

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

Erwan Plougonven^{1*}, Pierre Marchot¹, Christophe Detrembleur², Tran Minh Phuong², Angélique Léonard¹

¹Lab of Chemical Engineering, Department of Applied Chemistry

²Center for Education and Research on Macromolecules

University of Liège, Belgium

*eplougonven@ulg.ac.be

Abstract

We present in this paper a method, implemented in Avizo, for evaluating the shape and visualizing preferential orientations of objects in a structure that are not easily separable. The work concerns the use of X-ray microtomography for studying cell size and shape in polymer foams. These foams contain a few percent of carbon nanotubes, and are tailored for electromagnetic shielding applications. The nanotubes are not visible in the polymer at the observation scale of an X-ray microtomograph, but the cell structure is, and it also plays an important role in the effective properties of this material.

X-ray microtomography is a 3D non-destructive method for reconstructing a 3D X-ray attenuation map of the material. The greyscale 3D image can be used to visualize the internal geometry of the material, provided X-ray attenuation is not homogeneous (at the scale of observation). Unfortunately, there are many limitations that hinder our ability to acquire the structure with good quality and precision. The polymer is light, therefore hardly absorbs X-rays, resulting in low contrast in the tomograms. Cell size is small compared to the resolution capacity of the tomograph used, and cell wall thickness is extremely thin in some cases, making them very hard to discern in the images. Figure 1 shows the type of image that is reconstructed, side by side with a Scanning Electron Microscopy image of the same sample at the same scale, which shows the difficulty in the analysis of the tomograms. Subsequently, direct identification and delimitation of the cells was not the first choice. We have used a global measurement method, the 3D autocorrelation function, to determine statistical information, such as average cell size and anisotropy, without the need to binarise or separate the cells. By examining the behavior of the autocorrelation function as a function of correlation distance, we obtain a good indication of the characteristic length present in the images, which can be linked to cell size. Furthermore, as autocorrelation is computed in all directions, variations as a function of direction is used to characterize the anisotropy in the structure, if there is any. By creating and displaying a 2D mesh, deformed and coloured according to directional information in the autocorrelation function, a mesh we call a rose diagram, preferential orientation(s) can effectively be detected in the images. Figure 2 illustrates this process on an anisotropic foam sample.

Keywords: Polymer foam ; X-ray microtomography ; Autocorrelation ; Rose diagram

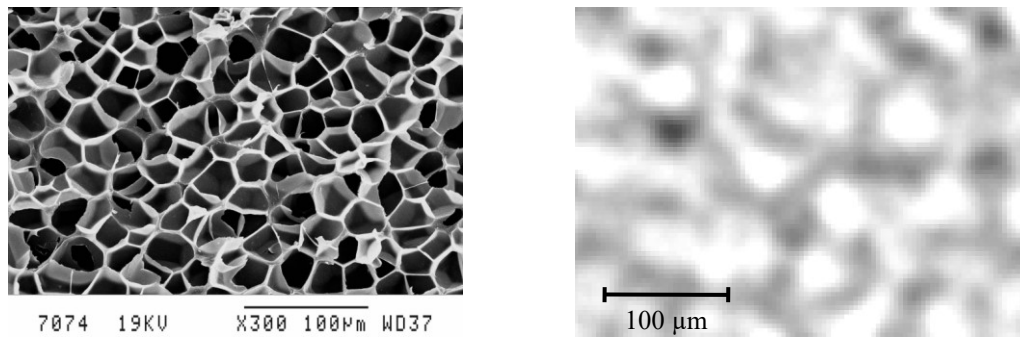


Figure 1. Microstructure of one type of cellular foam studied, observed by Scanning Electron Microscopy on the left, and X-ray microtomography on the right, at the same length scales.

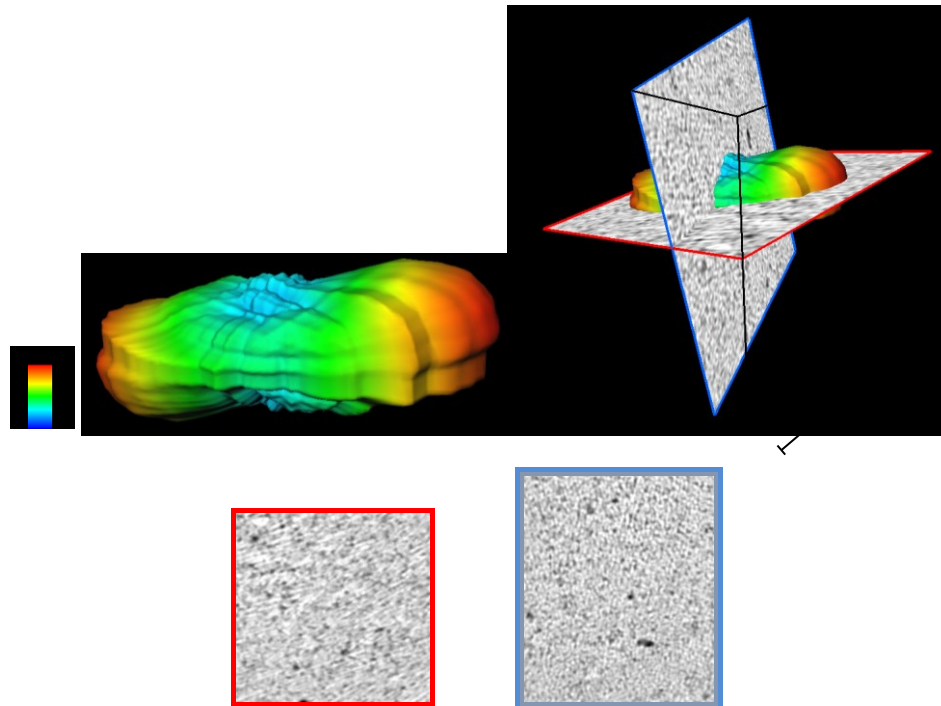


Figure 2. Top left: A rose diagram computed from the autocorrelation function, indicating the preferential orientation of the features in the image. Top right: the rose is superimposed with the original tomogram, from which 1mm^3 was cropped. Bottom: two cross-sections are taken in this volume in the direction indicated by the rose, and are displayed below.