Autocorrelation and the rose diagram for analyzing structure and anisotropy in polymer foams

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Mérignac -- June 1st, 2012
The project

Action de Recherche Concertée (ARC)

From imaging to geometrical modelling of complex micro-structured materials: Bridging computational engineering and material science

Application: ElectroMagnetic Interference (EMI) shielding
Microstructure characterisation

- Transmission Electron Microscopy (TEM)
- Scanning Electron Microscopy (SEM)
- X-ray Microtomography
X-Ray microtomography

- Two main things to think about:
  - Contrast
  - Resolution
Microtomograms

0.5 mm
Acquisition parameters

- Parameters
  - 25 kV – 250 mA
  - Exposure time per projection : 4.1 s
  - 3600 projections

- Projection histogram
Options

- Just use SEM
- Make better tomograms
- Make do
  - Make better samples
**Autocorrelation**

\[ R(\tau) = \frac{E[(X_t - \mu)(X_{t+\tau} - \mu)]}{\sigma^2} \]

- Statistical approach
- Global measurement
- Greyscale tomogram considered a 3D signal
- Identification of « pattern frequencies » in noisy signals
- Efficient global anisotropy measurement

Characteristic length

- Average autocorrelation = f(translation distance)
- Examples
Characteristic length

- Exemples
Characteristic length in polymer foams
Characteristic length in polymer foams

Average autocorrelation vs. Distance (µm)

-0.2
-0.4
-0.6
-0.8
-1
0
0.2
0.4
0.6
0.8
1

Distance (µm)

0
20
40
60
80
100

23 µm

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The rose diagram

\[ R(\tau_x, \tau_y, \tau_z) \]

- View autocorrelation in all directions
  - Meshed sphere
  - Map autocorrelation at each vertex

\[ r = \sqrt{\tau_x^2 + \tau_y^2 + \tau_z^2} \]
At what distance?
Better view of anisotropy

- Integration over a certain distance

\[
R_m(v_i) = R_m(c, v_i) = \frac{\sum R(p) * |p \cap [c, v_i]|}{|[c, v_i]|}
\]
Results

Correlation -0.1

Autocorrelation in all directions

Overlay with original image

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Anisotropic foams

1 mm
Anisotropic foams
Anisotropic foams
Conclusions & perspectives

- Autocorrelation
  - Efficient for low resolution or noisy data
  - No segmentation necessary
  - Subvoxel accuracy of characteristic length

- Rose diagram
  - Provides global preferential orientation of features
  - Insensitive to random noise (*very sensitive to directional noise!*)

- Directional characteristic lengths
  - Decompose average autocorrelation plots into directional cones

Acknowledgments

- The Belgian French-speaking Community for a post-doctorate
- The Fonds National de Recherche Scientifique for tomographic equipment
- Nicolas Combaret (VSG) for the integration of the autocorrelation module