Statistical Quantification Al-Cu Solidification Datasets Using 2-Point Spatial Correlations

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X-ray CT experimental details

- Voxel sizes of 0.75µm to 1.80µm
- 1024 x 1024 x 1024 to 2560 x 2560 x 2160 datasets
- Scan times of 45s to 150s
- Absorption contrast
- 500 to 1000 projections
- 14 TB of data
Mean Curvature

- Al-26wt%Cu
- 58vol% solid
- Directionally solidified
- 1mm diameter x 5mm tall samples
- Coarsened 5°C above the eutectic temperature
- Movie is over 6.5 hours of coarsening
Interfacial Velocity

(Velocities in microns/min)
Interface Shape Distribution
How are these curvatures distributed in space?
Data Pre-Processing for Computing 2-pt. Statistics

- Should the interface be only 1 voxel thick?

The probability distributions of curvature or velocity are not significantly affected.
Assignment of values between zero and one to the interface needs detailed attention. Such numbers will have to be interpreted as confidence indices and need to be translated to confidence indices on the computed 2-pt statistics. This enhancement to the theoretical framework is being pursued and will be reported in future presentations.
What is the right normalization? Does a trial vector whose head and tail do not fall on the interface count as a valid trial?

Although both formulations reveal similar trends, the interface reference provides higher contrast.
Data Pre-Processing for Computing 2-pt. Statistics

- Interface Location
- Interface Definition
- Statistical Reference
- Cleaning

Obtain curvature and velocity values at the boundary pixels.

Trim values for outliers.

Make sure values of curvature exist only where values of velocity exist.
Visualization of the Processed Interface
Auto-Correlation of the Interface Structure

- Statistically average structure.
- 4-Fold Symmetry of the dendrites is visible.

175 micron

70-80 micron

- 0.03
- 0.05  ~ 40 micron 4 fold
- 0.40  ~ 8 micron 4 fold
- 0.50  ~ 4 micron isotropic
Identification of Regions of Interest

Can we gain insight into how curvature and velocity values are spatially arranged on the interface?

**Binned Values** are selected for exploration

Threshold at 10% intervals for values of interest.

Obtain 2-pt Statistics between binned values of curvature and velocity.
Auto-Correlation of Near Zero Curvature

• Low values of curvature are dominantly observed aligned along a plane of particular orientation. In-plane arrangement is roughly isotropic.

• The planar arrangement of low curvatures are more likely to be separated by a distance of 70 to 80 microns.
Sanity Check

θ, φ = 30, -5
Sanity Check
A Cross-Correlation of Curvature and Velocity

- Curvature
- Velocity

High - 0.020
High - 0.025 ~25 micron
High - 0.030 ~20 micron
High - 0.045 ~10 micron

Curvature 1
High - 0
High + 1
Velocity 1
High - 0
High + 1
Spatial Arrangement of Curvature w.r.t. Curvature

- 9 possible spatial correlations.
- Only the plane of maximum anisotropy is shown from each full 3D correlation.
Spatial Arrangement of Velocity w.r.t. Velocity

- 9 possible spatial correlations.
- Only the plane of maximum anisotropy is shown from each full 3D correlation.
Spatial Arrangement of Velocity w.r.t. Curvature

- 9 possible spatial correlations.
- Only the plane of maximum anisotropy is shown from each full 3D correlation.
Future Outlook

• Continued development of automated protocols for analyses of large microstructure datasets that are fully guided by the interests of domain experts

• Extend the protocols to the new Al-Si-Cu system with multiphase polycrystalline microstructures

• Explore opportunities for in-line analytics for supporting “live” decisions in the experimental protocols

• Indentation measurements of local mechanical properties (can be in volumes as small as 50 nms) at specific locations of interest identified by team members