ADCIS

ADvanced **C**oncepts in **I**maging **S**oftware

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Company Profile

- **Founded in 1995**
  - Joint effort by Bruno Lay & Amerinex Applied Imaging, Inc., a New Jersey company specialized in Image Processing and Millimeter Wave technology
- **French SA (corporation)**
  - Privately held with 10 investors
- **Located in Normandy, France**
- **65% of sales outside France**
- **Worldwide product distribution**
  - Direct sales and distributors

Strategic Partnerships

- **Amerinex Applied Imaging (USA)**
  - ADCIS stockholder at 25%
  - Board of directors member
  - North American distribution
- **School of Mines, Paris**
  - Center of Mathematical Morphology
  - Cebio: Statistical Analysis
- **Relationships with universities worldwide**
  - Site licenses, teaming, technology licensing

Fields of Expertise

- ⇨ Image Processing, Analysis and Understanding
- ⇨ Custom application development
- ⇨ Windows, Visual C++ Programming
- ⇨ Interface to image acquisition systems
- ⇨ Internet, web service
- ⇨ Database management
- ⇨ Statistical Analysis

Customer Profile

- ⇨ Universities and Public Research laboratories
- ⇨ Research laboratories of private companies
- ⇨ Quality department
- ⇨ OEMs and Vision System suppliers
- ⇨ Machine Vision manufacturers

ADCIS Products

- Aphelion Imaging Software Suite
- Custom Engineering Work for Fortune 500 companies worldwide
- Training in Computer Vision and Image Processing
- Consulting work for big pharmaceutical companies
- And involvement in R&D projects funded by public organizations (France and Europe)

Material Science Expertise

- ADCIS engineers have a PhD from a school specialized in Material Science (e.g. Paris School of Mines, University of Caen)
- ADCIS and the Mathematical Morphology Department of the School of Mines are involved in French and European R&D projects
- The Aphelion Imaging Software Suite includes a set of specialized tools and extensions for the Material Science domain

The **Aphelion**® Imaging Software Suite

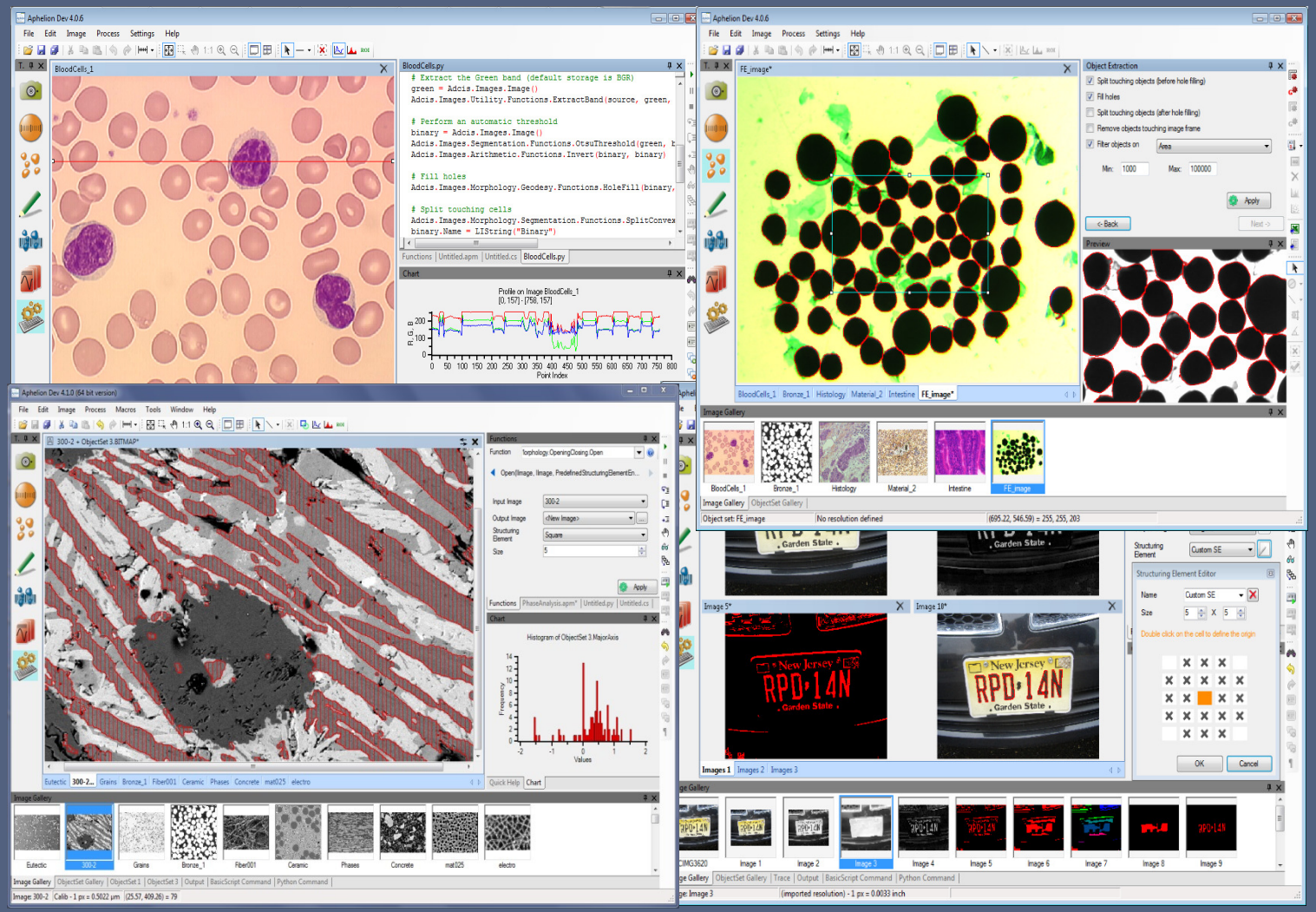


Image Acquisition

- **Image Acquisition Devices:**
  - Video or digital camera
  - In the field of microscopy:

    Move the stage to scan the whole sample. Images are captured in a set of small subimages and then stitched together

    Sample is not moving. The lens is moving as in a flat bed scanner. Reconstruction is performed internally by the system
  - Optical and Electron microscope
  - Micro-tomograph to generate a 3D image

Image Acquisition Challenges

- **Illumination**
  - Generate an image in which objects of interest are clearly visible
  - Avoid light reflex
- **Resolution**
  - Image size is such that objects on interest are more than a few pixels
- **Acquisition speed**
  - If the sample is moving, the image acquisition must be very fast (24 images/second)
- **Interface with the PC**
  - USB interfaces are more and more popular

Image Processing

- **Once the image is acquired, it can be automatically processed using a specialized Image Processing Software**
- **Market is divided into 2 groups:**
  - Specific software to address one application (grain sizing)
  - Off the Shelf Software with a large set of imaging operators:

    Aphelion, ImageJ, Matlab
- **The new trend is for large companies to sub contract the application development**

Mathematical Morphology - 1

- **The basis of Mathematical Morphology relies on the Set Theory**
  - Union (Or), intersection (And), Xor, minimum, maximum
- **Minkowski invented an algebra for the set theory in which addition and subtraction are introduced.**
- **The Minkowski's addition (1903) is the basis of dilation (Matheron, 1967)**

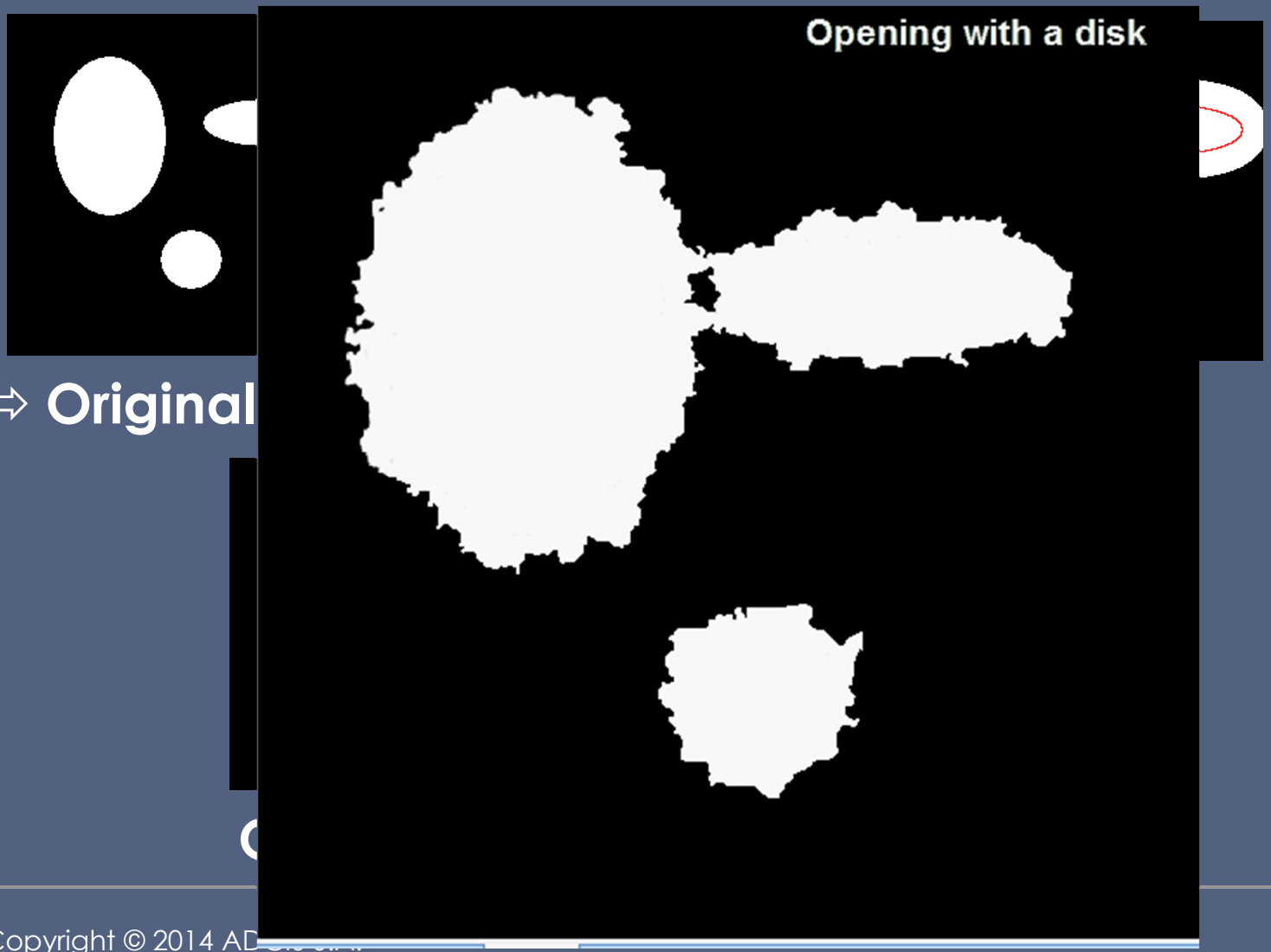
$$\{x/B_x \cap X \neq 0\} = X \oplus \breve{B} = \delta^B(X)$$

- **Erosion is derived from the Minkowski's subtraction**

$$\{x/B_x \subset X\} = X - \breve{B} = \varepsilon^B(X)$$

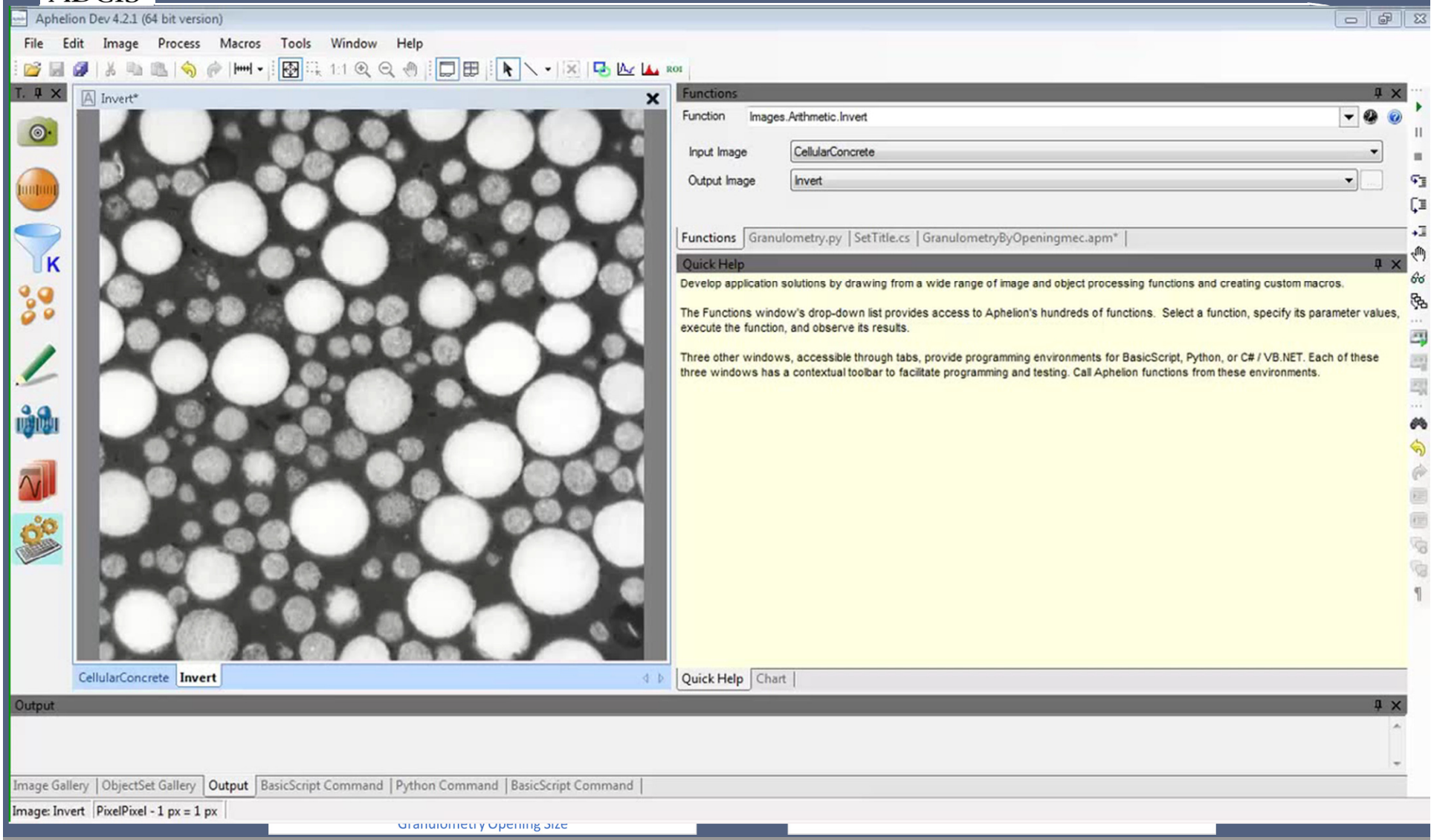
Mathematical Morphology - 2

Erode with a Disk Square

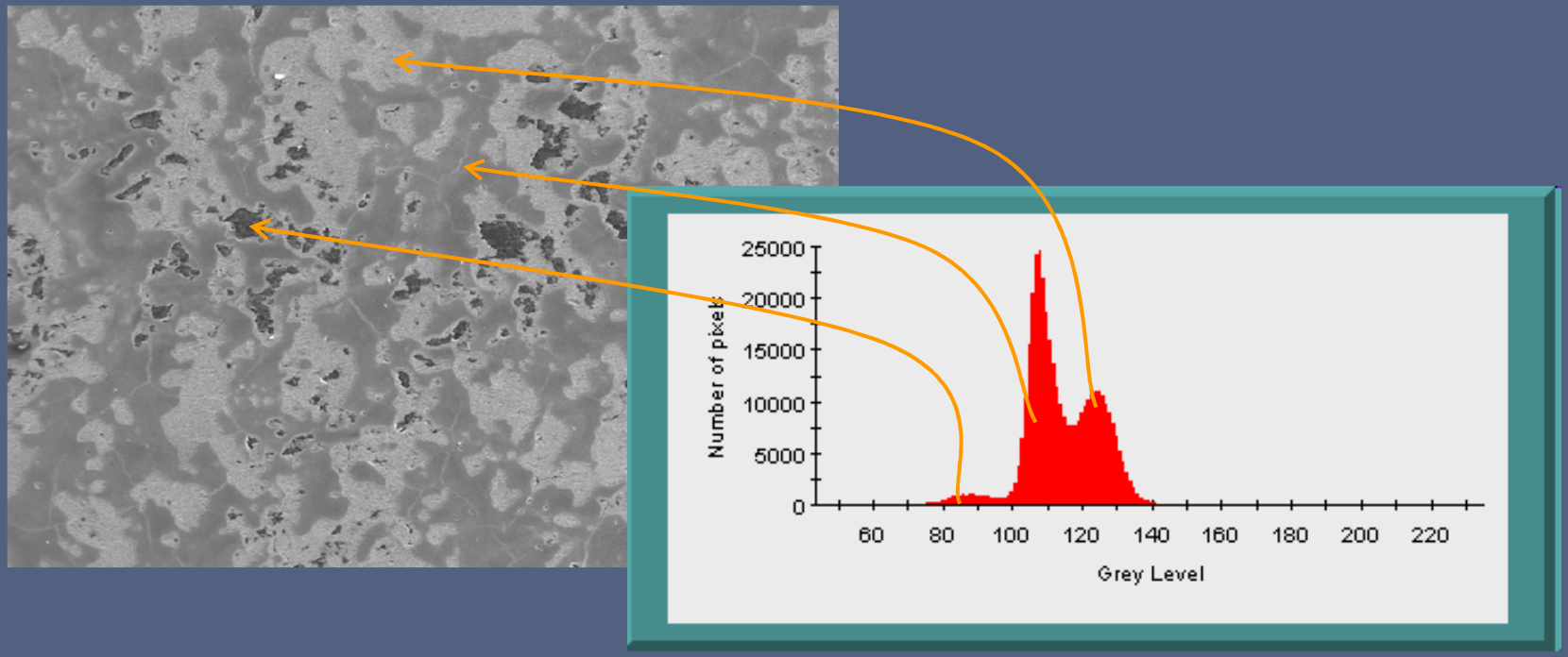


⇨ Original

Granulometry Particle Characterization



Segmentation - 1



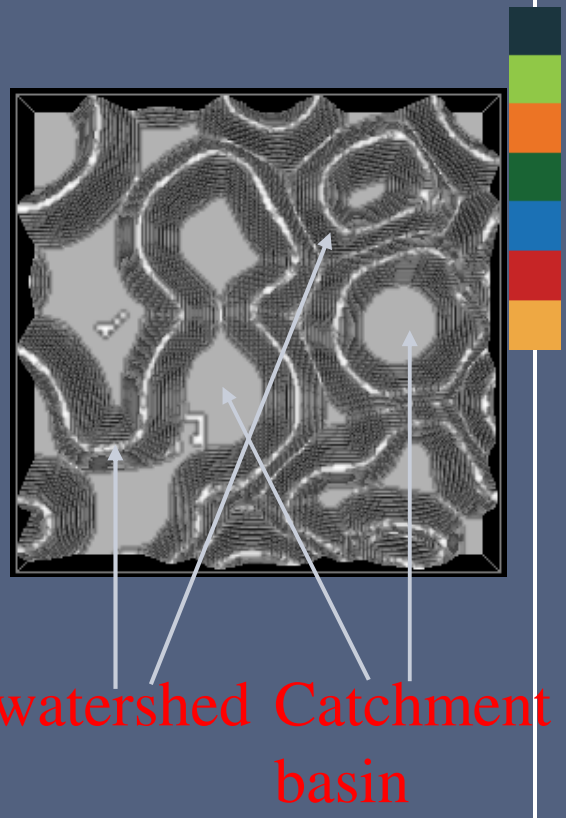
- ⇨ Segmentation based on histogram analysis
- ⇨ Output image is a binary image in which the different phases have been extracted
- ⇨ Very sensitive to noise, illumination artefacts ...

Segmentation - 2

- Smart Segmentation based on the “peaks and the valley” of the grey-scale image
- Detection watershed lines between the peaks and the valleys
- Usually, objects of interest have a given intensity versus the background of the image

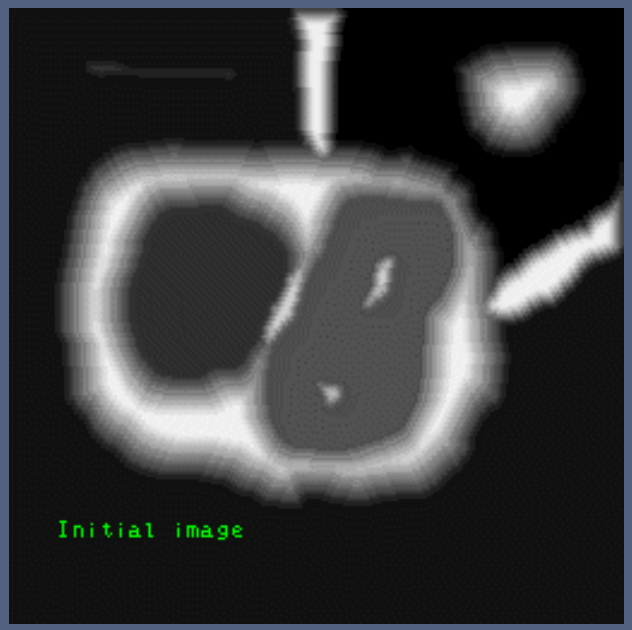
Watershed - 1

- The **watershed** is the boundary between **catchment basins**
- The **watershed** is a line on which a water droplet splits into two droplets and falls in **two catchment basins**
- In all other points, a water droplet falls in only one catchment basin

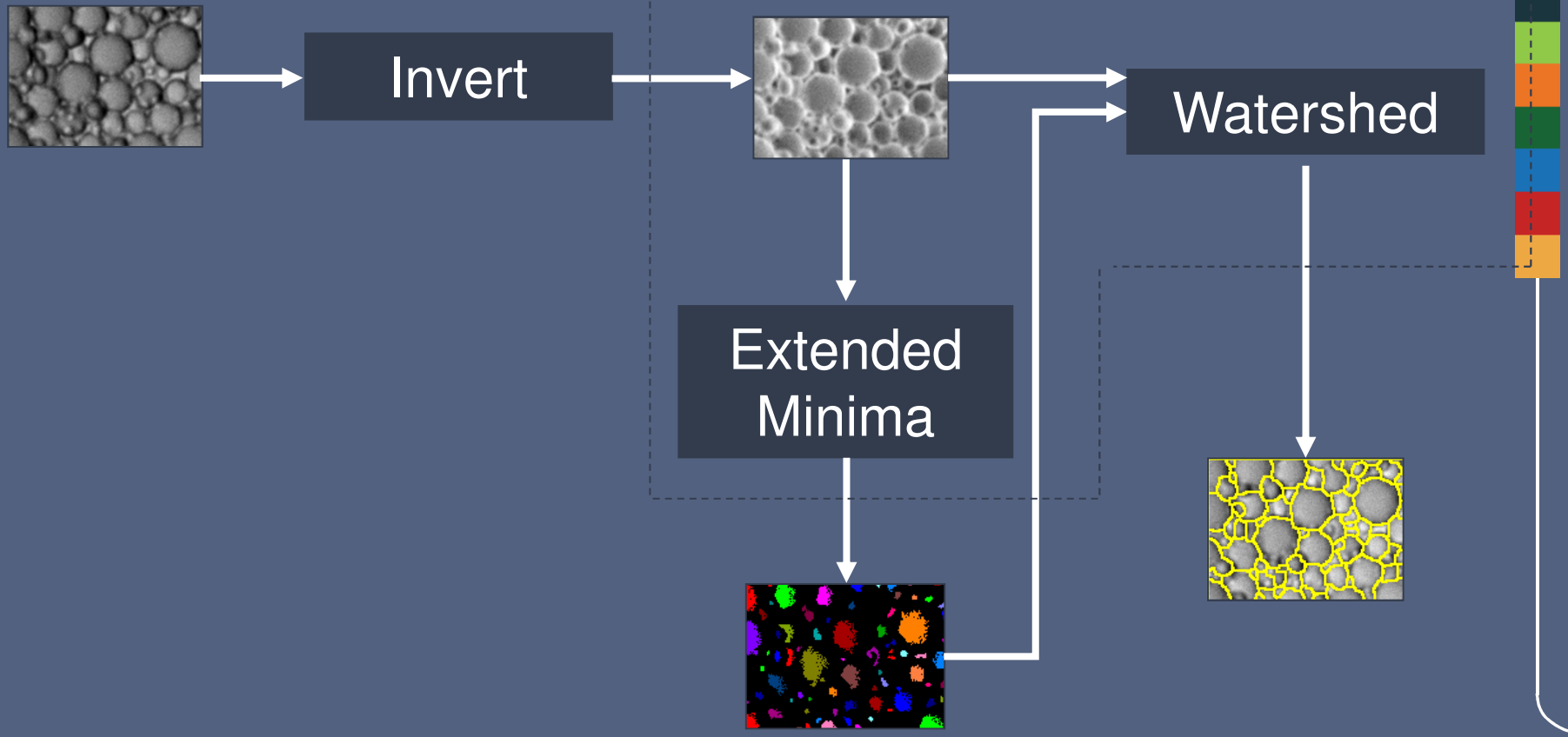


Watershed - 2

- Method to extract the watershed line and the catchment basins



Watershed - 3

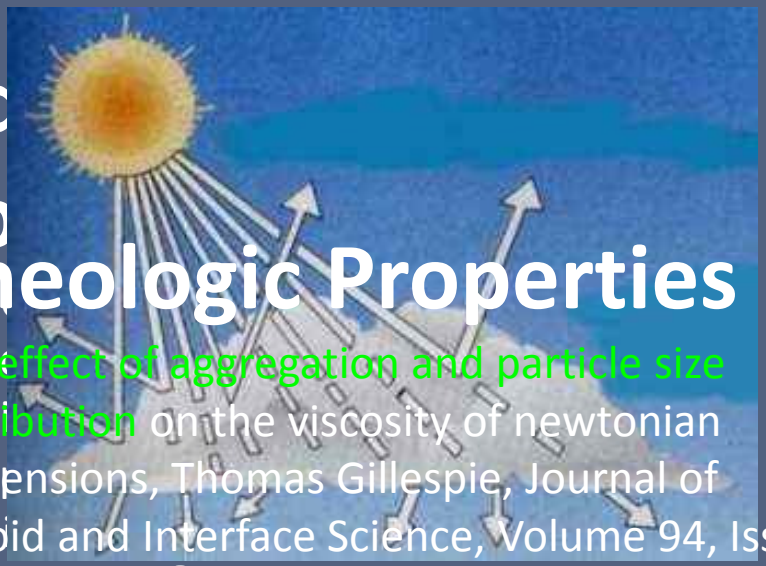


Measurements

- **Size and Shape Measurements**
  - Surface area, perimeter, convexity, orientation, minimum bounding box, etc.
- **Statistical Measurements**
  - Mean, minimum, maximum, standard deviation computed on one or RGB bands, and texture characteristics
- **Interactive Measurements**
  - Distance between two objects, angle between three points, length, width, etc.
- **Most of the measurements can be computed on 2D and 3D images**

Classification

- **Statistical analysis to help classifying objects on interest into categories**
- **Generate a classifier to perform the classification**
  - Fuzzy Logic, Neural Network, SVM, Random Forest
- **Input of the classifier can be pixel values or measurements**
- **An object database is built made of:**
  - Training database generated by an expert
  - Evaluation database to actually classify objects



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Rheologic Properties

The effect of aggregation and particle size distribution on the viscosity of newtonian suspensions, Thomas Gillespie, Journal of Colloid and Interface Science, Volume 94, Issue 2, 1983, Pages 371-380

Rheologic Properties, Volume 21, Issue 10, pp 1826-1833

Optical Properties

Effects of Very Fine Particle Size on Reflectance Spect

Christopher D. Cooper and John F. Mustard, Icarus, 142, (1999) 557-570

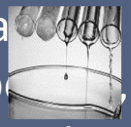
Mechanical Properties

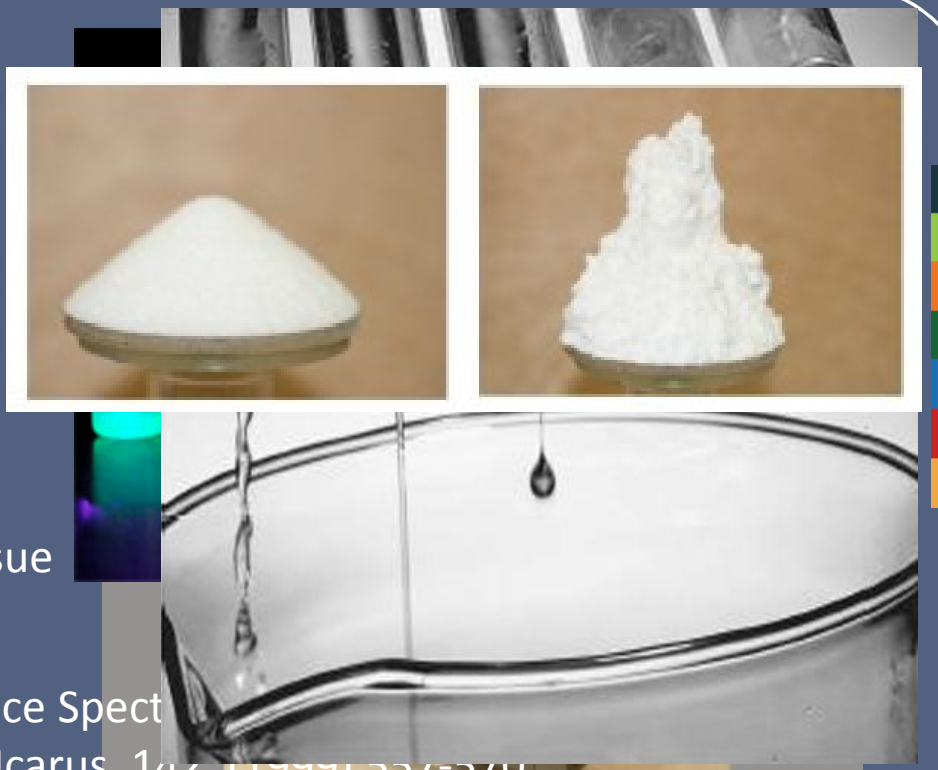
Effects of particle size, particle/matrix interface adhesion and particle loading on mecha

properties of particulate-polym

Shao-Yun Fu, Xi-Qiao Feng, Be

Ming Mai, Composites: Part B 39 (2008) 961





Rheologic Properties

Optical Properties

Mechanical Properties

Characterization of the morphological properties like size, shape, and spatial distribution is critical for understanding and controlling product properties in many industries

Medical & Toxicological Properties

Explosive Properties

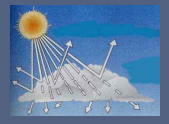
Effects of particle size fractions on reducing heart rate variability in cardiac and hypertensive patients, Chuang KJ, Chan CC, Chen NT, Su TC, Lin LY, Environmental Health Perspect. 2

Effects of HMX Particle Size on the Shock Initiation of PBXC03 Explosive, Li-Jing Wen, Zhuo-Ping Duan, Lian-Sheng Zhang, Zhen-Yu Zhang, Zhuo-Cheng Ou and Feng-Lei Huang, Int. J. Nonlinear Sci. Numer. Simul., Vol. 13 (2012), pp. 89-94

Explosive Properties

Adhesive/Cohesive Properties

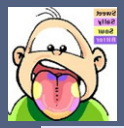
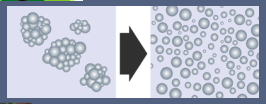
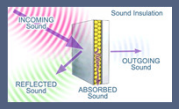
Rheologic Properties

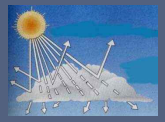


Optical Properties

Mechanical Properties

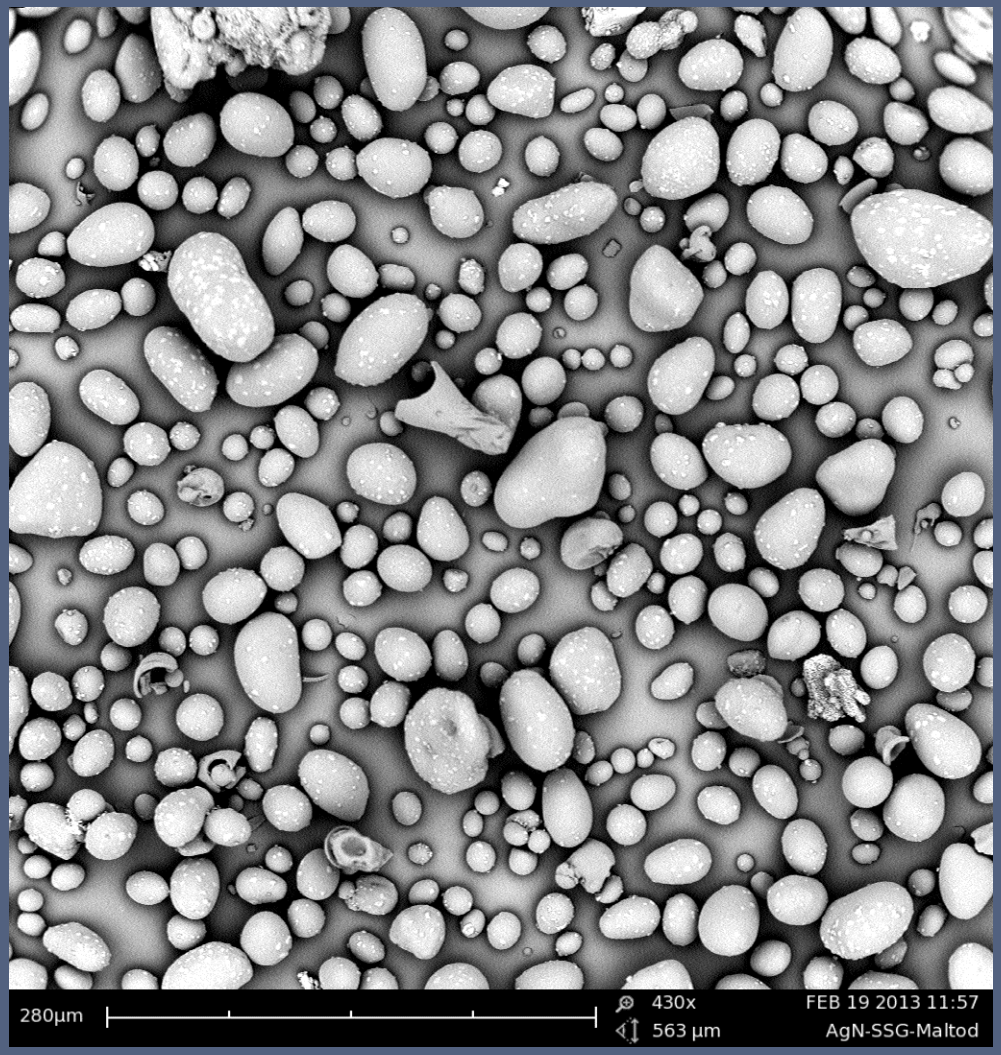
Characterization of the morphological properties like size, shape, and spatial distribution is critical for understanding and controlling product properties in many industries

- Texture Properties 
- Taste Properties 
- Dispersion Properties 
- Transport Properties 
- Acoustic Properties 

- Medical & Toxicological Properties 
- Explosive Properties 
- Adhesive/Cohesive Properties 
- Rheologic Properties 
- Optical Properties 
- Mechanical Properties 

Characterization of the morphological properties like size, shape, and spatial distribution is critical for understanding and controlling product properties in many industries

Particle Characterization – 1



- Automatic detection of particles
- Take into account border effects
- Plot the size distribution
- Compute shape measurements

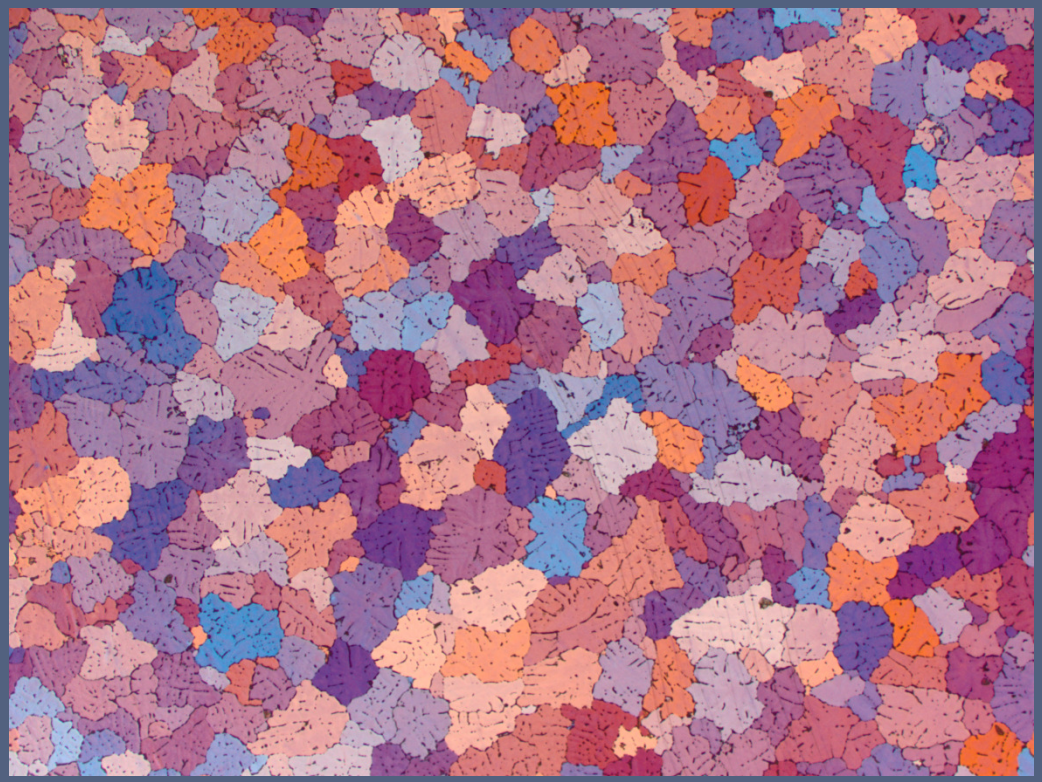
Particle Characterization – 2

- ⇨ Define a ROI (remove SEM information)
- ⇨ Histogram Equalization
- ⇨ Gaussian Filter to remove noise
- ⇨ Threshold
- ⇨ Opening to remove small particles
- ⇨ Invert the image
- ⇨ Extended regional minima extraction
- ⇨ Watershed
- ⇨ Aphelion ObjectSet generation

Particle Characterization - 3

- **Take care of border effects**
  - Many particles intersect the image frame
  - Apply a mathematical formula (Miles-Lantuejoul) to provide accurate measurements
- **Compute shape measurements to differentiate particles and background (convexity)**
  - Convex Area, convexity, surface area, convex perimeter
- **Compute intensity measurements and statistics**
  - Mean, minimum, maximum, standard deviation

Grain Sizing and Characterization -1



- Automatic detection of grains based on color
- Extract grain boundaries
- Compute average number of neighbors, average distance
- Compute shape measurements on grains

Grain Sizing and Characterization -2

- ⇨ Opening/Closing to remove thin black boundaries
- ⇨ Excess RGB transform to enhanced specific colors
- ⇨ Linear Scale to stretch pixel intensities (0-511)
- ⇨ Color Gradient based upon color distance
- ⇨ Extended Regional Minima to extract seeds
- ⇨ Morphological Partition
- ⇨ Region Fusion
- ⇨ Aphelion ObjectSet generation

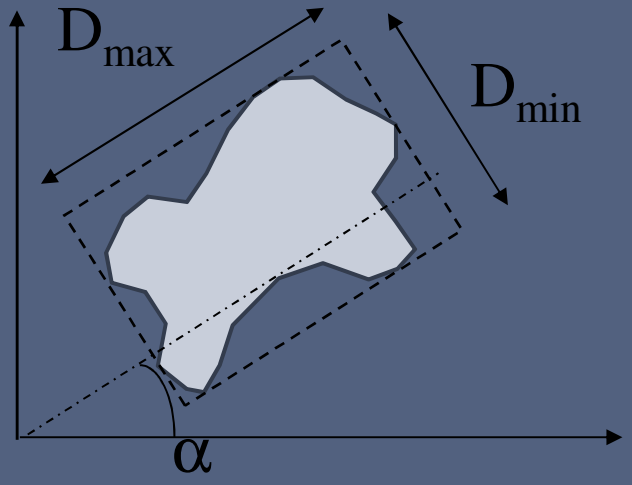
Grain Sizing and Characterization

- **Grain size distribution**
- **Distribution on grain neighbor count**
- **Rose of directions**
  - Maximum of Feret diameter (D_{max}) vs angle
- **Feret Diameter $D_f(X,\omega)$: projection on the axis in the ω orientation**

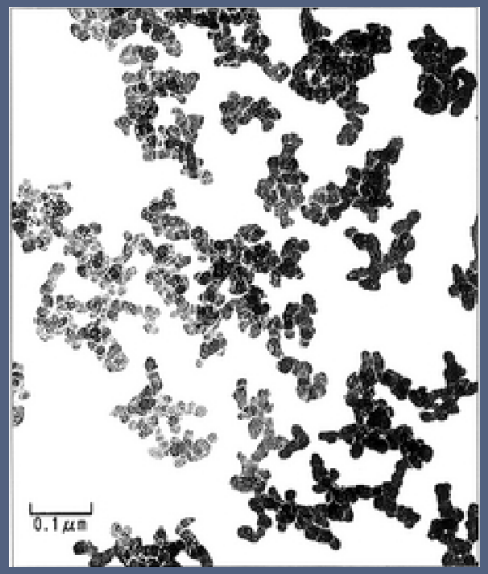
$\alpha=\omega$ such as $Min[D_f(X,\omega)xD_f(X,\omega+\pi/2)]$

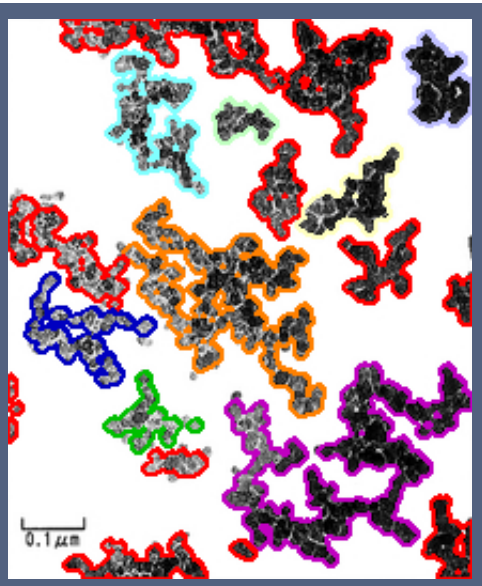
α is the object orientation

Large diameter = $D_f(X, \alpha)$



Other Material Science Applications





Images **ARE** data: they contain a huge amount of information!

Particle Size Distribution
Particle Shape Distribution
Spatial Density (#/Vol)

Cluster Size & Distribution

Cluster S.A. & Bounding S.A.
# of Particles Per Cluster

Cluster Shape & Distribution
# of NNs & distribution

Nearest Neighbor (NN) Distances (Max, Min, Ave, etc.) for Particles & Clusters

NN versus Particle or Cluster Size

Conclusion

- ***Particle characterization can be achieved with the following equipment:***
  - *Optical or electron microscope*
  - *Powerful image processing software with morphological functions*
  - *Classification software to classify and characterize particles based on shape and other measurements*
- ***ADCIS can help you to develop a successful application in the field of Material Science as follow:***
  - *Provide Aphelion software for "standard" application*
  - *Consulting and training on a specific application*
  - *Custom Engineering Work for a complex application or when there is a development time constraint*