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Aalto University
School of Engineering

COE-C2004 - Materials Science and Engineering

Exercise 1

Prof. Junhe Lian

Wenqi Liu (Teaching assistant)

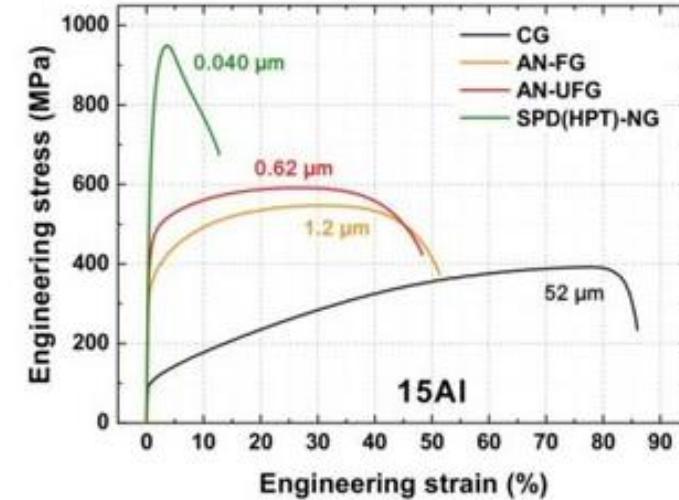
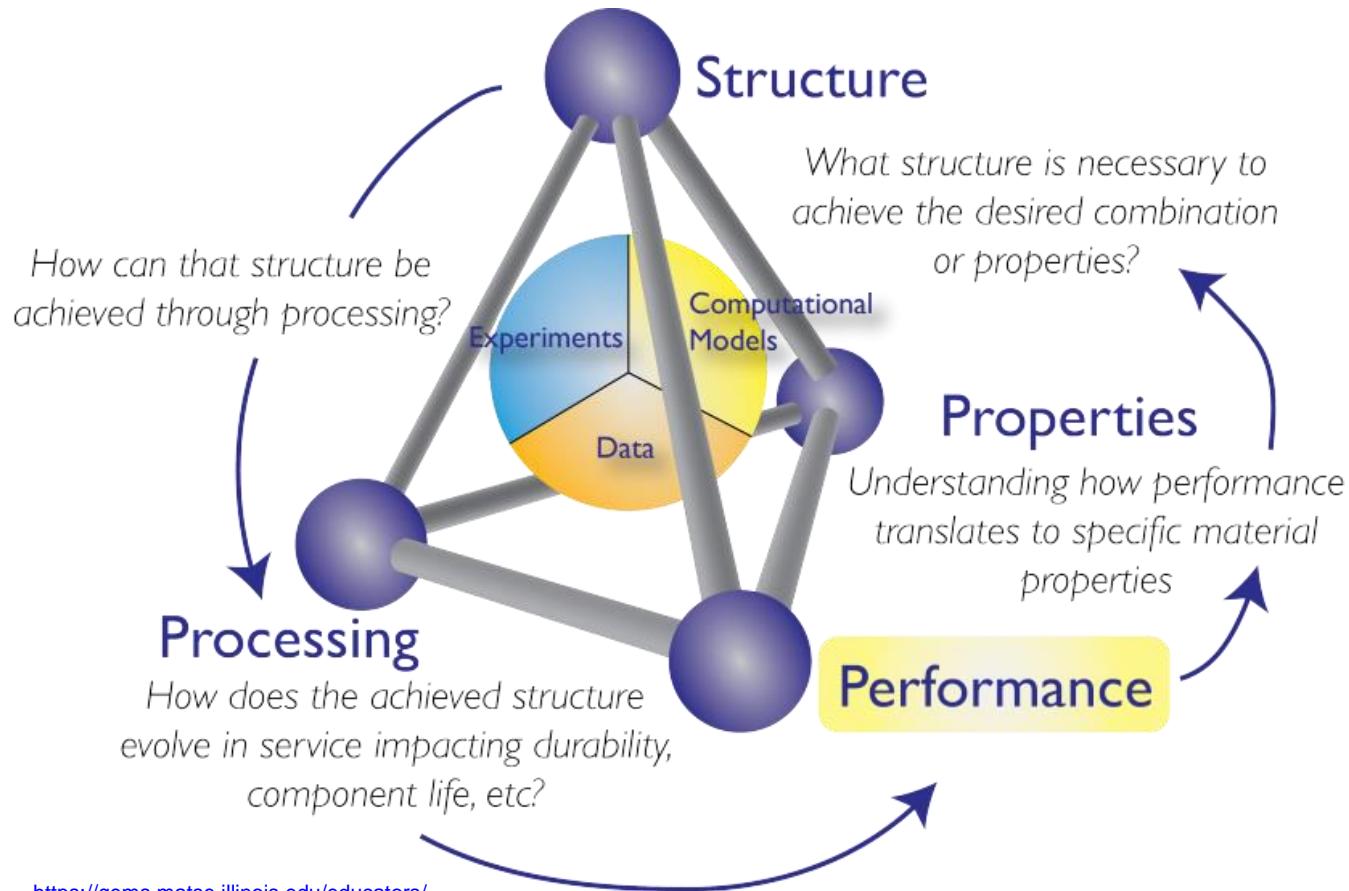
Rongfei Juan (Teaching assistant)

Outlines

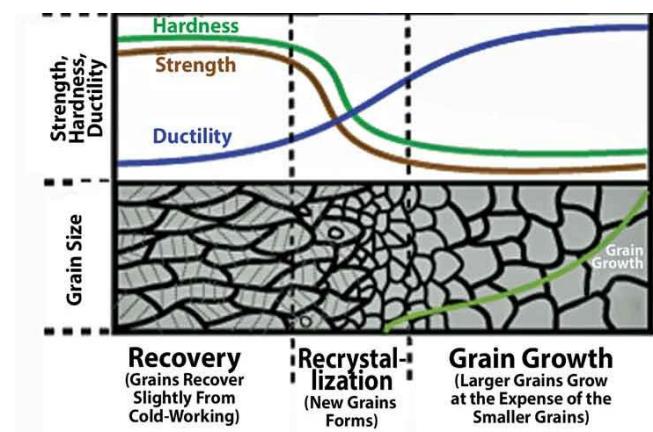
- Introduction
 - Microstructure characterization
 - Task
- Matlab - Mtex toolbox
 - Software installation
 - EBSD data analysis
- Assignment and questions

Microstructure characterization

Background

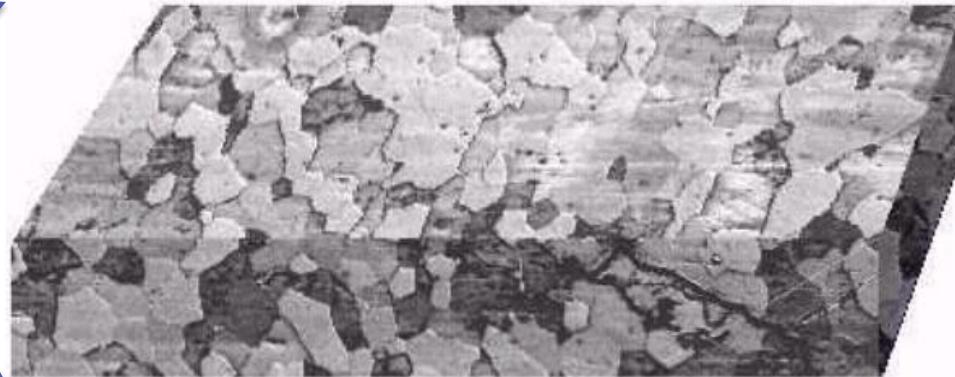


R.Liu et al. Acta Mat. 2018



<https://www.thefabricator.com/thefabricator/article/being-grain-size-part-ii-how-metal-grain-size-affects-a-bending-operation>

Crystalline Materials - Microstructure



[http://engineering.snu.ac.kr/lecture/texture&anisotropy/Texture%20&%20Anisotropy%2010\(Representation\).pdf](http://engineering.snu.ac.kr/lecture/texture&anisotropy/Texture%20&%20Anisotropy%2010(Representation).pdf)

Microstructure

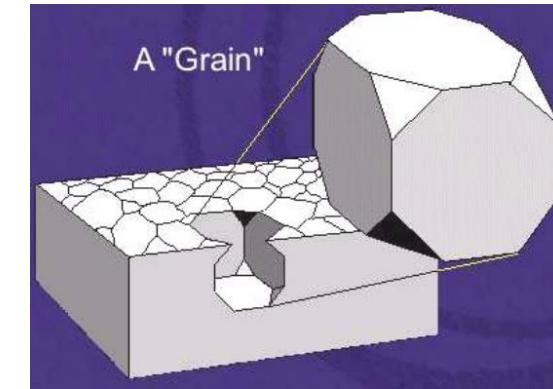
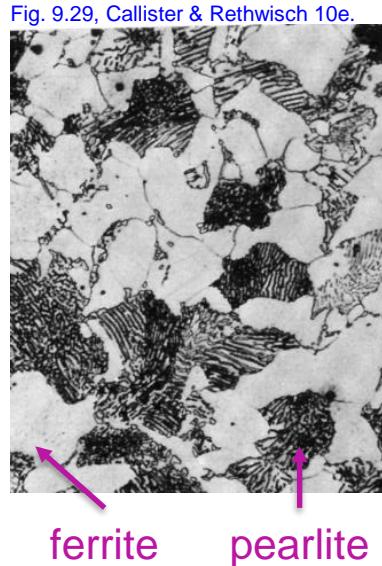
The arrangement of the constituents of a material, i.e. the spatial distribution of elements, phases, orientations, and defects. [1]

Length scale: nm-cm for microstructure

pm for crystal structure

Phase in material science

A phase is a region of material that shows the uniform chemical composition and structure.

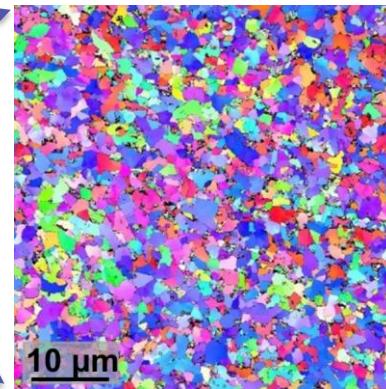
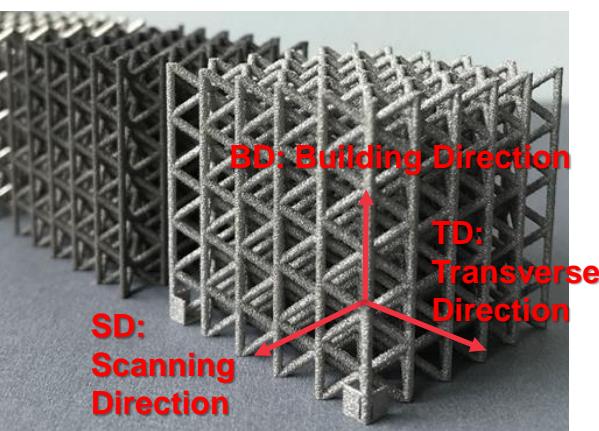
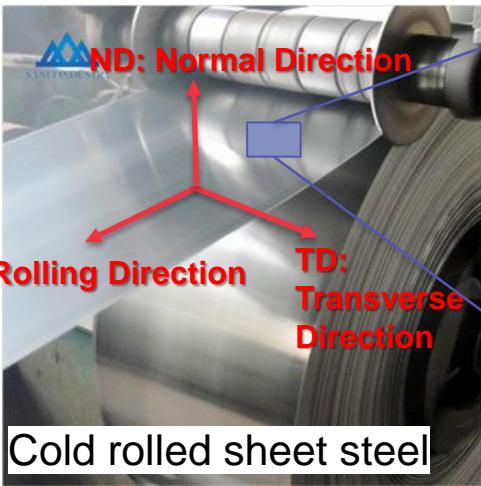


Crystal/Grain

A grain is a region of specific crystal orientation within a polycrystalline material.

- Most crystalline solids are composed of a collection of many small crystals or grains; such materials are termed as *polycrystalline*.
- In metals and other materials, the individual grains may fit together closely to form the solid.

Crystallographic orientation

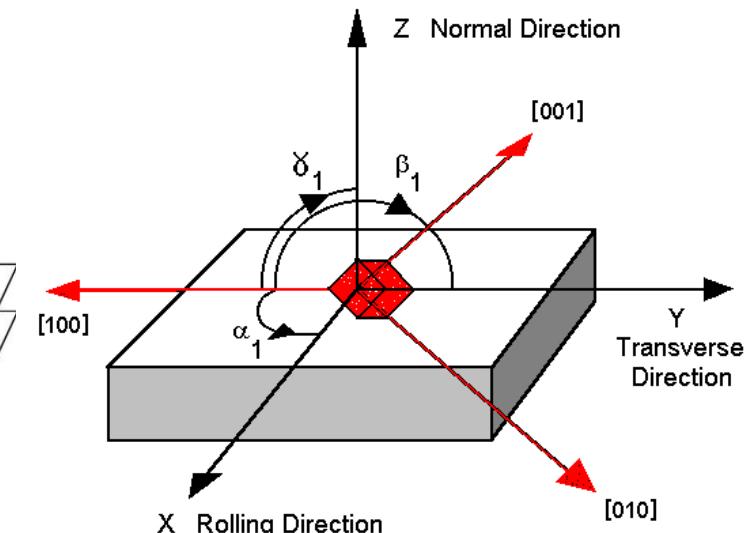
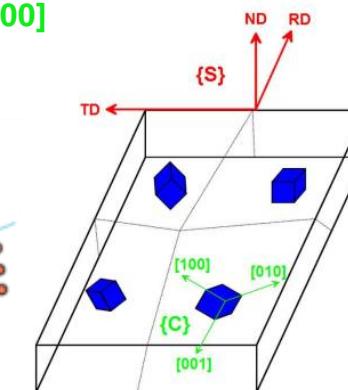
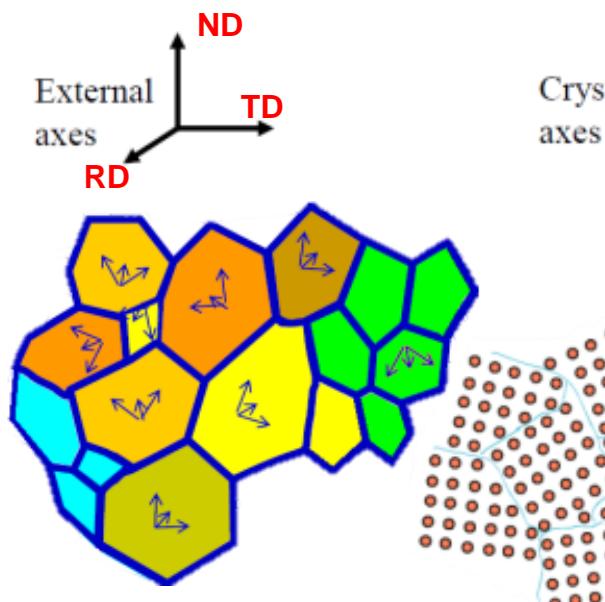


Crystallographic orientation:

Rotation g to transform the sample frame $\{S\}$ into the crystal frame $\{C\}$: $\{C\} = g \cdot \{S\}$

g : 3x3 rotation matrix

mathematical description $g = \begin{pmatrix} g_{11} & g_{12} & g_{13} \\ g_{21} & g_{22} & g_{23} \\ g_{31} & g_{32} & g_{33} \end{pmatrix} = \begin{pmatrix} \cos\alpha_1 & \cos\beta_1 & \cos\gamma_1 \\ \cos\alpha_2 & \cos\beta_2 & \cos\gamma_2 \\ \cos\alpha_3 & \cos\beta_3 & \cos\gamma_3 \end{pmatrix}$



Olaf Engler (Hydro Aluminium): Introduction to Texture Analysis: Macrotexuture, Microtexture, Orientation Microscopy

Crystallographic orientation

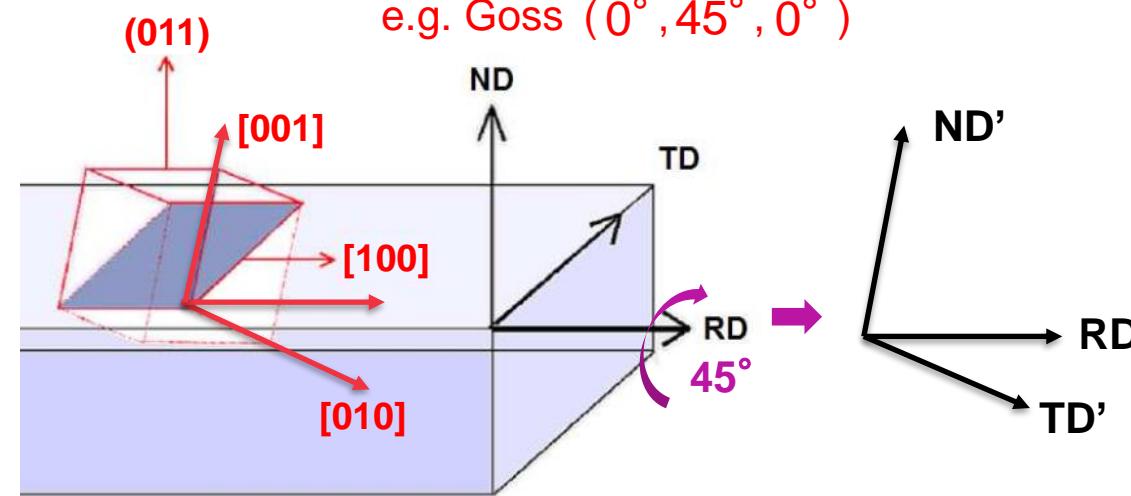
Euler angle method (φ_1 , Φ , φ_2)

Bunge method (Bunge, 1969): Rotate the sample frame {S} into the crystal frame {C}.

1. rotation by φ_1 about the normal direction ND, transforming the rolling direction RD into RD', on (001) plane of the crystal frame;
2. rotation by Φ about the axis RD' (in its new orientation), transforming the normal direction ND into direction [001] of the crystal frame and bringing TD into the (001) plane in the crystal frame;
3. rotation by φ_2 about ND" (in its new orientation, i.e. [001] direction).

$$g = g_{\varphi_2} \cdot g_{\Phi} \cdot g_{\varphi_1}$$

$$\left\{ \begin{array}{l} g_{\varphi_1} = \begin{pmatrix} \cos\varphi_1 & \sin\varphi_1 & 0 \\ -\sin\varphi_1 & \cos\varphi_1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \\ g_{\Phi} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\Phi & -\sin\Phi \\ 0 & -\sin\Phi & \cos\Phi \end{pmatrix} \\ g_{\varphi_2} = \begin{pmatrix} \cos\varphi_2 & \sin\varphi_2 & 0 \\ -\sin\varphi_2 & \cos\varphi_2 & 0 \\ 0 & 0 & 1 \end{pmatrix} \end{array} \right.$$



7

Crystallographic orientation

Rotation axis/angle method $[uvw]/\theta$

Rotate by angle θ about common axis $[uvw]$

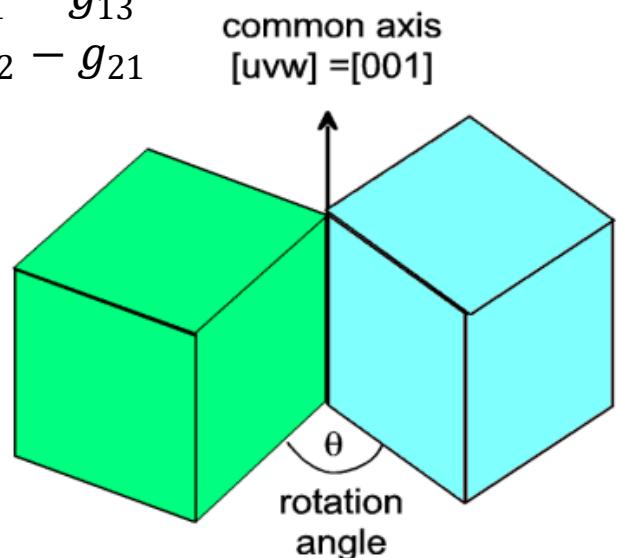
The axis is identical in both crystals

$$2\cos\theta = g_{11} + g_{22} + g_{33} - 1$$

$$u \cdot 2\sin\theta = g_{23} - g_{32}$$

$$v \cdot 2\sin\theta = g_{31} - g_{13}$$

$$w \cdot 2\sin\theta = g_{12} - g_{21}$$



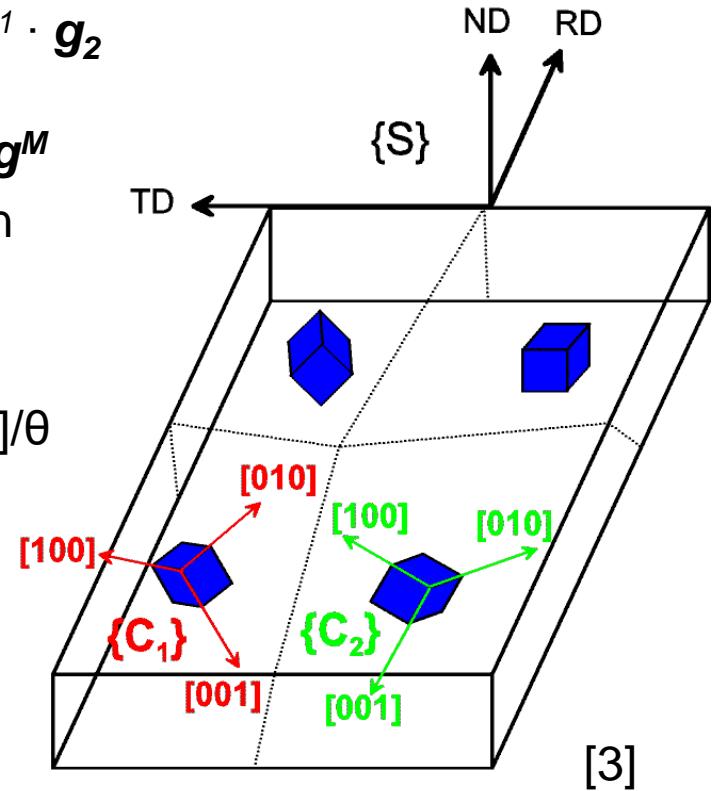
→ Misorientation between two grains

Rotation matrix g^M to transform crystal frame $\{C_1\}$ of grain 1 into the crystal frame $\{C_2\}$ of grain 2:

$$\{C_2\} = g^M \cdot \{C_1\} \text{ or } g^M = g_1^{-1} \cdot g_2$$

The misorientation matrix g^M is analogous to the rotation matrix g , and it can be expressed in the rotation axis/angle parameter $[uvw]/\theta$ method.

θ : misorientation angle



Grain boundaries

- regions between grains (crystals)
- crystallographic misalignment across a grain boundary
- Slight atomic disorder
- high atomic mobility
- high chemical reactivity

low-angle grain boundaries (LAGBs) are those with a misorientation less than about 15 degrees. In contrast, the misorientation of *high-angle grain boundaries (HAGBs)* is greater than about 15 degrees.

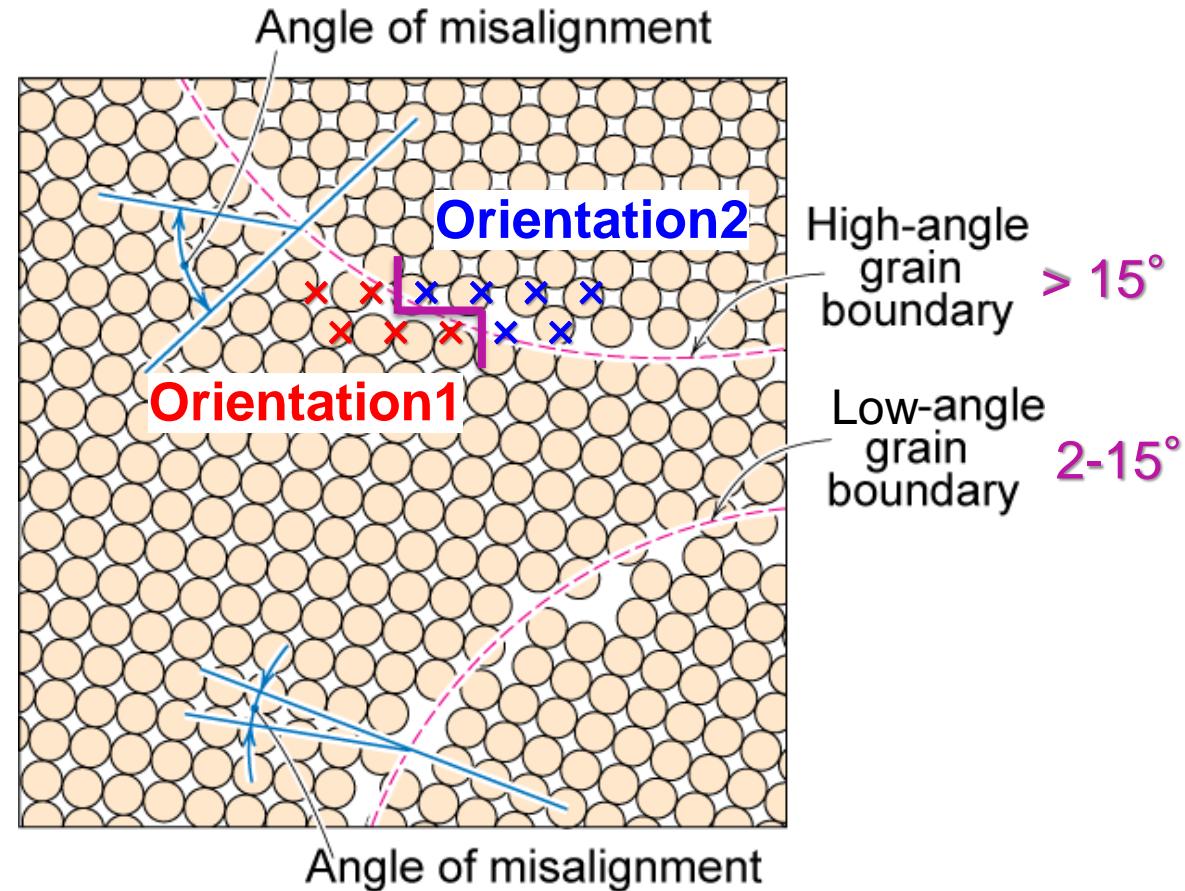


Fig. 4.8, Callister & Rethwisch 10e.

[3]

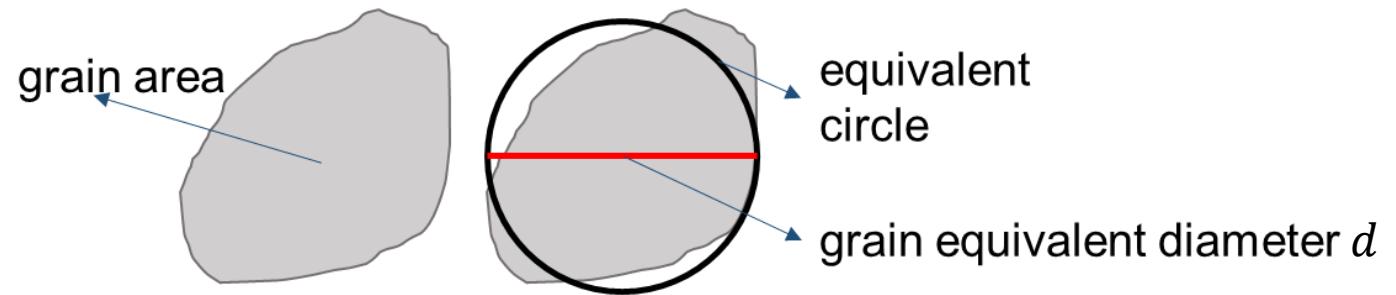
Grain size

Electron Backscatter Diffraction (EBSD)



S. Zaefferer (MPIE): Microstructures, Microscopy & Modelling.

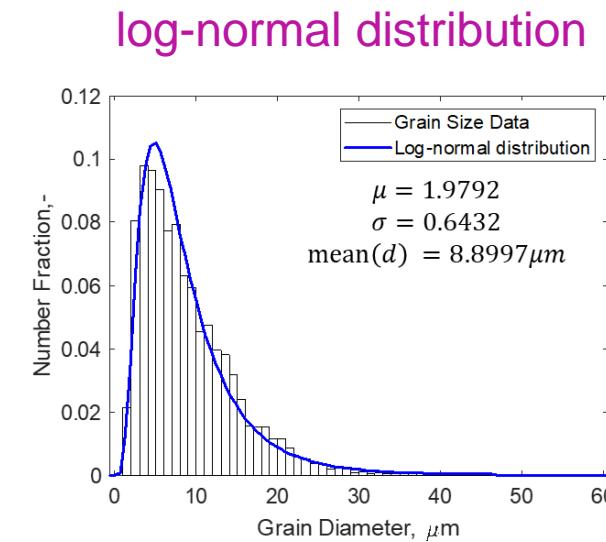
Equivalent grain diameter d



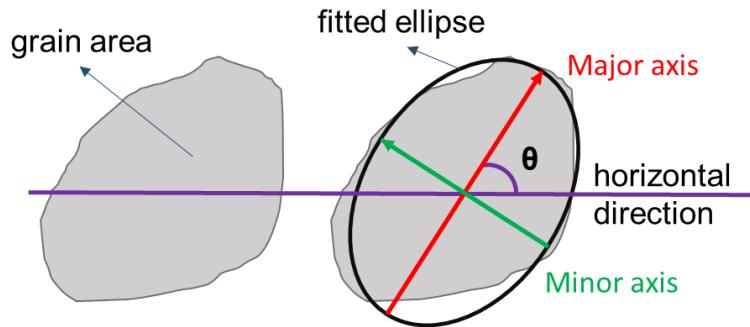
- Fit a circle to the points making up a grain based on the equivalent area criterion.

- For conventional polycrystals, the grain size distribution generally follow the log-normal distribution:

$$f(d; \mu, \sigma) dy = \frac{1}{d\sigma\sqrt{2\pi}} \exp\left(-\frac{(\ln d - \mu)^2}{2\sigma^2}\right) dy, \quad \text{mean}(d) = \exp(\mu + \sigma^2/2)$$



Grain shape



- Fit an ellipse to the points making up a grain based on the equivalent area criterion.

Beta distribution

$$f(x; \alpha, \beta) = \frac{1}{B(\alpha, \beta)} x^{\alpha-1} (1-x)^{\beta-1}$$

$$B(\alpha, \beta) = \int_0^1 x^{\alpha-1} (1-x)^{\beta-1} dt$$

$$\text{mean}(x) = \frac{1}{1 + \frac{\beta}{\alpha}}$$

Grain shape factor: Equivalent grain aspect ratio

$$\text{Aspect ratio} = \frac{\text{Length of the minor axis}}{\text{Length of the major axis}}$$

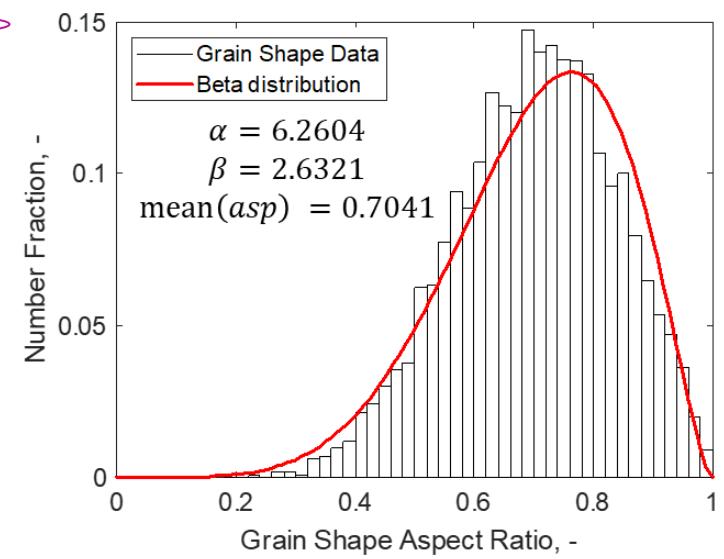
Ranges from 0 to 1.

Examples:

1 refers to equiaxed grains,



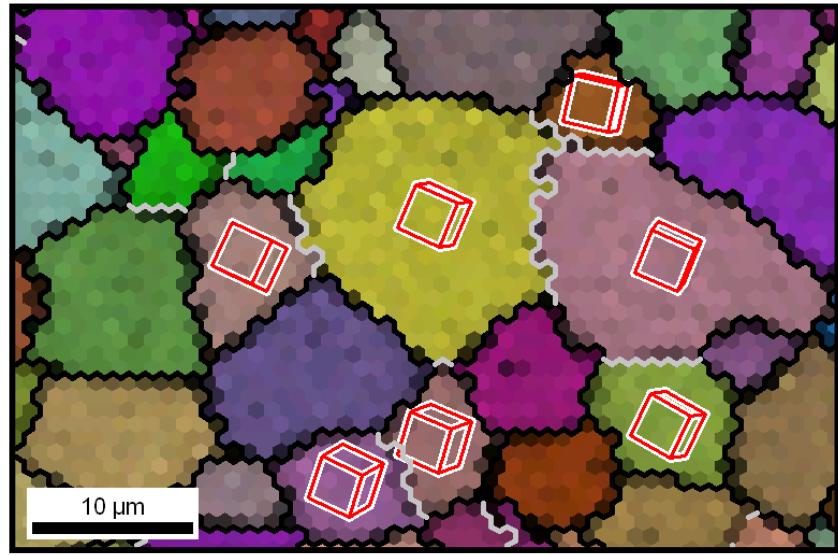
0.1 to cold-rolled grains,



Task

Task

EBSD measurement



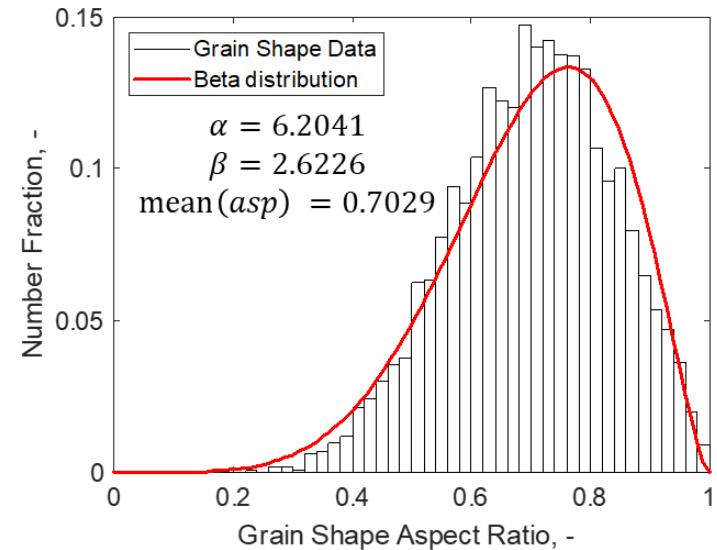
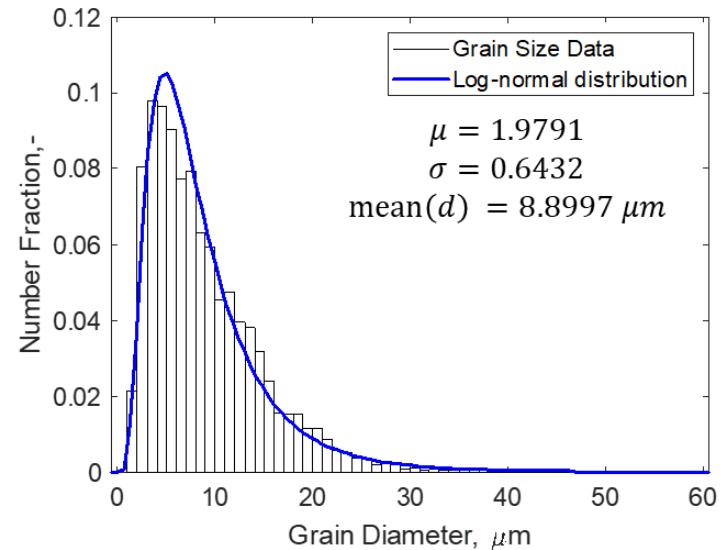
EBSD .ctf type data

Phase	X	Y	Bands	Error	Euler1	Euler2	Euler3	MAD	BC	BS
5	0.0000	0.0000	11	0	314.5405	30.5703	80.0588	0.7228	173	96
5	1.0000	0.0000	12	0	314.0926	30.7198	80.5870	0.4773	180	111
5	2.0000	0.0000	12	0	314.0436	30.7488	80.7497	0.4559	186	121
5	3.0000	0.0000	12	0	313.9620	30.7578	80.7800	0.5206	187	122
5	4.0000	0.0000	12	0	314.2286	30.9458	80.4102	0.4530	188	126
5	5.0000	0.0000	12	0	314.1959	30.5262	80.4533	0.4533	190	124
5	6.0000	0.0000	12	0	313.7000	31.0000	81.0110	0.5802	172	111
c	7.0000	0.0000	9	0	301.1475	34.0700	80.0400	0.2100	125	60

* EBSDdata.ctf for this exercise



- phi1, PHI, phi2/Euler123: Crystal orientation date
- XY: position, coordinates
- Phase/Grain: phase/grain ID
- Mean Angular Deviation (MAD) / Band Contrast(BC) / etc.: parameters to evaluate the measurement quality



Mtex toolbox installation

Mtex installation

Access

Matlab: Aalto software download service Download.aalto.fi (Aalto user credentials log in is needed).

MTEX toolbox: open-sourced software <https://mTEX-toolbox.github.io/>

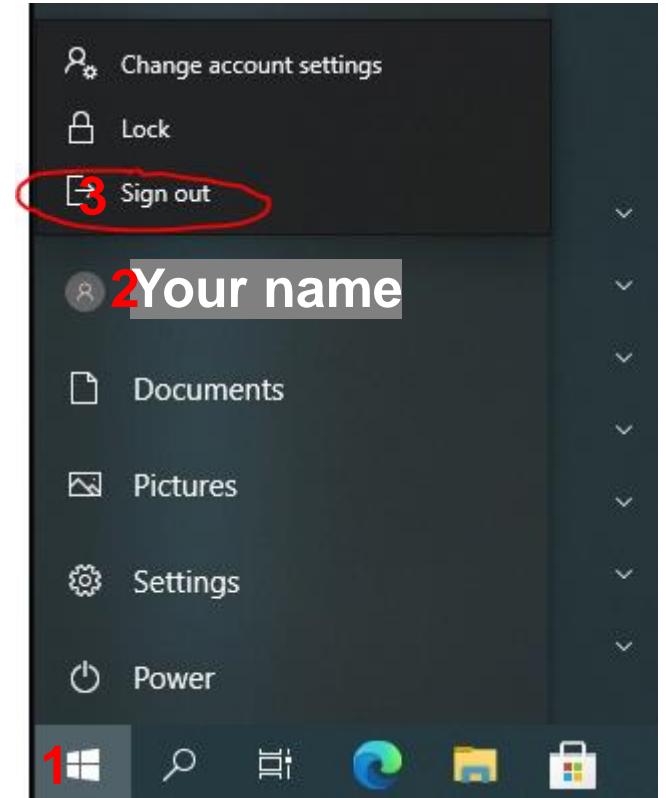
Aalto VDI system: mfavdi.aalto.fi, or VMware Horizon Client vdi.aalto.fi, for more information, please refer to [Remote access to Windows classroom computers](#).

IMPORTANT! Please remember to do '**Sign Out**' after the session (NOT Disconnect). Click your username in Start and click 'Sign Out'.

Basic Rule: Please use **DOT** as the decimal separator, **NO COMMA!**

Please download and extract the zip file of MTEX 5.4.0. Copy it to your Matlab work direction or add it to the Matlab work path.

Please also download the 'EBSDdata.ctf' file as input. (in MyCourses Exercise1)





Download

<https://mtex-toolbox.github.io/download>

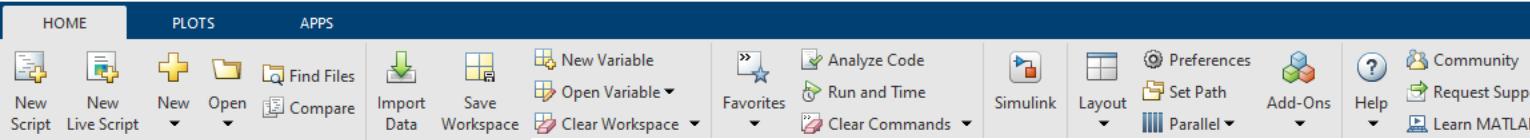
Installation

1. download and extract the zip file to an arbitrary folder
2. start Matlab (version 2016b or newer required - older versions have not been tested)
3. change the current folder in Matlab to the folder where MTEX is installed
4. type `startup_mtex` into the command window
5. click one of the menu items to import data or to consult the documentation

In case you experience any problems, especially on Mac OSX, have a look at our [trouble shooting page](#)

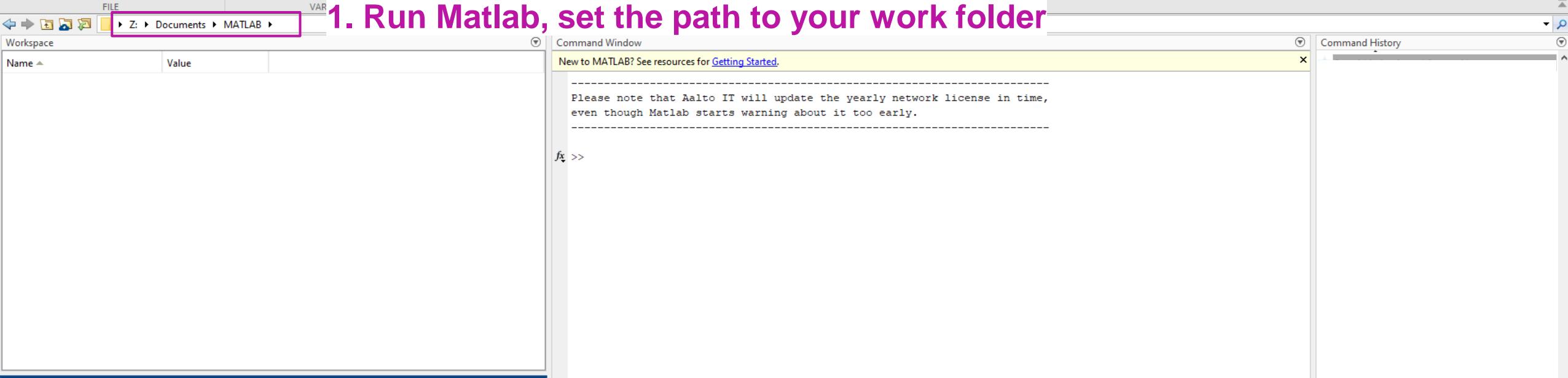
Downloads

File Name	Release Date	Comments	Downloads
mtex-5.7.0.zip ↗	May 2021	improved parent grain reconstruction, changelog	4.5k
mtex-5.6.1.zip ↗	March 2021	bug fix release, changelog	1.5k
mtex-5.6.0.zip ↗	January 2021	simplified parent grain reconstruction, changelog	2.4k
mtex-5.5.2.zip ↗		Download ‘mtex-5.4.0.zip’ to your Matlab folder	669
mtex-5.4.0.zip ↗	July 2020	parent grain reconstruction, changelog	2767
mtex-5.3.1.zip ↗	June 2020	bug fixes, boundary curvature, changelog	1051
mtex-5.3.zip ↗	April 2020	performance updates, changelog	2118

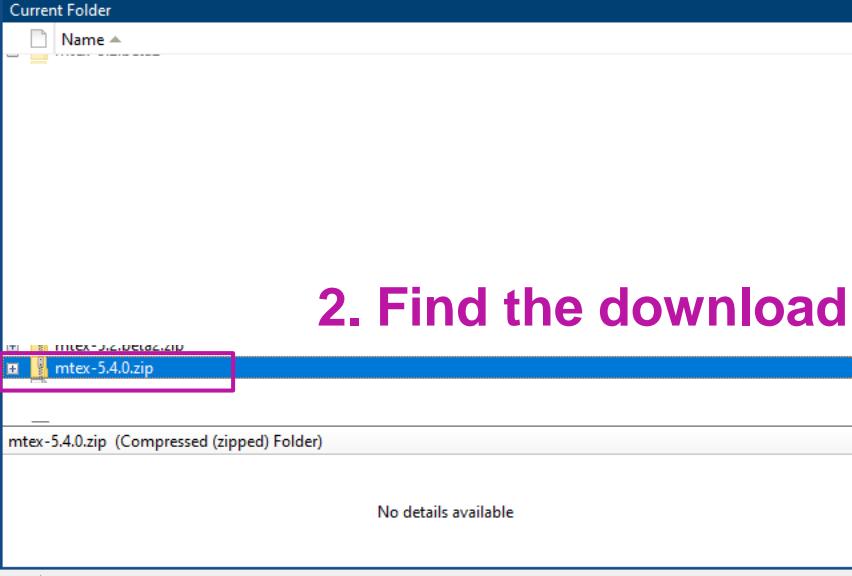


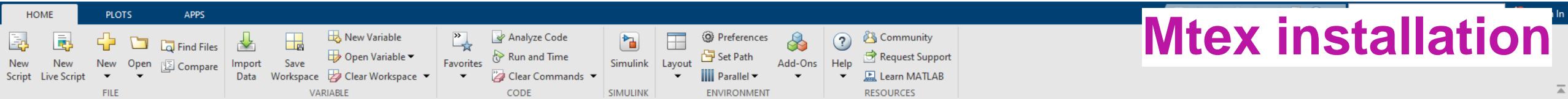
Mtex installation

1. Run Matlab, set the path to your work folder



2. Find the download .zip file. Double click to extract

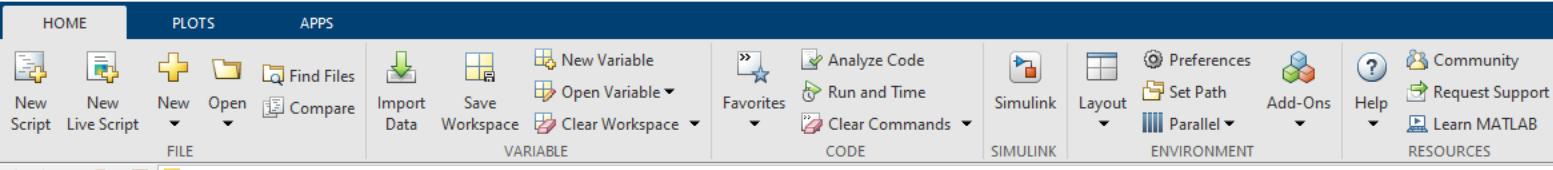




Double click the extracted folder to add it to the work path

Or right click -> Add path: make sure the MTEX folder has been added to your Matlab work path!

A screenshot of the MATLAB Current Folder browser. The 'mtex-5.4.0' folder is selected. A tooltip message appears over the folder: "This folder is not on your MATLAB path. Double-click mtex-5.4.0 to make it your current folder or select 'Add to Path' from its context menu to add it to your path." There is also a 'Do not show this message again' button. The browser shows other folders like 'mex-5.2.beta2' and 'mex-5.4.0'.



Mtex installation

The screenshot shows the MATLAB R2020a interface with the following components:

- Current Folder Browser:** Located at the bottom left, it shows the directory structure of the MTEX distribution. A context menu is open over the file `startup.m`, which is highlighted with a red box. The menu options include: Open, Open as Live Function, Hide Details, Run (which is also highlighted with a red box), Run Script as Batch Job, View Help, Show in Explorer, Create Zip File, Rename, Delete, Compare Selected Files/Folders, Compare Against, Cut, Copy, Paste, and Indicate Files Not on Path.
- Command Window:** Located in the center, it displays a message about network license updates and a prompt `f> >>`.
- Workspace Browser:** Located at the top left, it shows the variables available in the current workspace.
- Command History:** Located on the right side, it shows a history of previously run commands.

A large text overlay in the center of the image reads: **Right click 'startup.m' function and click 'Run' to install MTEX**.

Mtex installation

Generated data will be shown in the workspace window

Check commands in the command history window

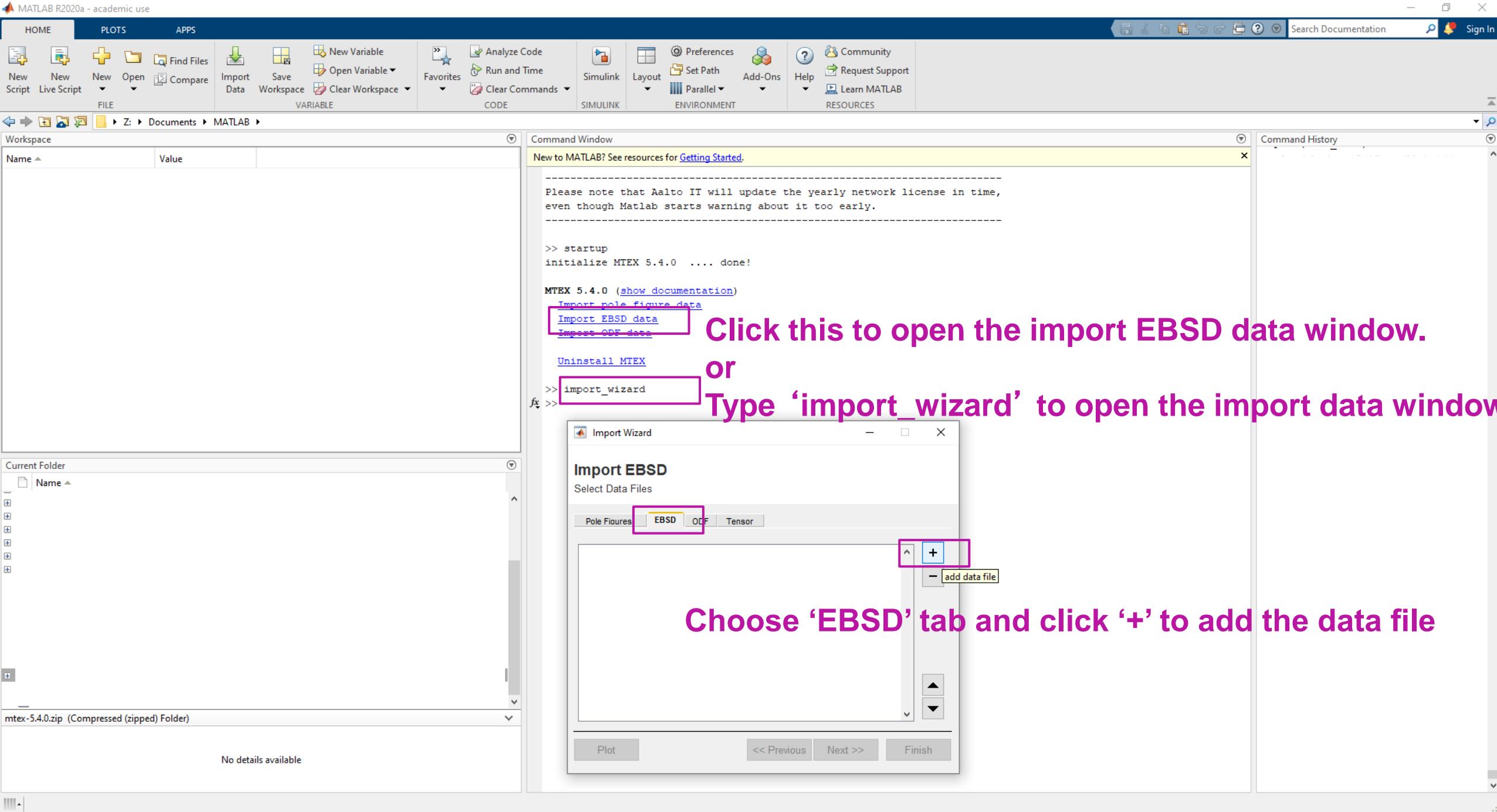
Type commands in the command window

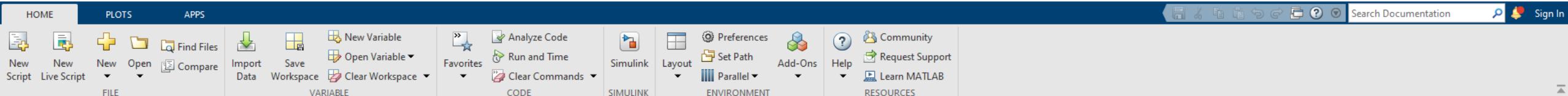
The screenshot shows the MATLAB R2020a interface with the following components visible:

- HOME**, **PLOTS**, **APPS** tabs at the top.
- FILE** tab selected, showing options: New Script, New Live Script, New, Open, Compare, Import Data, Save Workspace, New Variable, Open Variable, Favorites, Analyze Code, Run and Time, Clear Commands, Simulink, Layout, Preferences, Set Path, Add-Ons, Parallel, Help, Community, Request Support, Learn MATLAB, RESOURCES.
- VARIABLE** tab selected in the top menu bar.
- Workspace** window showing a table with columns "Name" and "Value".
- Current Folder** browser showing the directory structure of the installed MTEX 5.4.0 package, including files like tests, tools, CHANGELOG, compile-mtex, COPYING.txt, info.xml, install_mtex.m, Makefile, mtex_icon.gif, mtex_settings.m, mtex-include, README.md, startup.m, startup_mtex.m, and uninstall_mtex.m.
- Command Window** showing the output of the startup command:

```
Please note that Aalto IT will update the yearly network license in time,  
even though Matlab starts warning about it too early.  
  
->> startup  
initialize MTEX 5.4.0 .... done!  
  
MTEX 5.4.0 (show documentation)  
Import pole figure data  
Import EBSD data  
Import ODF data  
  
Uninstall MTEX
```
- Command History** window on the right.

Mtex - EBSD data analysis





Workspace

Name	Value

Command Window

New to MATLAB? See resources for [Getting Started](#).

Please note that Aalto IT will update the yearly network license in time, even though Matlab starts warning about it too early.

Import Wizard

Select Data files

This PC > data (\\\home.org.aalto.fi\liuw7) (Z:) > Documents > MATLAB >

Organize New folder

Name	Date modified	Type	Size
mtex-5.2.0	1/13/2020 11:01 AM	File folder	
mtex-5.2.beta2	1/13/2020 4:39 PM	File folder	
mtex-5.4.0	10/21/2020 1:29 PM	File folder	

Current Folder

Name

- Lian group
- 图片
- 文档
- This PC
- 3D Objects
- Desktop
- Documents
- Downloads
- Music
- Pictures
- T21203
- Videos
- Aalto HD (C:)
- data (\\\home.or

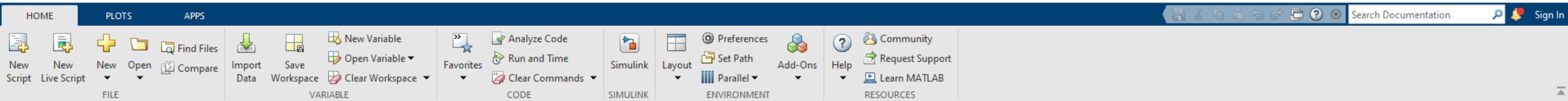
File name: EBSDdata.ctf

EBSDdata.ctf
Type: CTF File
Size: 28.3 MB
Date modified: 11/19/2019 1:43 PM

Open Cancel

In the select data file window, choose the aimed data file and 'Open'

startup.m (Function)
startup()



Z: > Documents > MATLAB > mtex-5.4.0 > mtex-5.4.0 >

Workspace

Name	Value

Command Window

New to MATLAB? See resources for [Getting Started](#).

Please note that Aalto IT will update the yearly network license in time, even though Matlab starts warning about it too early.

Import Wizard

Import EBSD

Select Data Files

Pole Figures EBSD ODF Tensor

EBSDdata.ctf

Plot << Previous Next >> Finish

Current Folder

- Name
- tests
- tools
- CHANGELOG
- compile-mtex
- COPYING.txt
- info.xml
- install_mtex.m
- Makefile
- mtex_icon.gif
- mtex_settings.m
- mtex-include
- README.md
- startup.m
- startup_mtex.m
- uninstall_mtex.m
- VERSION

startup.m (Function)

startup()

After add the EBSD data file, click for 'Next' step

The screenshot shows the MATLAB interface with the 'Import Wizard' dialog open. The 'EBSD' tab is selected in the 'Select Data Files' section. A file named 'EBSDdata.ctf' is listed in the file list, highlighted with a pink rectangle. Below the file list are buttons for 'Plot', '<< Previous', 'Next >>', and 'Finish'. The 'Next >>' button is also highlighted with a pink rectangle. The 'Current Folder' browser on the left shows a directory structure with various MATLAB files and scripts. The 'Command Window' at the top right contains a note about network license updates and a link to 'Getting Started'. The 'Workspace' browser is empty.

Crystal Reference Frame for Phase 0

Crystal Symmetry

Mineral
 Indexed Not Indexed
 mineral name: notIndexed
 plotting color:

Crystal Coordinate System
 Point Group: 1
 Axis Length: a , b , c
 Axis Angle: alpha , beta , gamma
 << Previous Next >>

Crystal Reference Frame for Phase 1

Crystal Symmetry

Mineral
 Indexed Not Indexed
 mineral name: Ti3Al - alpha2
 plotting color:

Crystal Coordinate System
 Point Group: 6/mmm
 Axis Length: a , b , c
 Axis Angle: alpha , beta , gamma
 << Previous Next >>

Crystal Reference Frame for Phase 2

Crystal Symmetry

Mineral
 Indexed Not Indexed
 mineral name: TiAl - gamma
 plotting color:

Crystal Coordinate System
 Point Group: 4/mmm
 Axis Length: a , b , c
 Axis Angle: alpha , beta , gamma
 << Previous Next >>

Different Phase parameter/setting will be shown based on the measured data. Just leave with the default and click 'Next'.

Phase 0

Crystal Syn

Mineral
 Indexed Not Indexed
 mineral name: Titanium-Cubic
 plotting color:

Crystal Coordinate System
 Point Group: m-3m
 Axis Length: a , b , c
 Axis Angle: alpha , beta , gamma
 << Previous Next >>

Phase 1

Crystal Syn

Mineral
 Indexed Not Indexed
 mineral name: Aluminium
 plotting color:

Crystal Coordinate System
 Point Group: m-3m
 Axis Length: a , b , c
 Axis Angle: alpha , beta , gamma
 << Previous Next >>

Phase 2

Crystal Syn

Mineral
 Indexed Not Indexed
 mineral name: Aluminium
 plotting color:

Crystal Coordinate System
 Point Group: m-3m
 Axis Length: a , b , c
 Axis Angle: alpha , beta , gamma
 << Previous Next >>



Specimen Reference Frame

Specimen Symmetry

Specimen Coordinate System

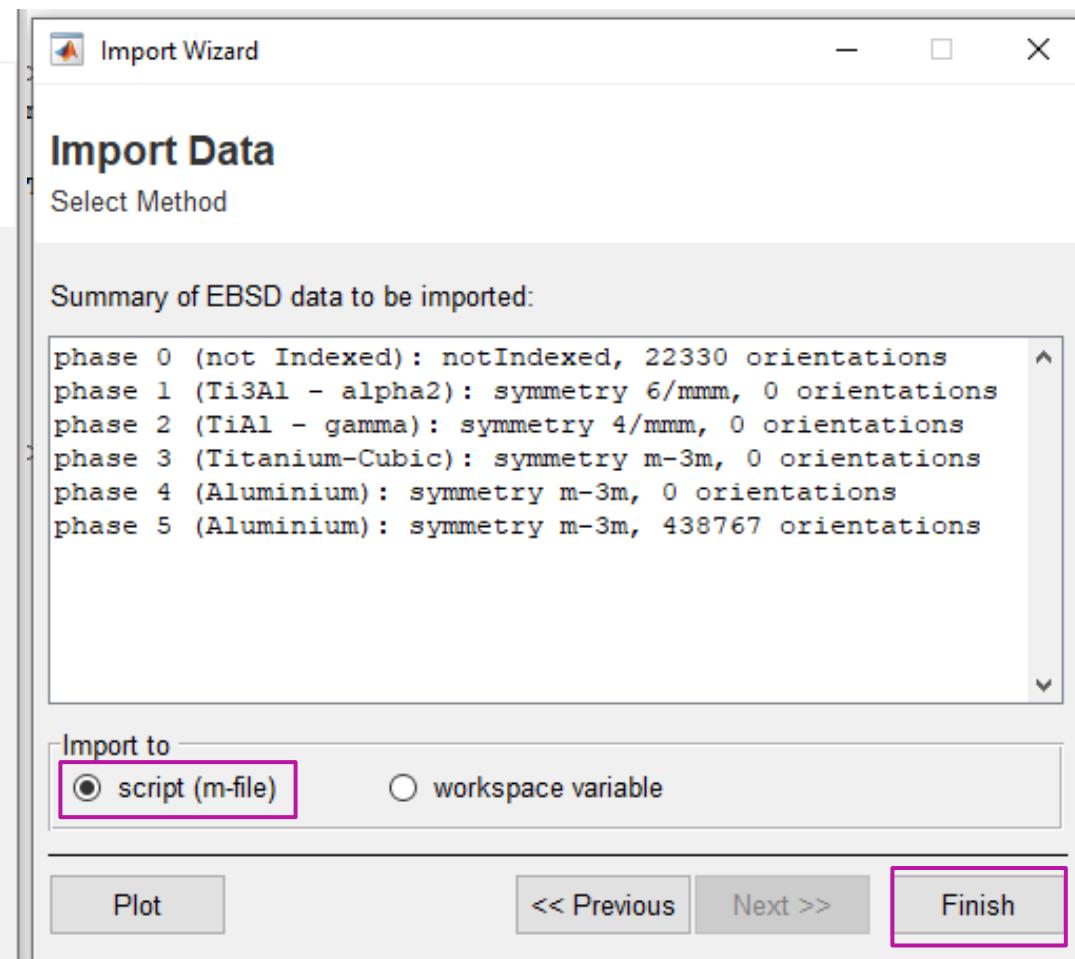
rotate data by Euler angles (Bunge) in degree

apply rotation to Euler angles and spatial coordinates
 apply rotation only to Euler angles
 apply rotation only to spatial coordinates
 use CTF interface flag 'convertSpatial2EulerReferenceFrame'
 use CTF interface flag 'convertEuler2SpatialReferenceFrame'

MTEX Plotting Convention

A row of eight small diagrams illustrating different MTEX plotting conventions for coordinate axes (X, Y, Z).

Plot the data to verify that the coordinate system is properly aligned!



Import Data

Select Method

Summary of EBSD data to be imported:

```
phase 0 (not Indexed): notIndexed, 22330 orientations
phase 1 (Ti3Al - alpha2): symmetry 6/mmm, 0 orientations
phase 2 (TiAl - gamma): symmetry 4/mmm, 0 orientations
phase 3 (Titanium-Cubic): symmetry m-3m, 0 orientations
phase 4 (Aluminium): symmetry m-3m, 0 orientations
phase 5 (Aluminium): symmetry m-3m, 438767 orientations
```

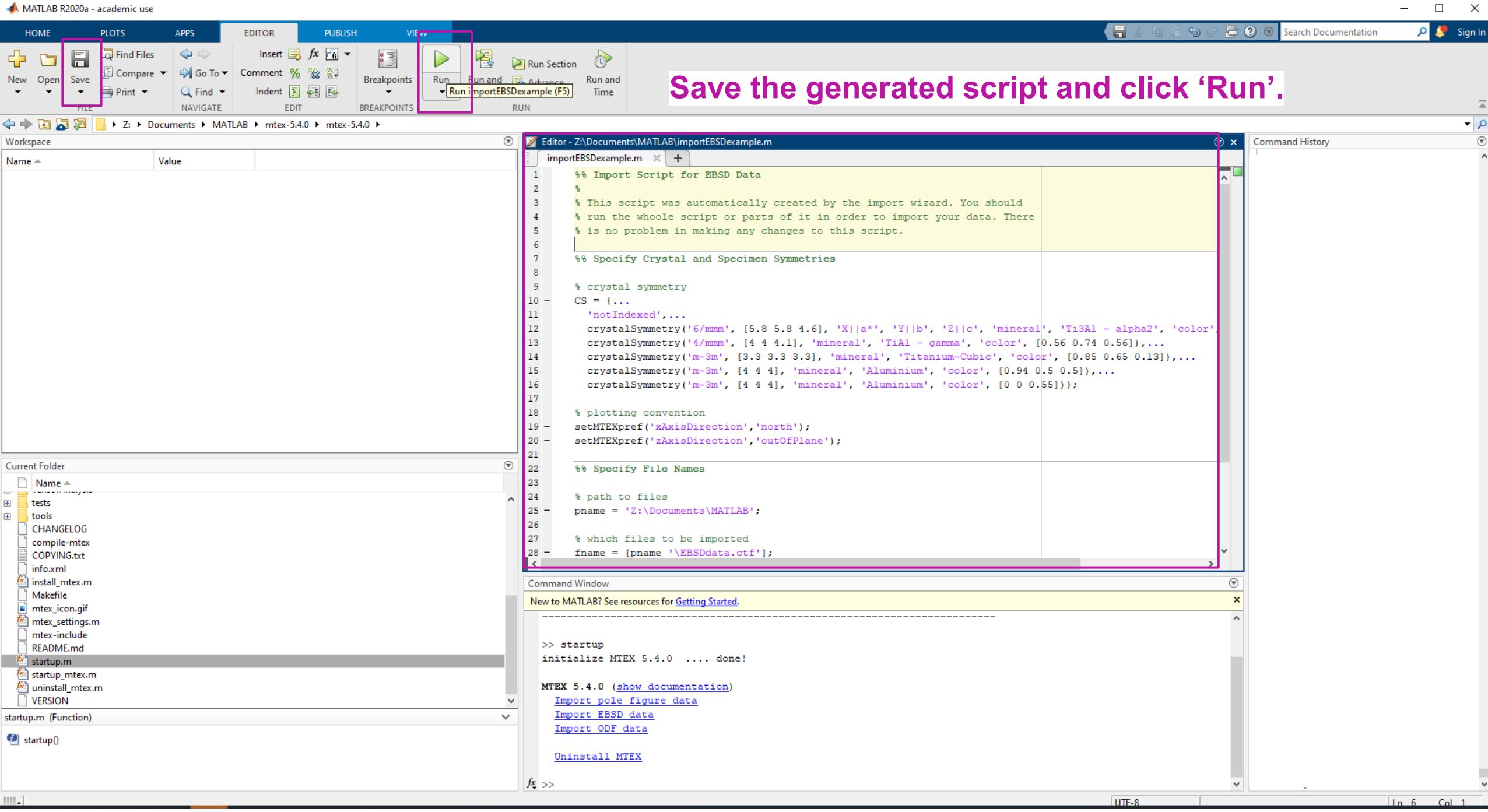
Import to

script (m-file)

workspace variable

Specimen coordinate setting,
use the default.

Generate the script file for importing.



Commands for importing EBSD data - Examples

```
%% Specify Crystal and Specimen Symmetries  
% crystal symmetry  
CS = {  
    'notIndexed',  
    crystalSymmetry('6/mmm', [5.8 5.8 4.6], 'X||a*', 'Y||b', 'Z||c', 'mineral', 'Ti3Al - alpha2',  
    'color', [0.53 0.81 0.98]),  
    crystalSymmetry('4/mmm', [4 4 4.1], 'mineral', 'TiAl - gamma', 'color', [0.56 0.74 0.56]),  
    crystalSymmetry('m-3m', [3.3 3.3 3.3], 'mineral', 'Titanium-Cubic', 'color', [0.85 0.65  
0.13]),  
    crystalSymmetry('m-3m', [4 4 4], 'mineral', 'Aluminium', 'color', [0.94 0.5 0.5]),  
    crystalSymmetry('m-3m', [4 4 4], 'mineral', 'Aluminium', 'color', [0 0 0.55])};  
% plotting convention  
setMTEXpref('xAxisDirection', 'north');  
setMTEXpref('zAxisDirection', 'outOfPlane');
```

```
%% Specify File Names  
pname = 'Z:\Documents\MATLAB'; % path to files  
fname = [pname '\EBSDdata.ctf']; % which files to be imported  
%% Import the Data, create an EBSD variable containing the data  
ebsd = EBSD.load(fname, CS, 'interface', 'ctf', 'convertEuler2SpatialReferenceFrame');
```

1. Crystal structure setting for each phase, default based on the measured EBDS data.

2. EBSD file path and name.

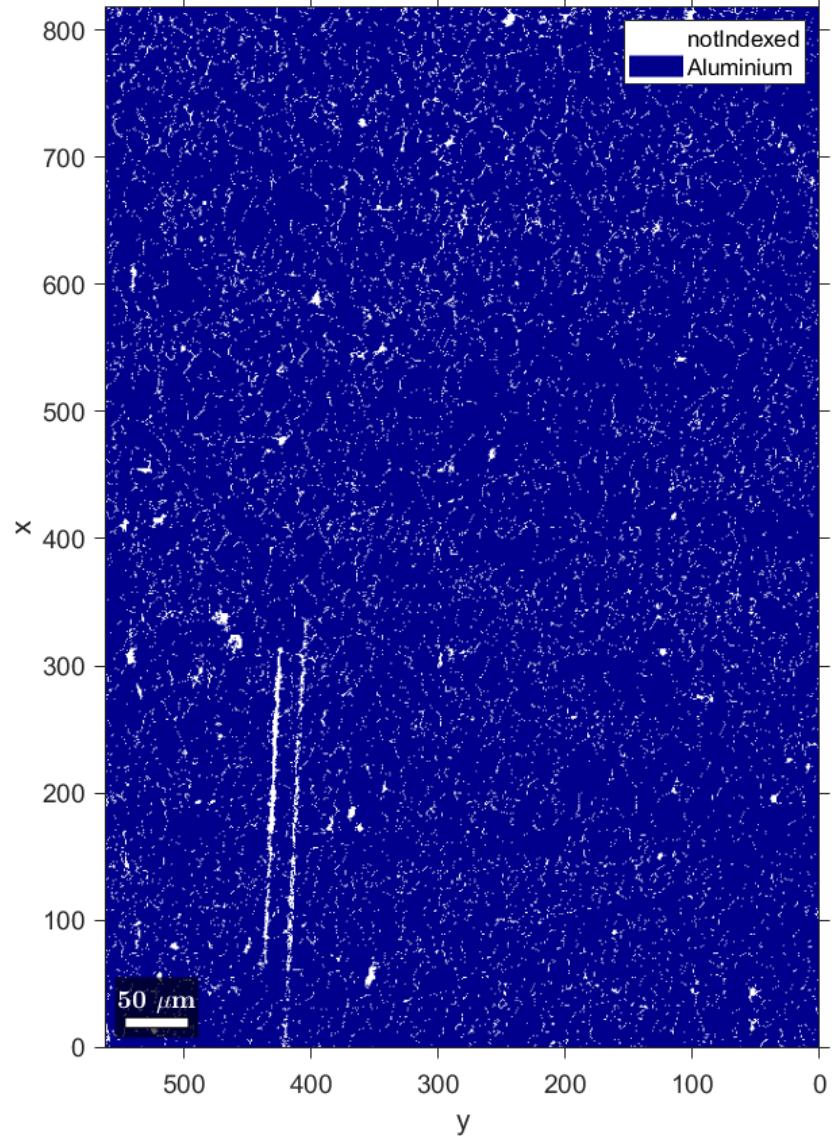
3. Load EBSD data.

Commands for EBSD data plotting

```
%% Initial analyses and plotting  
% Plot the Index/Phase map  
figure; plot(ebsd, 'coordinates', 'on');
```

Check the phase(s) in the investigated material and the measured area.

EBSD phase map + coordinates
Nonindexed
Aluminum



Commands for EBSD data analysis

```
%> Grain reconstruction  
% Consider only indexed & corrected data.  
ebsd_corrected = ebsd(ebsd.mad<1);  
ebsdcorri = ebsd_corrected('indexed');  
  
% Reconstruct the grain structure.  
[grains,ebsdcorri.grainId,ebsdcorri.mis2mean] = calcGrains(ebsdcorri,'angle',15*degree);  
initialGrainNr = length(grains);  
  
% Delete the very small grains which might be caused by the measurement error.  
ebsdcorri(grains(grains.grainSize<2)) = [];  
  
% Redo grain segmentation.  
[grains,ebsdcorri.grainId] = calcGrains(ebsdcorri,'angle',15*degree);  
  
% Pick up the focused phase.  
grainsAl=grains('Aluminium');  
totalGrainNr=length(grainsAl);
```

Set the accuracy criterion for measured data, delete the points with $MAD>1$.

Pick up only indexed points.

Check the number of initial grains after first reconstruction.

Delete grains with only 1 or 2 measured points.

Set the grain boundary as 15° .

Pick up grains for the focused phase.

Check the number of total grains of the focused phase.

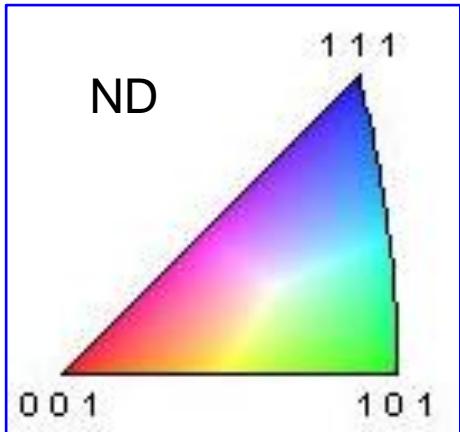
Total grains: 5350

Commands for EBSD data plotting

```
% Plot the EBSD orientation map.
```

```
ipfKey = ipfColorKey(ebsd('Aluminium'));  
ipfKey.inversePoleFigureDirection = vector3d.Z;  
colors =ipfKey.orientation2color...  
(grainsAl.meanOrientation); Set the orientation map color
```

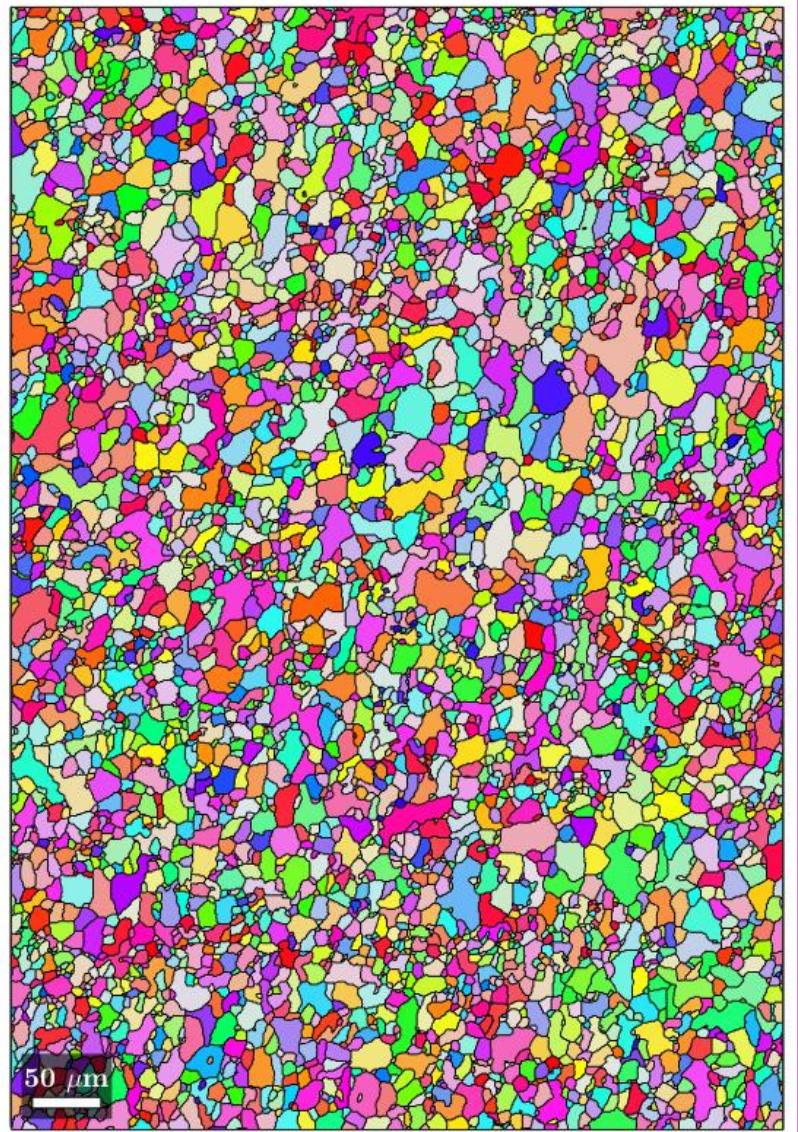
```
figure; plot(grainsAl,colors);
```



Legend for the color map

**Plot grain map with
grain mean orientation.**

Grain mean
orientation map
with
grain boundaries
in black lines



Commands for EBSD data analysis

The grains at the measured area boundaries should be removed for grain size and shape analysis.

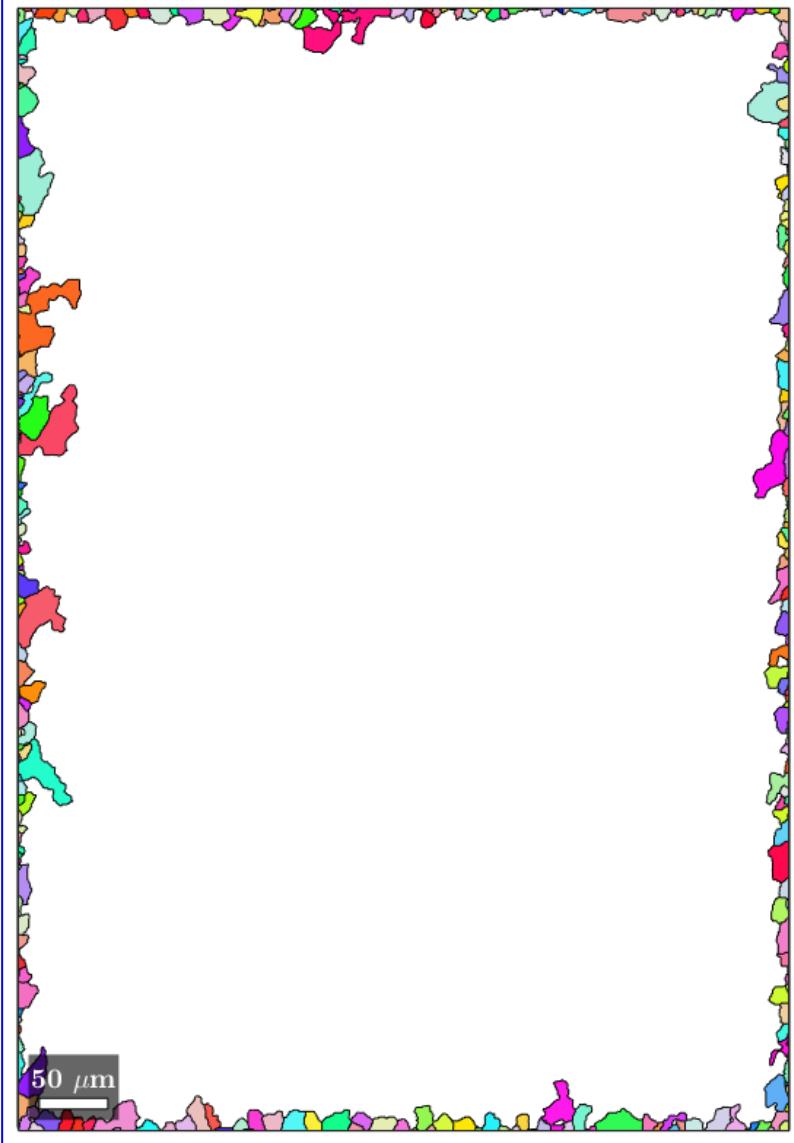
```
%% Grain Size & Shape Data analyses
% Find the boundary grains.
outerBoundary_id = any(grainsAl.boundary.grainId==0, 2);
grain_id = grainsAl.boundary(outerBoundary_id).grainId;
grain_id(grain_id==0) = [];
Pick up the boundary grains.

% Plot the boundary grains with their mean orientations.
figure; plot(grainsAl(grain_id),grainsAl(grain_id).meanOrientation);

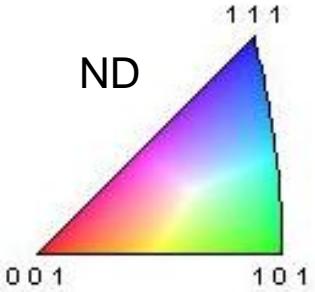
% Remove the boundary grains.
grainsAl(grain_id) = [];
innerGrainNr = length(grainsAl);
Plot the boundary grain map with grain mean orientation.
Check the number of inner grains of the focused phase. Inner grains: 5036

% Plot the inner grains with their mean orientations.
figure; plot(grainsAl,grainsAl.meanOrientation);

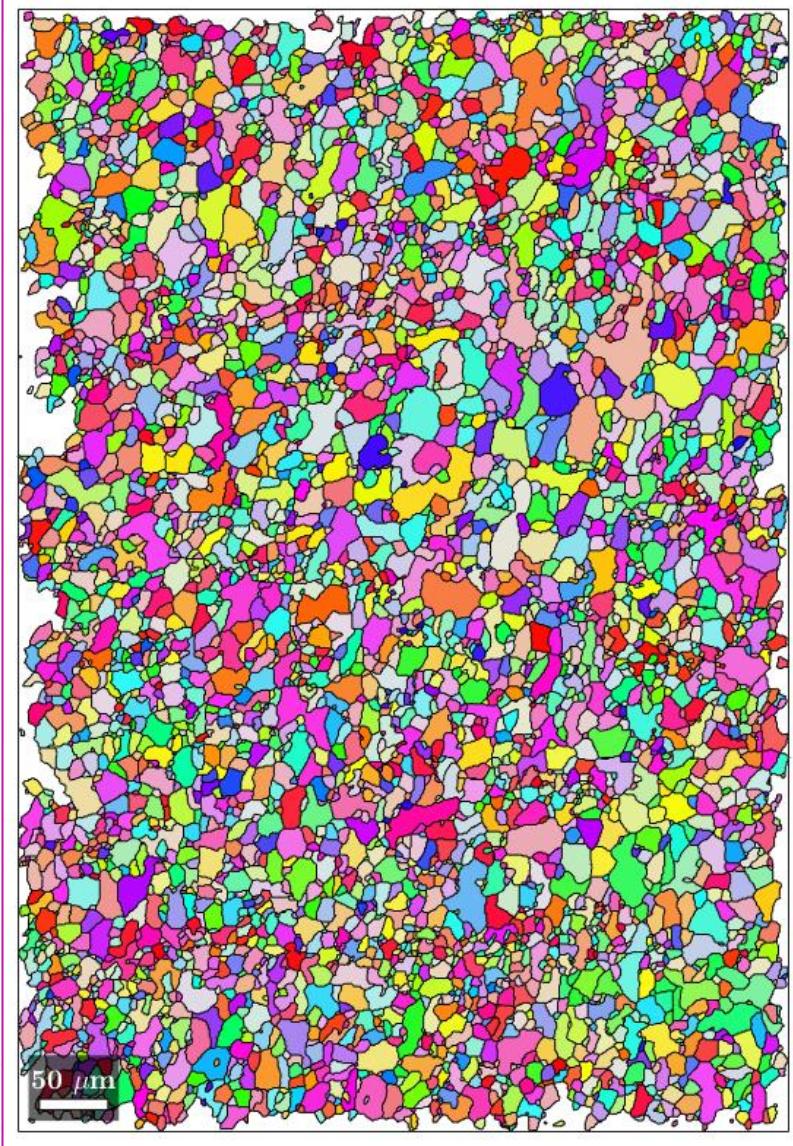
Plot the inner grain map with grain mean orientation.
```



Boundary grains
map with their
mean orientation



Inner grains map
with their mean
orientation
↓
For further grain
size and shape
analysis



Commands for EBSD data analysis

```
% Fit and plot the equivalent ellipses of grains  
[GrainfitEangle,GrainfitElongA,GrainfitEshortb] = fitEllipse(grainsAl);  
  
% Extract grains data  
Grainarea = grainsAl.area;  
GraineqR = grainsAl.equivalentRadius;  
GraineqD = GraineqR*2;  
Grainasp = 1./grainsAl.aspectRatio;  
  
% Plot fitted ellipses  
figure;  
plot(grainsAl,grainsAl.meanOrientation,'linewidth',1);  
hold on;  
plotEllipse(grainsAl.centroid,GrainfitElongA,GrainfitEshortb, ...  
    GrainfitEangle,'lineColor','r');  
hold off;
```

Ellipse grain longest and shortest axes.

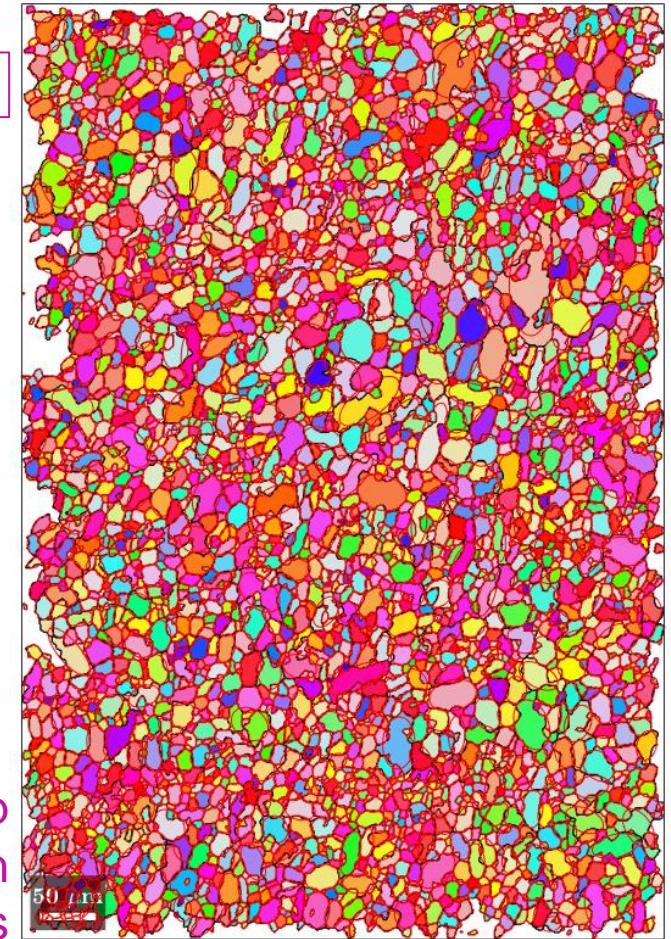
Grain area

Equivalent grain radius

Equivalent grain diameter

Grain shape factor: aspect ratio

Inner grains map
with mean orientation
and fitted equivalent ellipses



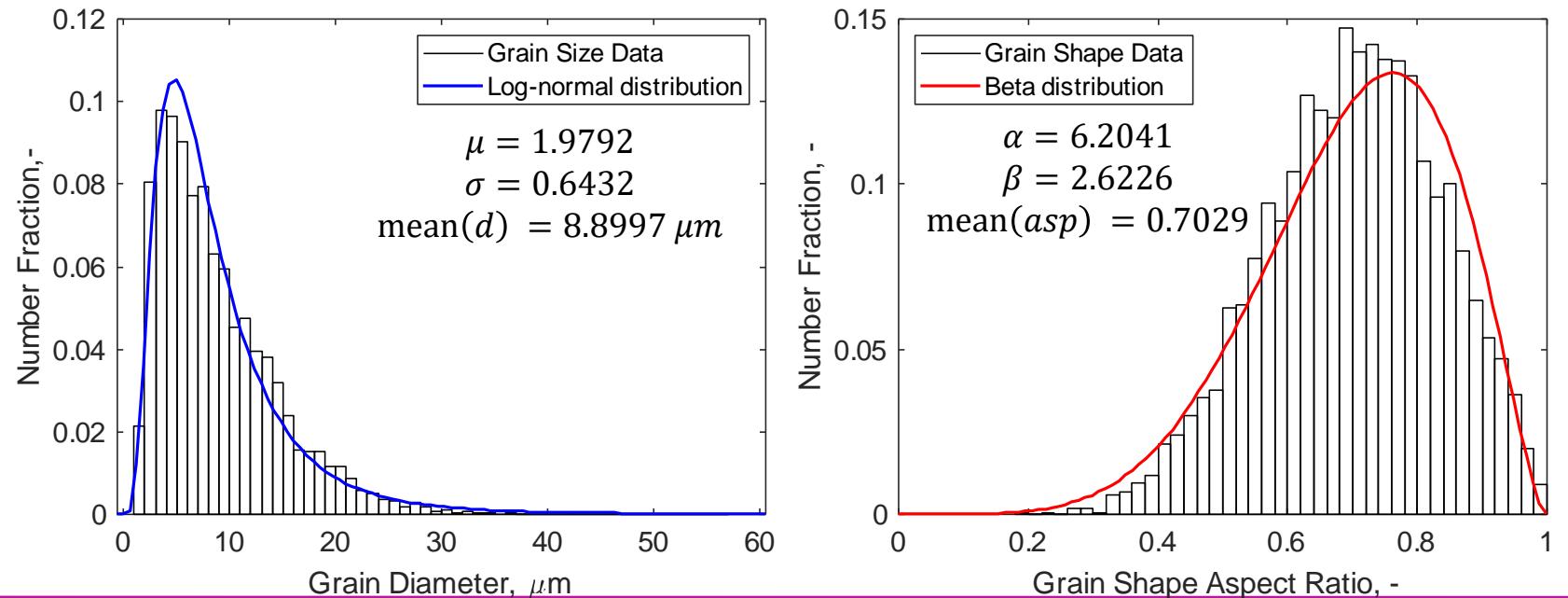
Grain size/shape distribution fitting

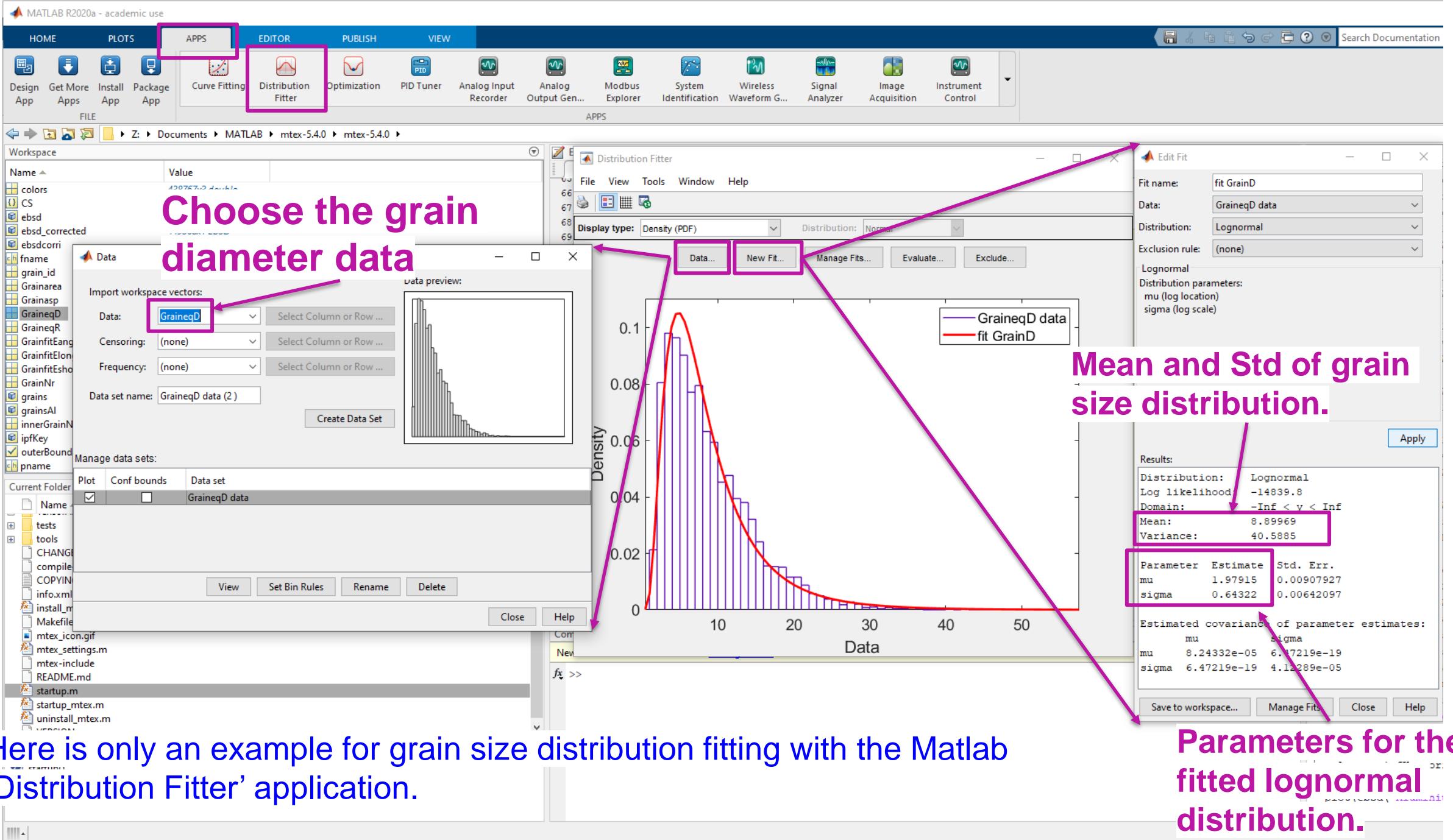
Grain size: log-normal distribution

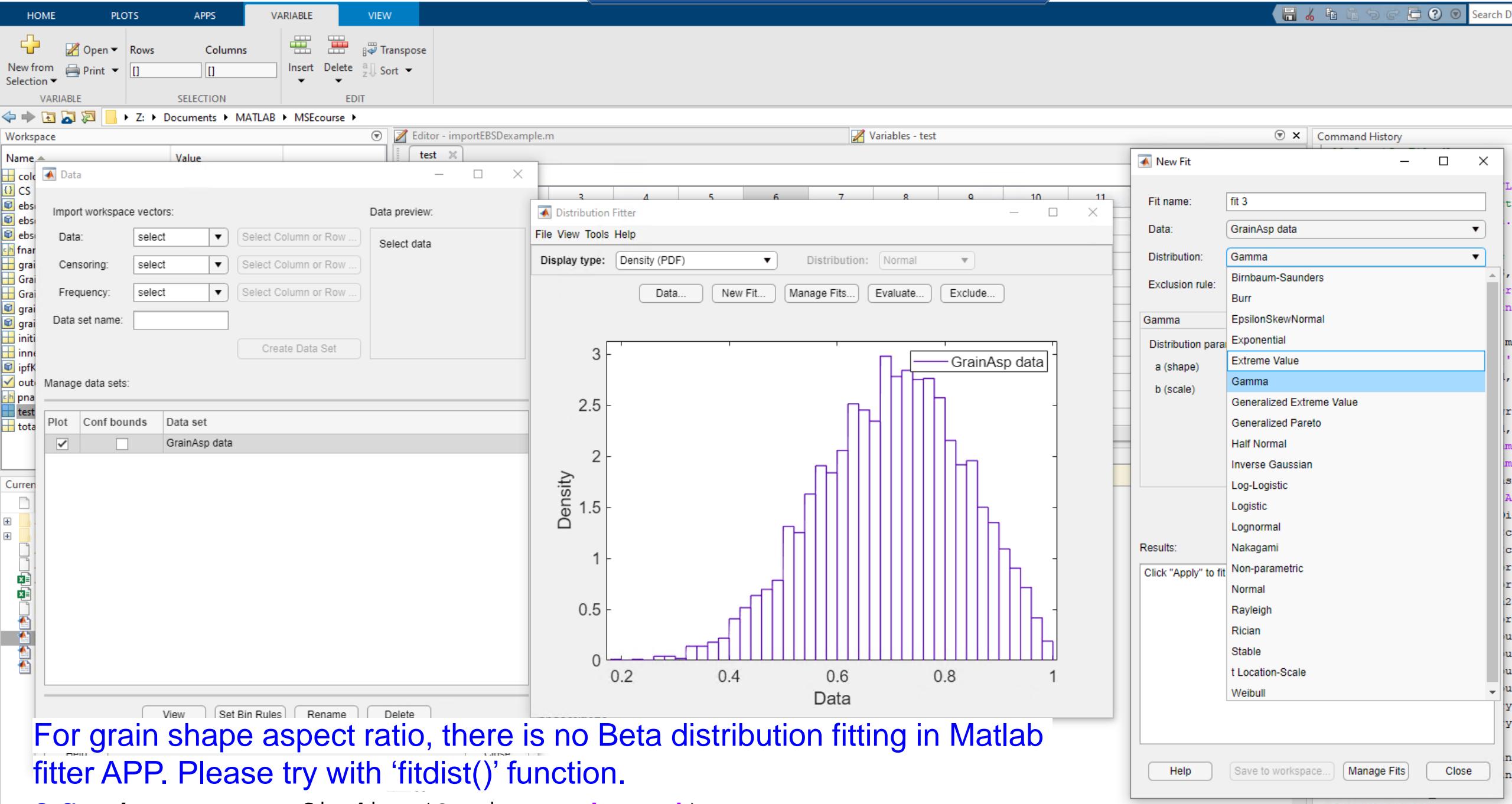
Grain shape aspect ratio: Beta distribution

Tools:

- Matlab ‘Distribution Fitter’, ‘fitdist()’ function, etc.
- Origin
- Etc.





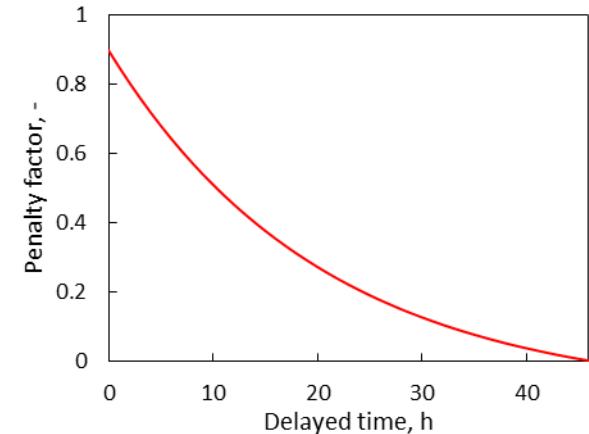


Assignments

General rules

Timelines

- Open on MyCourses: every Monday before 18:00.
- Deadline: every Sunday at 18:00 to MyCourses.
- Cut-off deadline: every Tuesday at 16:00 to MyCourses.
- Solution open on MyCourses: every Tuesday at 16:30.
- Q&A time: every Tuesday at 16:30-18:00 (via Zoom: <https://aalto.zoom.us/j/62428835336>).
- For the last assignment (A6), no extension and later submission allowed, solution will be given on MyCourses before 18:30, 12.12.2020.



Grades

- Delayed submission will be subjected to a penalty function in an exponential relation with time.
- Full points: 100 for every assignment, which will be calculated as 5-7 points in the final grade system.
The weighted pointes will be indicated in each assignment.
- In total, 40 points for 6 assignments.

General rules

Submission rules

- Only PDF type file is accepted for submission, please summarize all your answers/solutions in **one PDF file for every assignment**.
- Please name your assignment files with the assignment number and your first name and surname, and link them with short underlines: '**ANr_Firstname_Surname.pdf**', e.g. for the first Assignment 'A1_Wenqi_Liu.pdf'.
- It is appreciated to **sort the PDF pages in the TaskNr order**, which is helpful to speed up the evaluation process.
- Learning Group work is encouraged for this course. You could form a group with **max one additional peer** to review the lecture/exercise content and discuss the tasks in the assignment. After discussion, please **finish your assignment independently** and submit your individual report. Please note the **duplicate report is not accepted!** If you have a learning group, please **indicate who your group member is** in the submitted report. In addition, clearly state the individual contributions of each group member.

General rules

- When required, always show the step-by-step derivation or calculation processes, without which hinting the number does not qualify for grades.
- When required, always give a brief and concise explanation or description, without which hinting the right choice or answer does not qualify for grades.
- **Citation is necessary** if you are using any figures/data that are not generated by yourself.
- Handwriting/plotting is acceptable, just **make sure that your handwriting/final photo in the system is clear enough, otherwise it may affect the grading for details/calculation process.**
- Tolerant grading, **high points ≠ exactly accurate answers!**
- **Check the assignment solution carefully!** This is the only standard answer (for calculations, equations, derivations, definitions) if there are similar questions in the exam.

If you have further questions, please use the 'General discussion' channel in MyCourses.

=> **1 points for forum activities.**

Course grade

- 10 points for participation
 - 0.5 points x 12 **lectures/seminars**
 - 0.5 points x 6 **exercises**
 - 1 point for **forum** activities
- 40 points quality of tasks
 - (5-7) points x 6 weekly **assignments**
- 50 points on **exam**
- 10 points on **extra activities**
 - 5 points on a computational task (details given during Exercise sessions)
 - 5 points on an essay task (details given during Exercise sessions)

Total	Grade
≥90	5
≥80	4
≥70	3
≥60	2
≥50	1
<50	0

Resources

Textbook:

- [1] Günter Gottstein, Physical Foundations of Materials Science, 2004.
- [2] Olaf Engler and Valerie Randle, Introduction to texture analysis: macrotexture, microtexture, and orientation mapping, 2010, 2nd ed.
- [3] William D. Callister, Jr. and David G. Rethwisch, Materials science and engineering: an introduction, 2011, 8th ed.

Software:

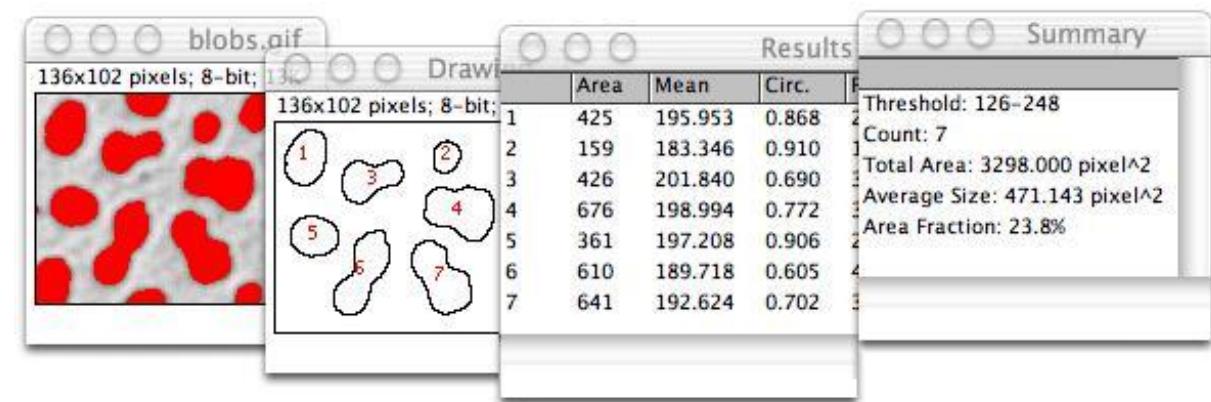
- Matlab (<https://se.mathworks.com/help/matlab/index.html>)
- MTEX toolbox 5.4.0 (<https://mtex-toolbox.github.io/>)
- ImageJ (<https://imagej.nih.gov/ij/>)



ImageJ

Image Processing & Analysis in Java

ImageJ for phase/particle analysis



Questions?

- Use the Zoom Chat function or raise your hands!
- Please avoid emails and use the “General discussion” on MyCourses!