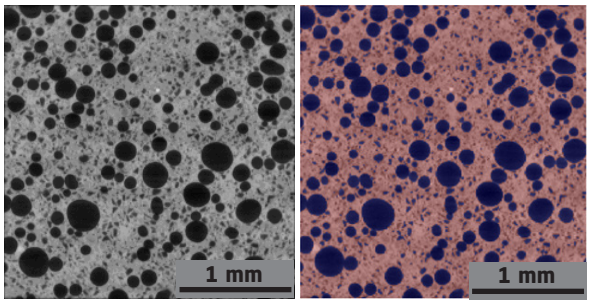
VELUX LINX
Innovation Fund Denmark

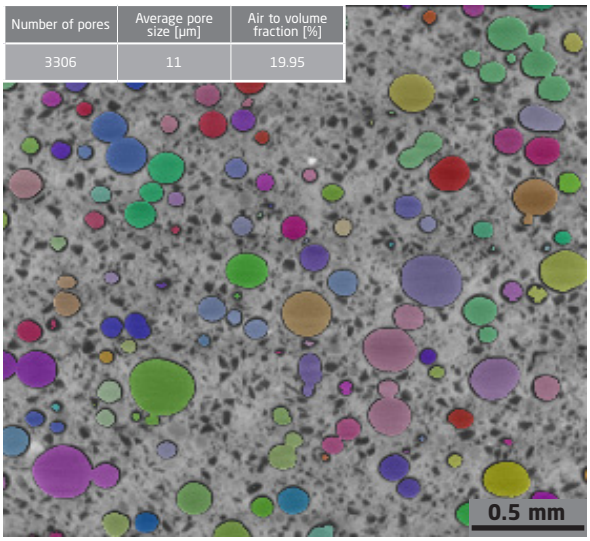
Artificial intelligence used in characterisation of porosity

VELUX entered a collaboration with the 3D Imaging Centre through LINX, a project funded by the Innovation Foundation in Denmark. The goal of the project was to study the air content - also called porosity - of a polymer material used as a spacer inbetween glass sheets in windows. In order to study the spatial distribution and size of the pores, which is in the micrometer range, X-ray micro Computed Tomography (CT) is used to study the samples non-destructively in 3D. To characterise samples produced via different means, a range of them was imaged. Afterwards, artificial intelligence was used to determine the location and size of the pores in all the 3D measured samples. This study of pore distribution and pore size quantification can be used in quality control, testing new material designs and processes for their manufacturing.



2D image showing the two types of polymer and the pores of one of the samples. a) Raw image: the polymers are shown in light and dark grey (small and irregular shaped) and pores (rounder) in black. b) Thresholded image: the light polymer is shown in red, the dark polymer and the pores in blue, illustrating the challenge of separating the pores from the dark polymer.

Number of pores	Average pore size [µm]	Air to volume fraction [%]
3306	11	19.95



Result from detecting the pores by artificial intelligence. A random colour is assigned to each set of connected pores, so that it is possible to understand which pores are connected to each other in the third dimension, not visible in this 2D image. Note that the dark polymer is not regarded in the porosity analysis when using the U-net.

Challenge

The polymer samples under study are composed of two types of polymer and air. Even though the three components can be easily distinguished in the images by the human eye, a simple automatic image analysis method that relies on the image intensities would not be able to differentiate between the lower density polymer and the air pores of similar image intensity. Therefore, to study just the air we had to use a machine learning method based on neural networks.

Collaboration

Through the collaboration between VELUX and the 3D Imaging Centre at DTU, a range of samples was imaged in house with X-ray CT and analysed subsequently at the Imaging Center. This collaboration was part of the LINX project in which researchers at leading Danish universities collaborate with scientists in industry to solve industry relevant problems using advanced neutron and X-ray techniques.

Results

To help VELUX with the characterisation of their samples, we built an analysis pipeline to determine the size and location of pores using artificial intelligence. We employed a well-known deep neural network architecture (called the *U-net*) for the task of differentiating between air and polymers. The *U-net* was trained to learn the appearance of the pores in the samples, using a subset of 2D images where we marked the pixels corresponding to air manually. The neural network was then used to find all the air pixels in each 3D volume. Afterwards, an air pore, defined as a region of connected air pixels, was characterised through its position and size. From these measures, we produced pore size distributions for each sample and computed the percentage of air within each sample.

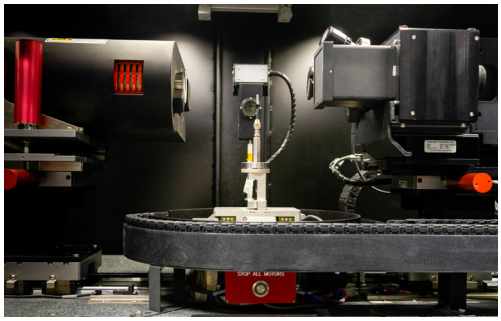
Perspectives

In the future, this method could also be used locally, that means on sub-regions of the whole sample, to study the distribution of air pores and thereby reveal spatial variations in air content. In fact, the method could work for other materials than polymer and air as well, as long as the X-ray signal differs.

Imaging Industry Portal

The Imaging Industry Portal is a part of the 3D Imaging Centre at DTU and assists companies in using and implementing 3D Imaging in research, development and production. The portal offers research-based 3D Imaging services and provides companies with the latest equipment and the most advanced knowledge within 3D Imaging and data analysis. The Imaging Industry Portal works as a gateway to ESS and MAX IV, as well as other large scale facilities.

www.imaging.dtu.dk/Industry-Portal



DTU 3D Imaging Centre