
  - Major Axis Inverse Pole Figure
  - Grain Average IQ
  - Grain Average CI
  - Grain Average Fit
  - Grain Average Video Signal
  - Twin Parent/Daughter
- Property maps
  - Taylor Factor
  - Schmid Factor
  - Elastic Stiffness
- Custom
  - Import Data

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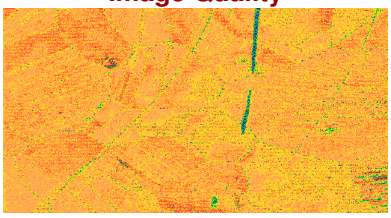
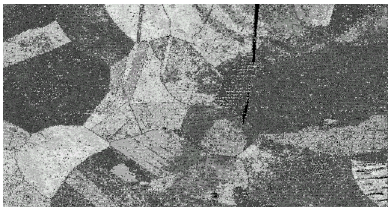
OIM: IQ, CI, video signal

Image Quality

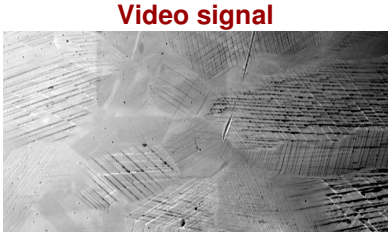
Image Quality



Confidence index



Video signal



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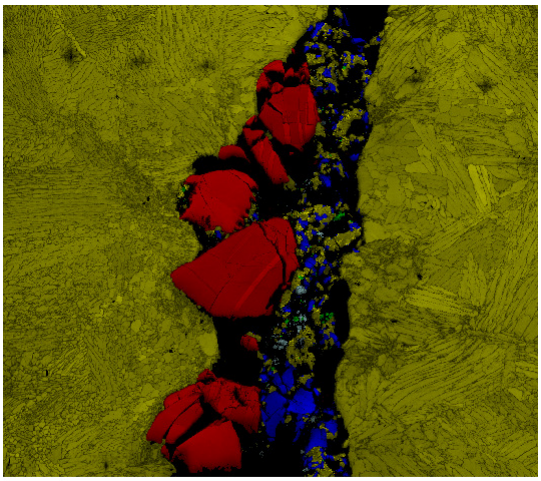
Maps: phase



- Aluminum Titanium
- Alumina
- Erbium Oxide
- Zirconium Oxide

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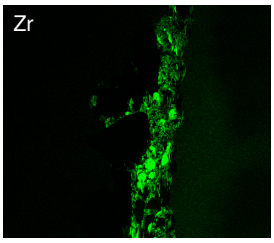
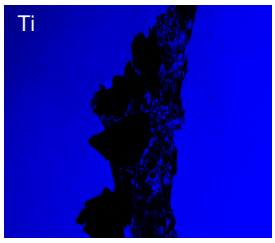
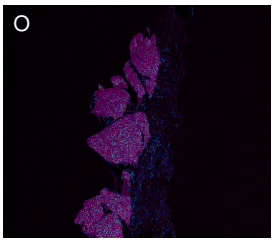
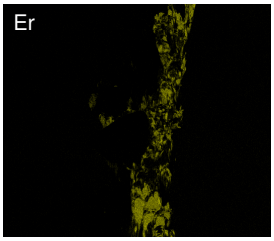
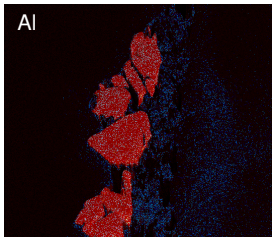
Maps: EDS











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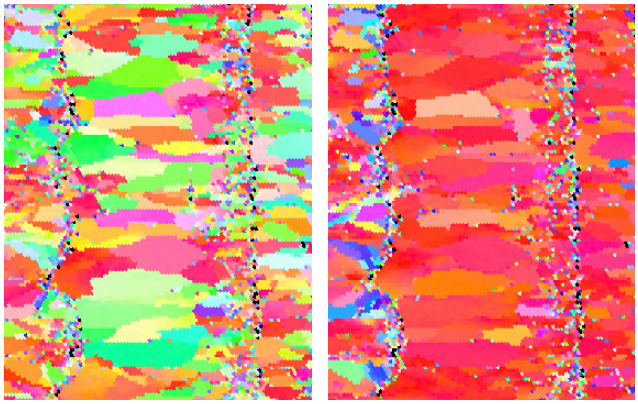
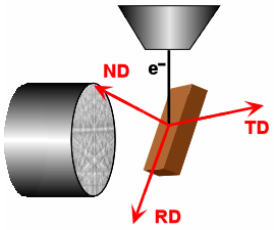
Maps: orientation based

IPF maps (2D)





Normal direction **Transverse direction**

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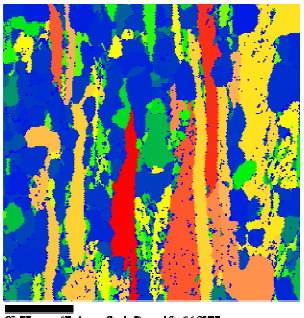
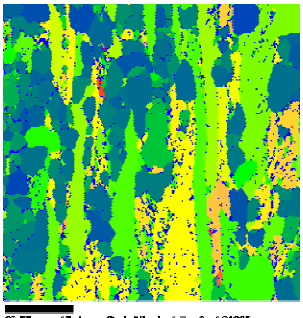
OIM: local misorientation

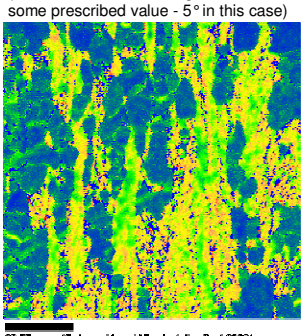
Grain Orientation Spread
For a given grain calculate the average misorientation between all data points in the grain.

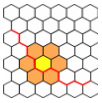
Grain Average Misorientation
For a given grain calculate the average misorientation between all neighboring data points in the grain.

Kernel Average Misorientation
For a given data point calculate the average misorientation between the data point and all of it's neighbors (exclude misorientations greater than some prescribed value - 5° in this case)









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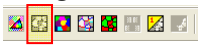
Practice session - mapping

- Open CVDTa.osc
- Create an IQ map using the QuickGen button



- Do a right mouse click on the map and select properties
- Set “Color Coded” to crystal direction
- Press the “Edit >>” Button
- Press the “Add” Button
- Set Sample Direction to RD=0, TD=1 & ND=0
- Switch to Color Gradient and choose a color scheme
- Look at the map legend – does it make sense?
  - Try changing the tolerance value and note effect

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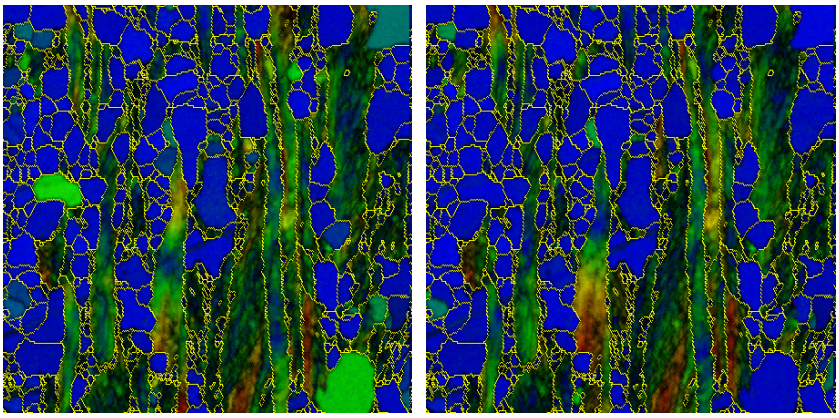
Maps: local misorientation

Grain Reference Orientation Deviation

Show the deviation of each point in the grain with respect to a reference orientation. Two types of references are possible: 1) The average orientation for the grain and 2) the orientation of the point in the grain with the lowest Average Kernel Misorientation.



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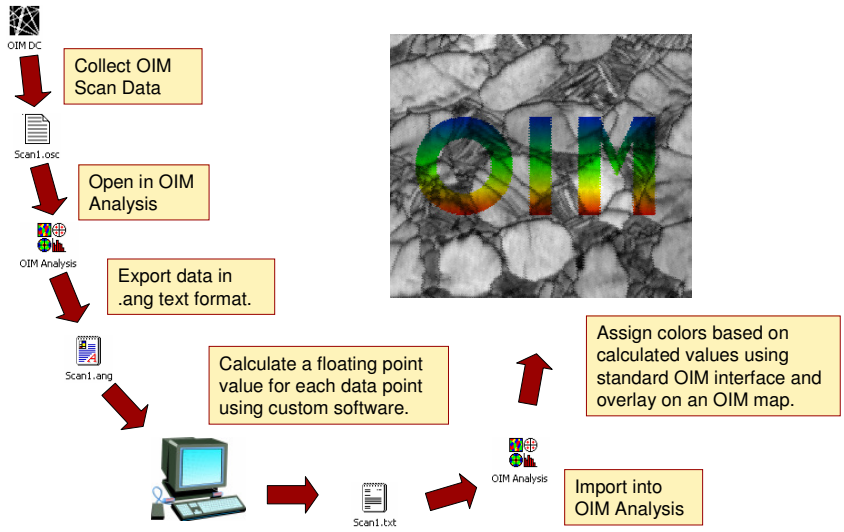
Maps: import



Boundaries

Rotation angle – A line segment is drawn between two neighboring points if the misorientation falls in a given range (e.g. between 5 and 15 degrees)

Rotation axis – A line segment is drawn between two neighboring points if the two orientations have a specified direction (e.g. <0001>) in coincidence within a specified tolerance.

Axis/angle – A line segment is drawn between two neighboring points if the misorientation between the two points is within a given tolerance of a specified ideal misorientation where defined by an axis/angle pair (e.g. 60 degrees about <111>).

Grain – A line segment is drawn between two neighboring points if they belong to two different grains.

Phase – A line segment is drawn between two neighboring points if they belong to two different phases.

CSL – A line segment is drawn between two neighboring points if they are within a given tolerance of specified CSL (coincident site lattice boundary).

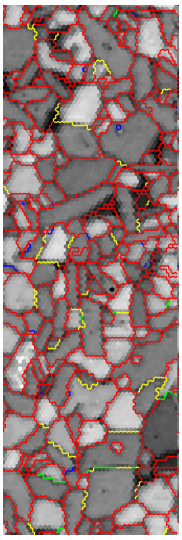
Shape ellipses – An ellipse is fit to each grain in the map and then overlaid on the map.

Reconstructed – A line is fit to a set of "grain" boundary line segments and drawn on the map.

Reconstructed twins – Reconstructed boundaries can be colored according to their fit to specific twin boundary criteria – both in terms of misorientation and twin plane alignment.

Plane traces – A set of lines corresponding to the traces of specified planes are drawn in each grain.

Boundaries: rotation angle



Rotation angle – This is the most fundamental boundary type. A line segment is drawn between two neighboring points if the misorientation falls in a given range (e.g. between 5 and 15 degrees)

Gray Scale Map Type: Image Quality
11.7...127.2 (11.7...127.2)

Color Coded Map Type: <none>

Boundaries: Rotation Angle

	Min	Max	Fraction	Number	Length
	3°	6°	0.015	64	18.48 microns
	6°	9°	0.014	60	17.32 microns
	9°	15°	0.072	311	89.78 microns
	15°	180°	0.887	3807	1.10 mm

*For statistics - any point pair with misorientation exceeding 2° is considered a boundary
(total number = 4293, total length = 1.24 mm)

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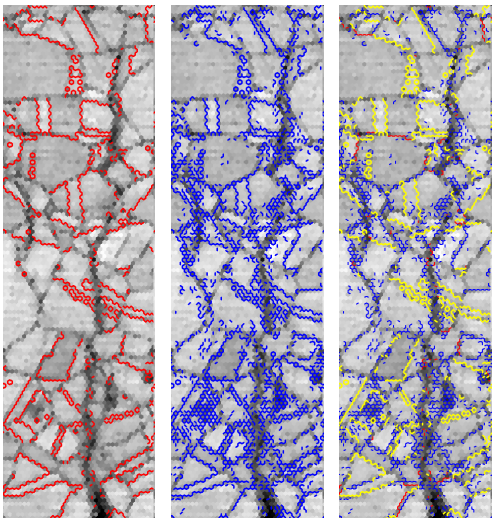
Boundaries: axis/angle



Rotation angle – A line segment is drawn between two neighboring points if the misorientation falls in a given range. (60° ± 5° in this example.)

Rotation axis – A line segment is drawn between two neighboring points if the two orientations have specified directions aligned within a specified tolerance. (<111> crystal directions aligned within 5° of each other in this example.)

Axis/angle – A line segment is drawn between two neighboring points if the misorientation between the two points is within a given tolerance of a specified ideal misorientation where defined by an axis/angle pair. (within 10° of 60° about <111> in this example.)

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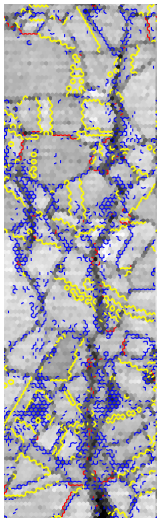
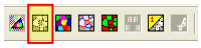
Practice session



- Open SCCcrack.osc
- Create an IQ map using QuickGen button



- Open Map Properties (right mouse click on map)
- Add rotation angle boundaries
  - Range: 55-65 degrees
  - Color: red (segment tab)
- Add rotation axis boundaries
  - Axis [*uvw*]: 111
  - Tolerance: 5 degrees
  - Color: blue
- Add axis-angle boundaries
  - Tolerance:10 degrees
  - Angle: 60 degrees
  - Axis [*uvw*]: 111
  - Color: yellow
- Extra: change the widths to 9, 5 and 1
  - Zoom in to see effect

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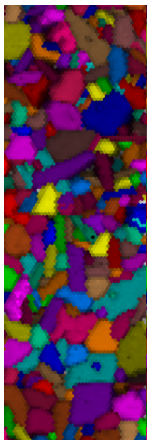
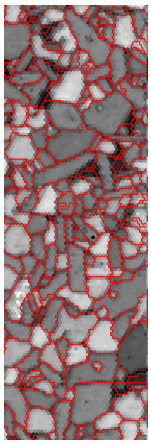
EDAX TSL

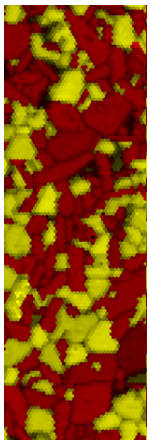
Boundaries: grains & phase

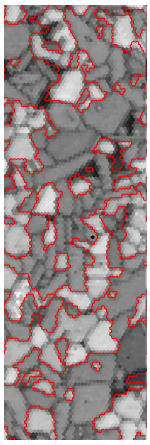
Grain: A line segment is drawn between two neighboring points if they belong to two different grains.

Phase: A line segment is drawn between two neighboring points if they belong to two different phases.









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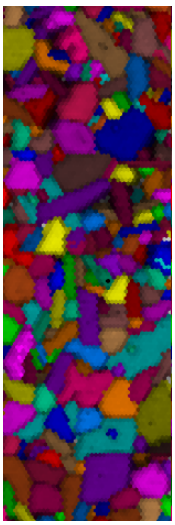
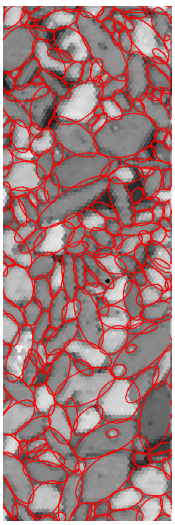
EDAX TSL

Boundaries: grain ellipses





Shape ellipses – An ellipse is fit to each grain in the map and then overlaid on the map. This works best for grains that are not touching the edges of the scan area.

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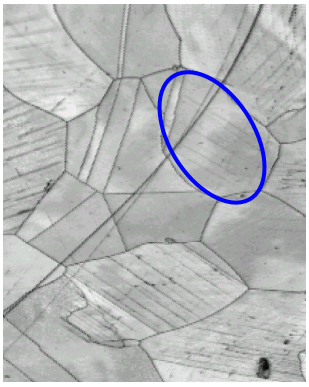
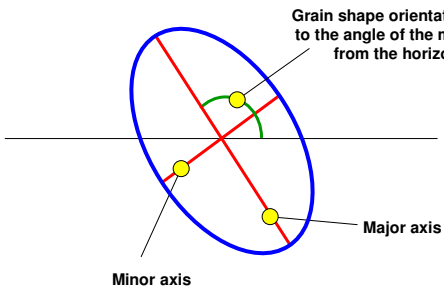
Boundaries: grain ellipses





Grain shape aspect ratio is the length of the minor axis divided by the length of the major axis

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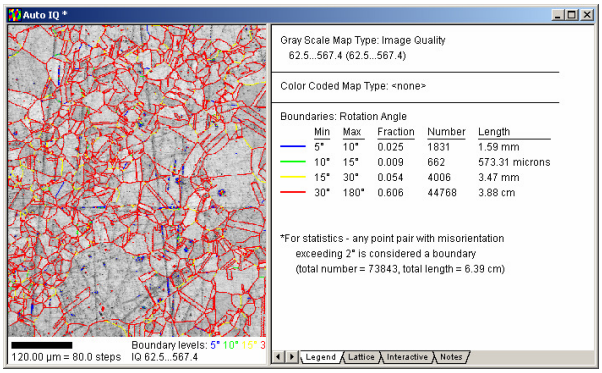
Boundaries: minimum misorientation

The minimum boundary misorientation is part of the Settings>Preferences dialog. It is needed for calculations of boundary fractions. For example, if the fraction of boundaries between 5 and 15 degrees misorientation is desired, this fraction is calculated by dividing the number of boundary segments with misorientations between 5 and 15 degrees by the number of boundary segments with misorientations greater than the “minimum boundary misorientation”. Thus, the choice will affect the fractions calculated.



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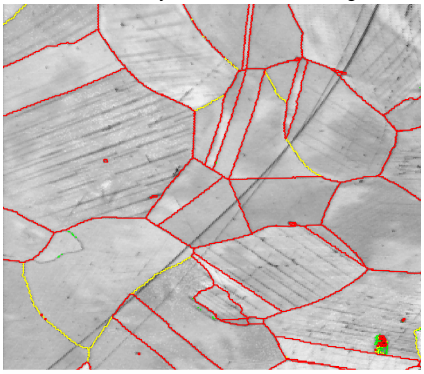
Boundaries: minimum misorientation

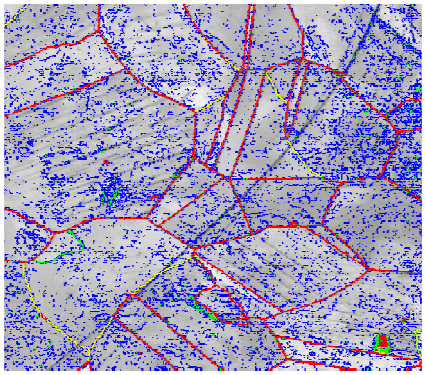
In addition, only boundary segments with misorientations exceeding the “minimum boundary misorientation” will be drawn.

minimum boundary misorientation = 2 degrees



100.00 µm = 100.0 steps Boundary levels: 0.5° 1° 5° IQ 18.4...207.5

minimum boundary misorientation = 0.5 degrees



100.00 µm = 100.0 steps Boundary levels: 0.5° 1° 5° IQ 18.4...207.5

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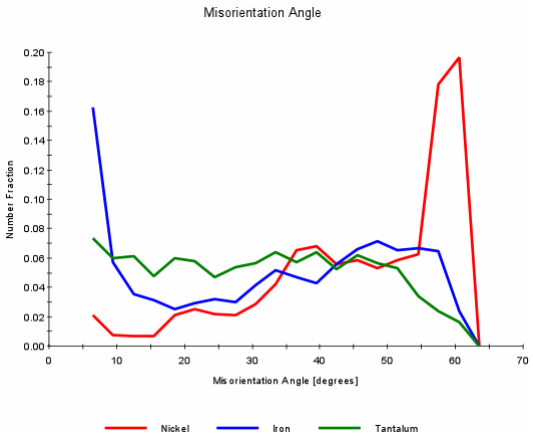
Charts

Image Quality
Confidence Index
Video Signal
Grain Size (points)
Grain Size (diameter)
Grain Size (area)
Grain Shape Orientation
Grain Shape Aspect Ratio
Grain Average IQ
Grain Average CI
Grain Average Video Signal
Grain Orientation Spread
Grain Average Misorientation
Kernel Average Misorientation
Crystal Orientation
Crystal Direction
Taylor Factor
Schmid Factor
EDS
Phase
Misorientation Angle
CSL Boundaries
Boundary Normal Angle
Pole Plot
Pseudo Rocking Curve
Misorientation Profile
Texture Fiber
Texture Index



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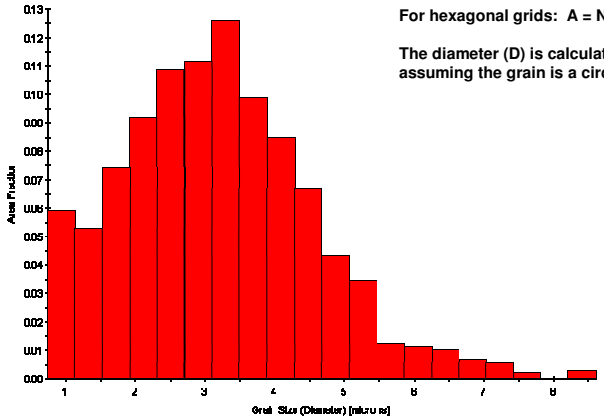
OIM: grain size

The area (A) of a grain is the number (N) of points in the grain multiplied by a factor of the step size (s).

For square grids: $A = Ns^2$

For hexagonal grids: $A = N\sqrt{3}/2s^2$

The diameter (D) is calculated from the area (A) assuming the grain is a circle: $D = (4A/\pi)^{1/2}$.



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Charts: grain size

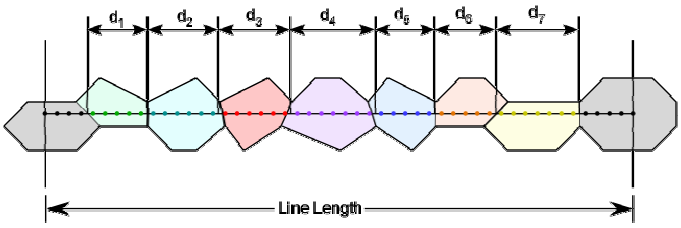
Grain Size (points): Number of measurement points in a grain

Grain Size (diameter): The diameter (D) is calculated from the area (A) assuming the grain is a circle: $D = (4A/\pi)^{1/2}$.

Grain Size (area): The area (A) of a grain is the number (N) of points in the grain multiplied by a factor of the step size (s). For square grids: $A = Ns^2$. For hexagonal grids: $A = N\sqrt{3}/2s^2$

Grain Size (ASTM): $G = -6.64*\log10(D) - 2.95$ where D is the grain diameter given in mm

Grain Size (Intercept): Vertical or linear intercepts



Number of grains = 7

Number of intercepts = 8

Average diameter = $\bar{d} = \frac{1}{7}\sum_{i=1}^{7} d_i$

Grains per mm = $\bar{d}^{-1}$

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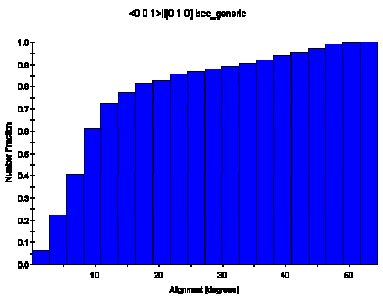
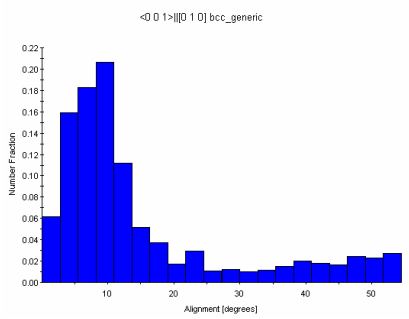
Charts: crystal direction

Cumulative



Non-Cumulative



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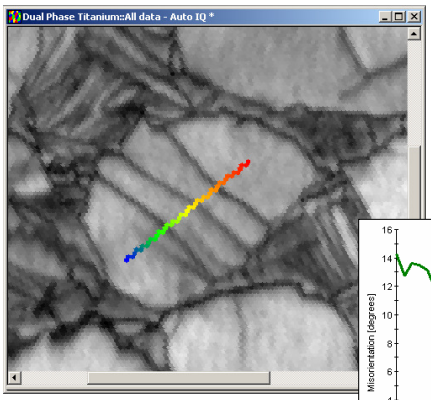
Charts: misorientation profile



- In addition to the standard misorientation functions, show the map values as well.

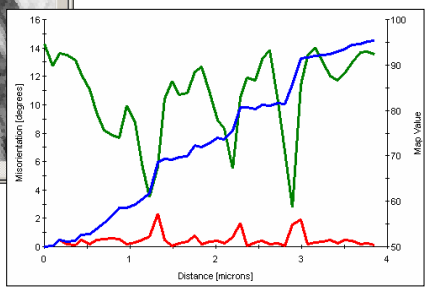
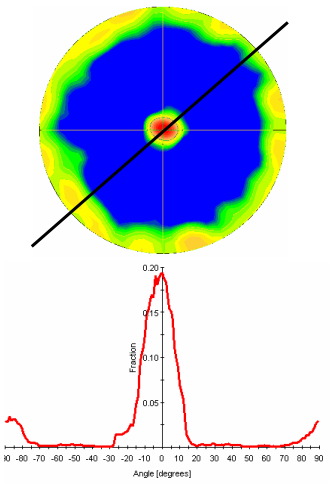


Image Quality
Point-to-point misorientation
Point-to-origin misorientation

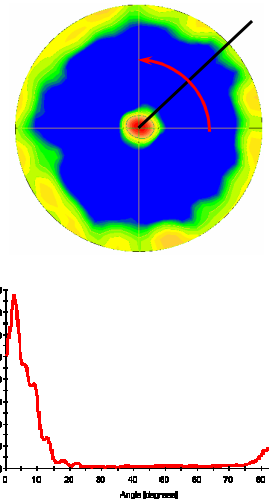
EDAX TSL

Charts: pole plot & pseudo rocking curve

Pseudo Rocking Curve



Pole Plot



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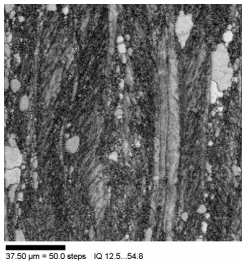
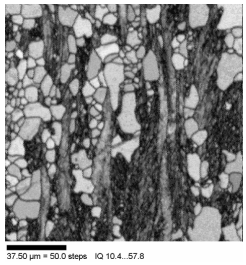
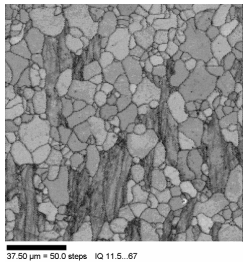
Charts: boundary density

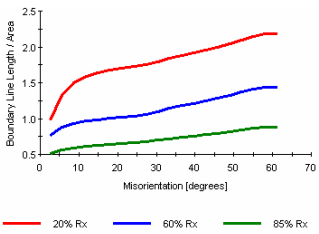






In OIM we have considerably more information on the true character of boundaries, it is a shame to discard such information in comparing structures. We have implemented a new chart called a "Boundary Density" chart. The Boundary Density chart shows the line length of boundaries divided by the area as a function of misorientation. It provides a means for linking the boundary structure and grain size together without having as many parameters involved (i.e. boundary tolerance angle, min grain size…).

Partially recrystallized low carbon steel.



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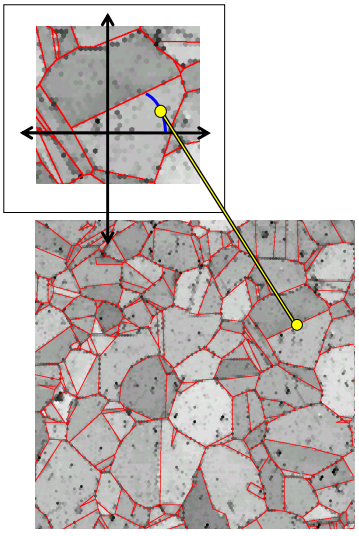
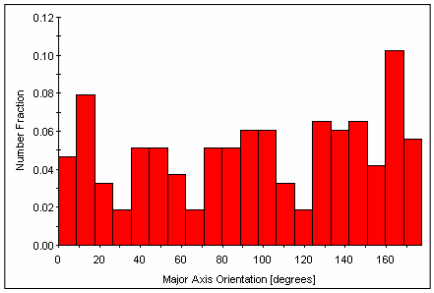
Charts: boundary angle





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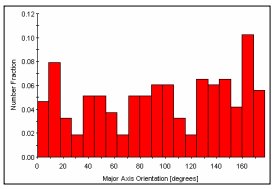
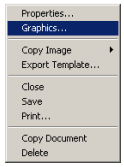
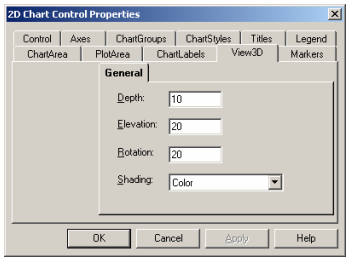
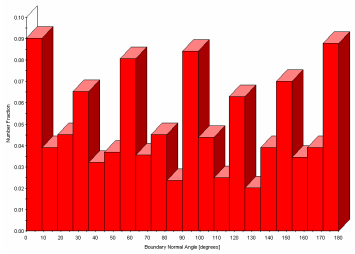
Charts: graphics









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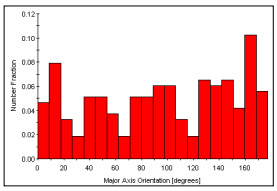
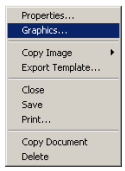
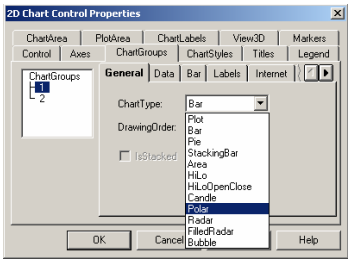
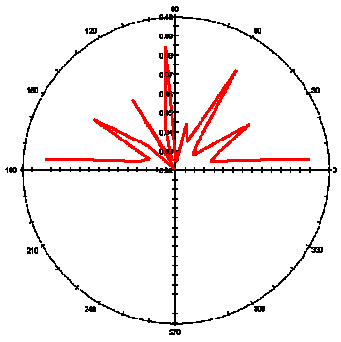
Charts: graphics









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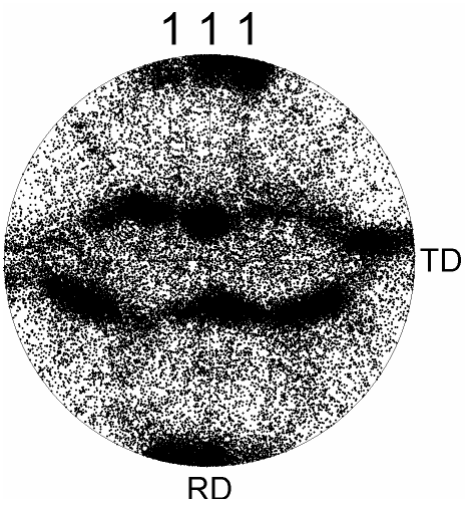
Discrete plots

Pole Figure
Inverse Pole Figure
Euler Space
  Bunge
  Kocks
  Roe
Rodrigues Orientations
Rodrigues Misorientations
Axis/Angle Misorientations



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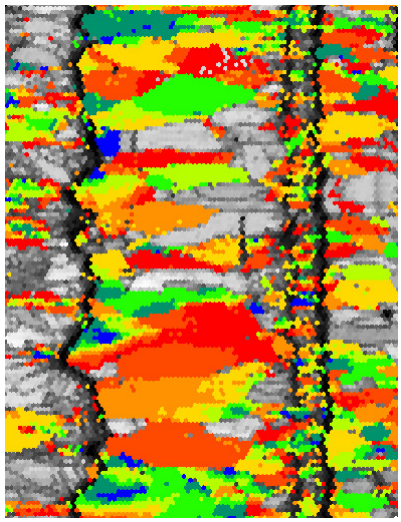
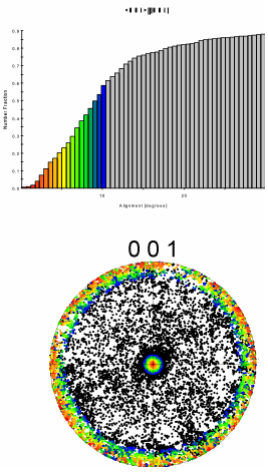
EDAX TSL

Highlighting





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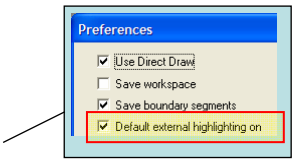
EDAX TSL

Practice session - highlighting



- Open CVDTa.osc
- Go to the Settings menu and select Preferences and make sure highlighting is defaulted on.
- Create an IQ map using the QuickGen button

- Create a (001) pole figure using the QuickGen button

- Create a Crystal Direction Chart
  - Set the Sample Direction to RD=0, TD=1, ND=0
- Next Slide…

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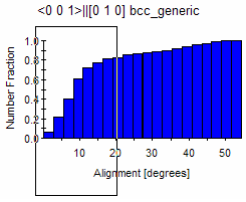
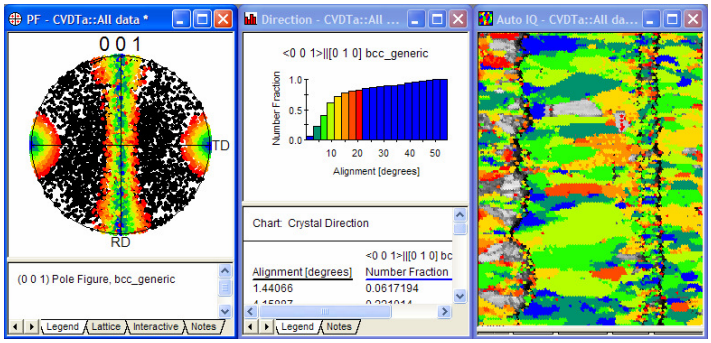
EDAX TSL

Practice session – highlighting continued

- Drag a box on the chart
  - Make sure you start inside chart area
- Note Highlighting Effects
  - Change the pole figure markers to a larger size to see effects better (right mouse click to select properties, press "Edit >>" and select point tab.





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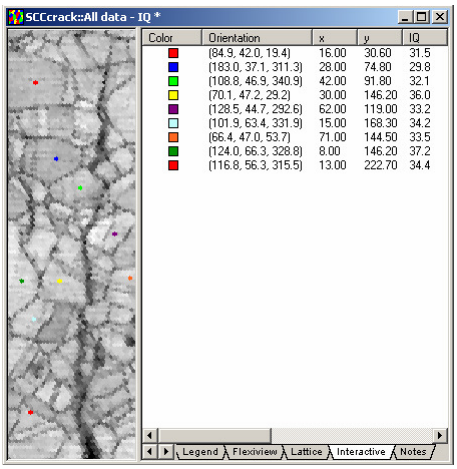
EDAX TSL

Highlighting

Record: record highlighting results in the Interactive pane of the map window.



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EDAX TSL

Highlighting: toolbar

Undo previous highlight.
Redo deleted highlight.
Clear all highlights.

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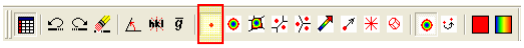
EDAX TSL

Practice session - highlighting

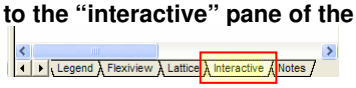
- Open SCCcrack.osc
- Create an IQ map
- Turn on “record” button for highlighting

- Select the single point highlighting mode



- Click on a few points in the map
- Switch colors in-between clicks

- Switch to the “interactive” pane of the map window

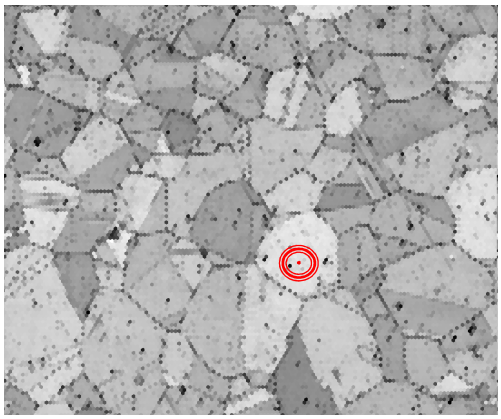


- Note the items recorded in the table
  - Right mouse click to show preferences for interactive table
- Follow along with subsequent highlighting examples

EDAX TSL

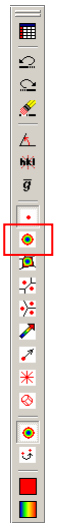
Highlighting: toolbar

Highlight the point clicked.

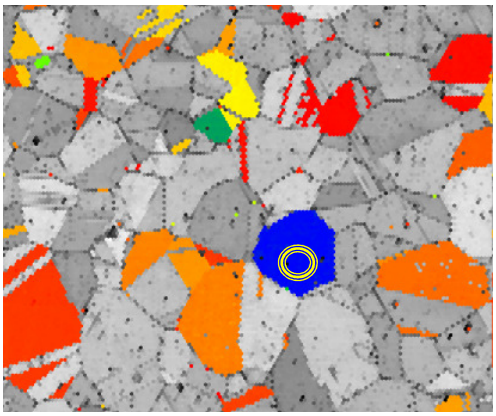


EDAX TSL

Highlighting: toolbar



Highlight all orientations within a given tolerance of the point clicked.



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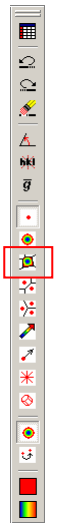
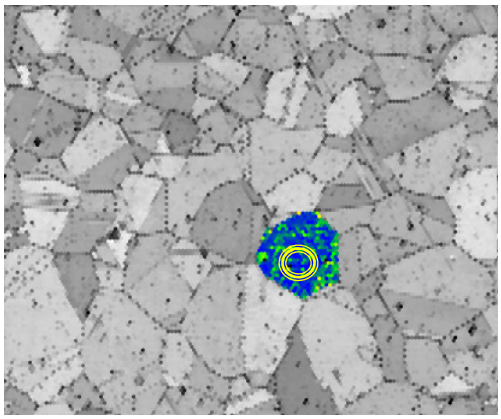
Highlighting: toolbar



Highlight all orientations within grain and color them according to the angular distance from the point clicked.



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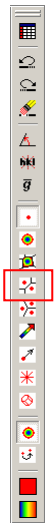
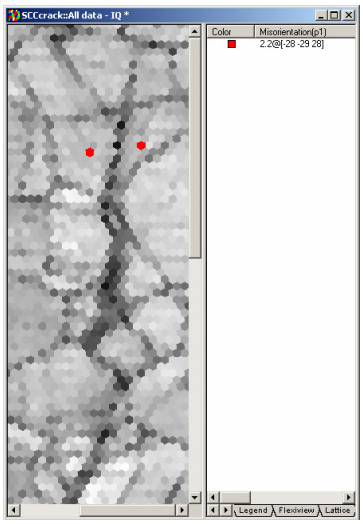
Highlighting: toolbar



Calculate misorientation between two points.



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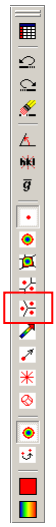
EDAX TSL

Highlighting: toolbar



Calculate misorientations at a triple junction

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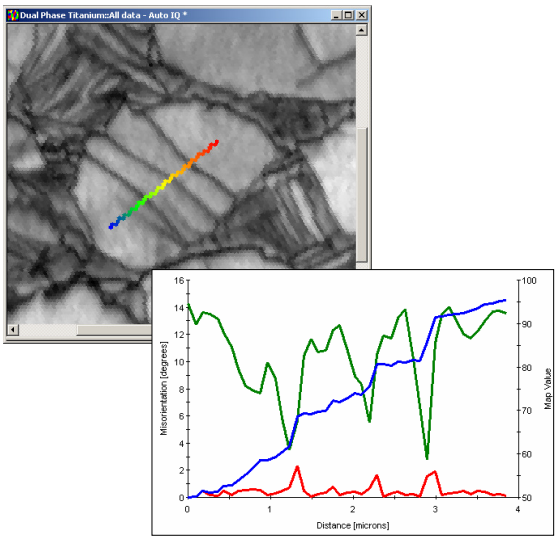
EDAX TSL

Highlighting: toolbar

Misorientation profile: Creates a chart plotting misorientations along a line.



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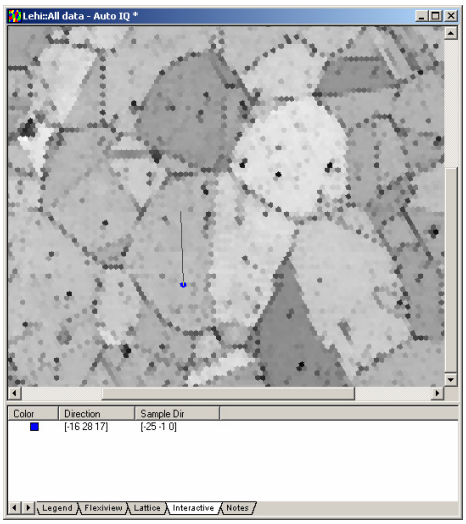
EDAX TSL

Highlighting: toolbar

Displays a crystal direction parallel to a line.



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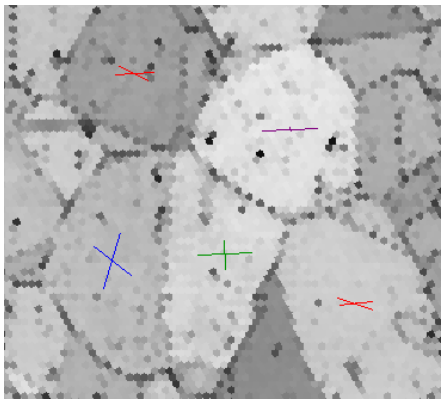
EDAX TSL

Highlighting: toolbar

Draw traces of a specified plane at a point.



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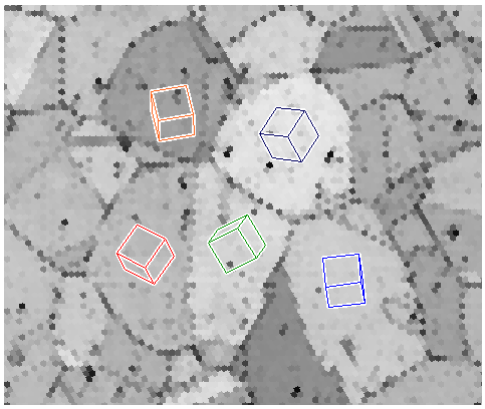
EDAX TSL

Highlighting: toolbar

Draw a unit cell representing the orientation at a point.



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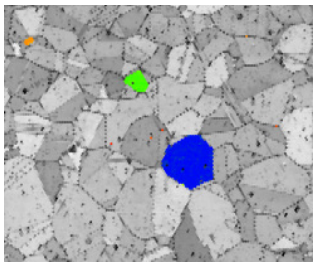
EDAX TSL

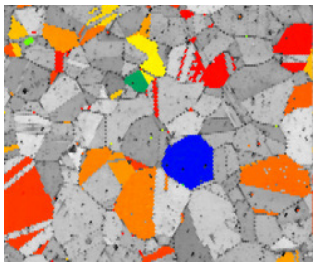
Highlighting: toolbar

Angular tolerance used for various highlighting modes.

Tolerance = 15°



Tolerance = 30°



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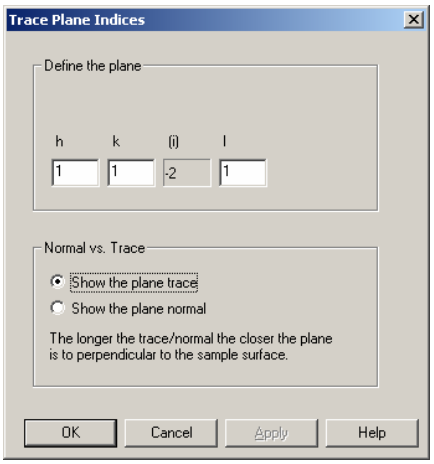
EDAX TSL

Highlighting: toolbar

Define the (*hkl*) for the plane traces.



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EDAX TSL

Highlighting: toolbar

Use the average grain orientations when calculating misorientations.

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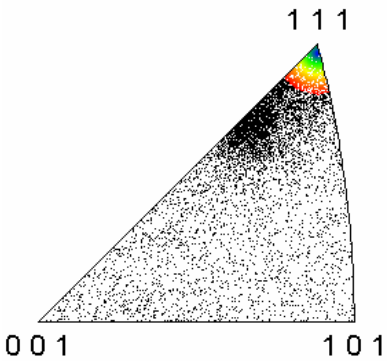
EDAX TSL

Highlighting: toolbar



Find all points in the scan within the angular tolerance of the point clicked in discrete plot.

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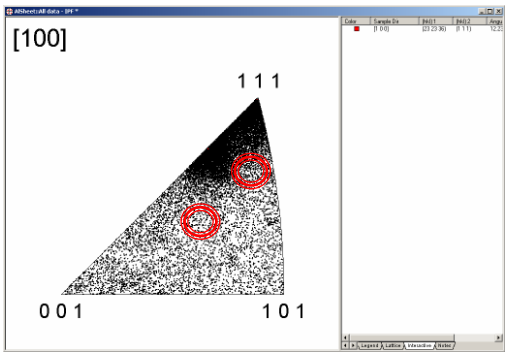
EDAX TSL

Highlighting: toolbar



Calculate the misorientation between two points in a discrete plot

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EDAX TSL

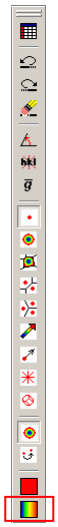
Highlighting: toolbar

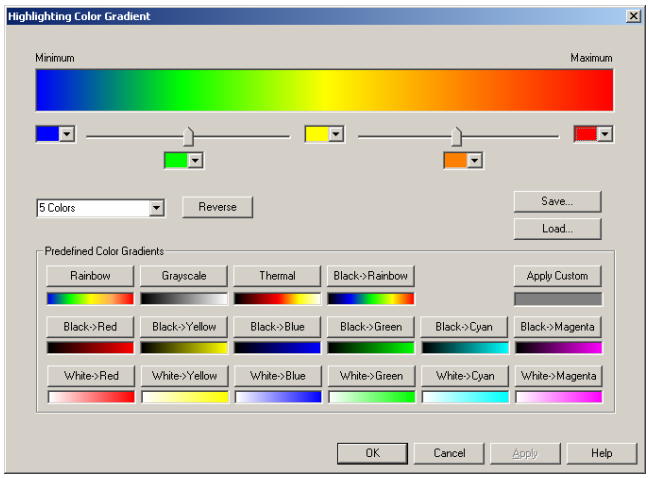
Select a color for individual highlights.

64

EDAX TSL

Highlighting: toolbar





Select a color gradient multiple point highlights.

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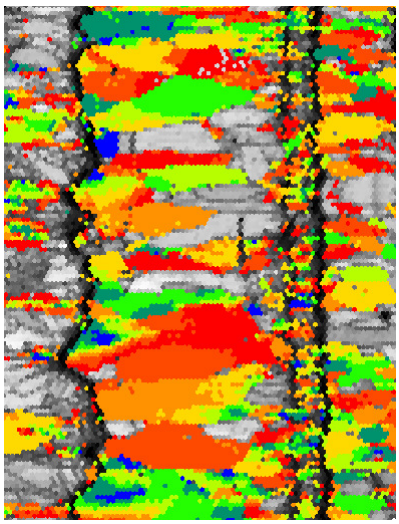
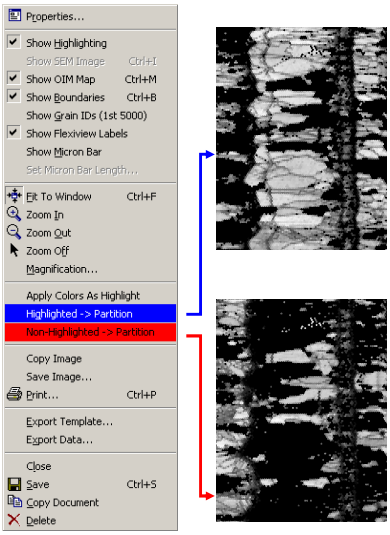
EDAX TSL

Highlighted → partition





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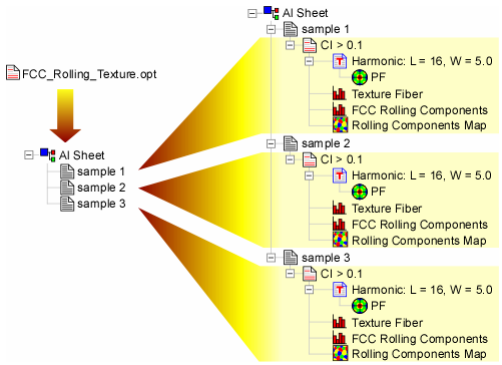
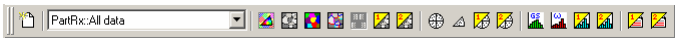
EDAX TSL

Templates



User defined templates can be assigned to buttons on the QuickGen Toolbar.



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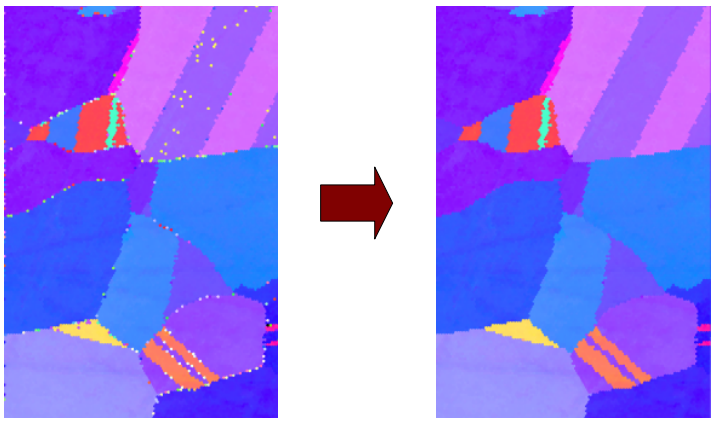
Clean up

Sometimes there are isolated points that are not indexed correctly or at all due to dust particles or pits on the surface. Various clean up schemes are available to assign these points an orientation based on their neighbors.



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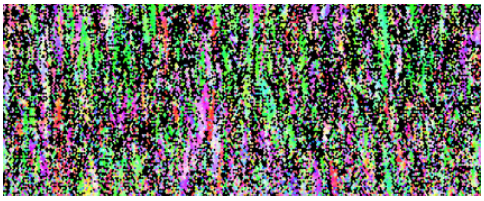
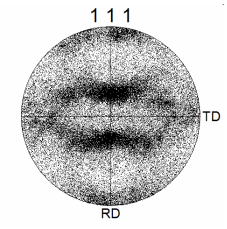
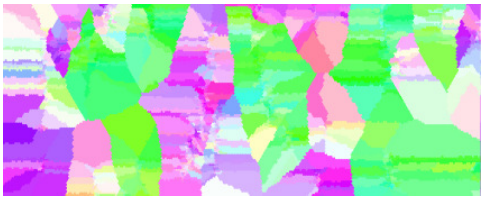
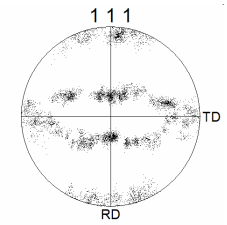
Clean up

However, it is important to make sure that the resulting microstructure makes sense also watch the texture and grain boundary changes.









EDAX TSL

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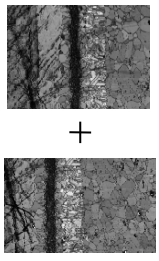
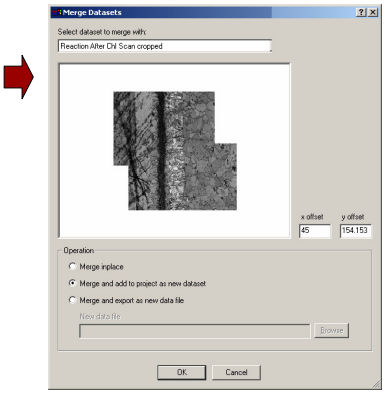
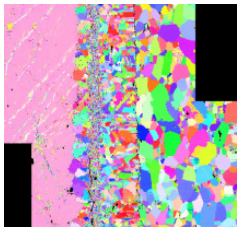
Merge





- Datasets can be merged together.
- The relative positioning of the datasets is controlled by the user.



EDAX TSL

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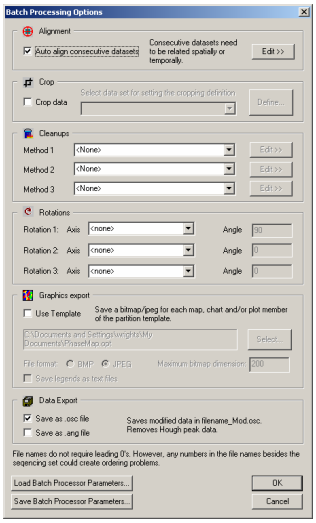
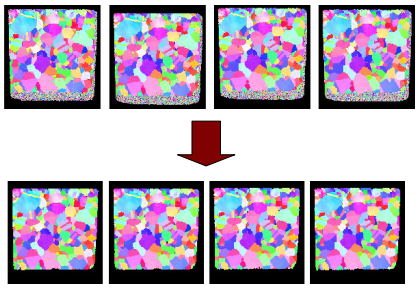
Batch processor



- A tool to apply a partition template to multiple sets of data.
- Includes Rotate, Cleanup, Crop, and Export functions.
- An alignment function to align consecutive sets of data for a sequence of scans, e.g. from serial sectioning or slices in time.



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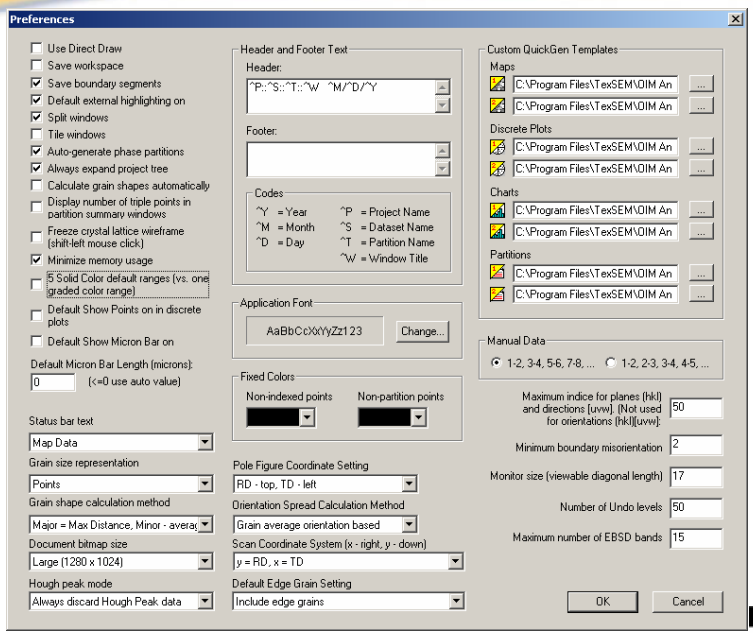
Preferences



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EDAX TSL