ESRF	**Experiment title:** In-situ imaging of an open-cell flexible polyurethane foam during macroscopic deformation via X-ray tomography.	**Experiment number**: ME-104
Beamline: ID19	**Date of experiment**: from: 03/05/2001 to: 06/05/2001	**Date of report**: 02/01/2002
Shifts: 9	**Local contact(s)**: E. BOLLER	*Received at ESRF:*

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Report:

The purpose of this experiment was to use x-ray tomographic imaging to examine the precise mechanisms by which a flexible foam material deforms under a compressive load. The experiment was a continuation of a previous experiment (SC-564) with the additional aims of having an *in-situ* measurement of stress on the foam during the compression and also a greater number of compression steps being imaged to determine in more exact detail the mechanisms of foam collapse. Results from the previous experiment have been accepted for publication in the Journal of Materials Science.

This experiment was successful. Two separate compression cycles were performed with different compression rates. The original height of the sample was 25.0 mm and it was compressed in 30 steps of 0.5 mm each. This corresponded to 2% compression steps and a total imposed strain of 60%. In the fast compression test the rate was 3 seconds per step and at each state of compression a single radiograph image was taken. In the slow compression test the rate was approximately 40 minutes per step and at each step sufficient radiographs were taken to form a complete 3D tomograph of the sample. For each compression level, 800 projection images were recorded. The X-ray beam energy was 8.8 keV and the sample to detector distance was 65 mm. The resolution recorded at the detector was 6.65 µm.

The cylindrical foam sample was 25 mm in diameter and was compressed inside a highly polished perspex tube by a plunger diven by a stepper motor. The control of the stepper motor was integrated with the crate electronics of the beamline. In addition a stress transducer was located at the surface of the foam opposing the plunger enabling *in-situ* measurement of the load on the sample.

The 3D voxel data was reconstructed using the computing facilities and codes available on the ID19 beamline and all 61 datasets were reconstructed within 5 days.

Since completion of the experiments further data analysis has been performed on the volume data. Codes developed by Sébastien Bouchet of the ESRF were used to convert the volume data to skeletons of nodes and struts. These data were then converted to a format that could be read into the Cerius molecular modelling package in order to visualise the nodes and struts. The advantage of using this software for visualisation was that the trajectories taken by individual nodes during the compression process could be tracked in a semi-automated fashion. 85 nodes were tracked from 0 to 40% compression and from 40% to 0 decompression (skeletonisation failed at higher compressions due to strut/strut contacts). The node trajectory data was converted to a set of vectors representing the change in the position from one step to the next. The vectors were further treated by subtraction of the affine (overall) deformation and the resulting strain fields were visualised in the AVS software.

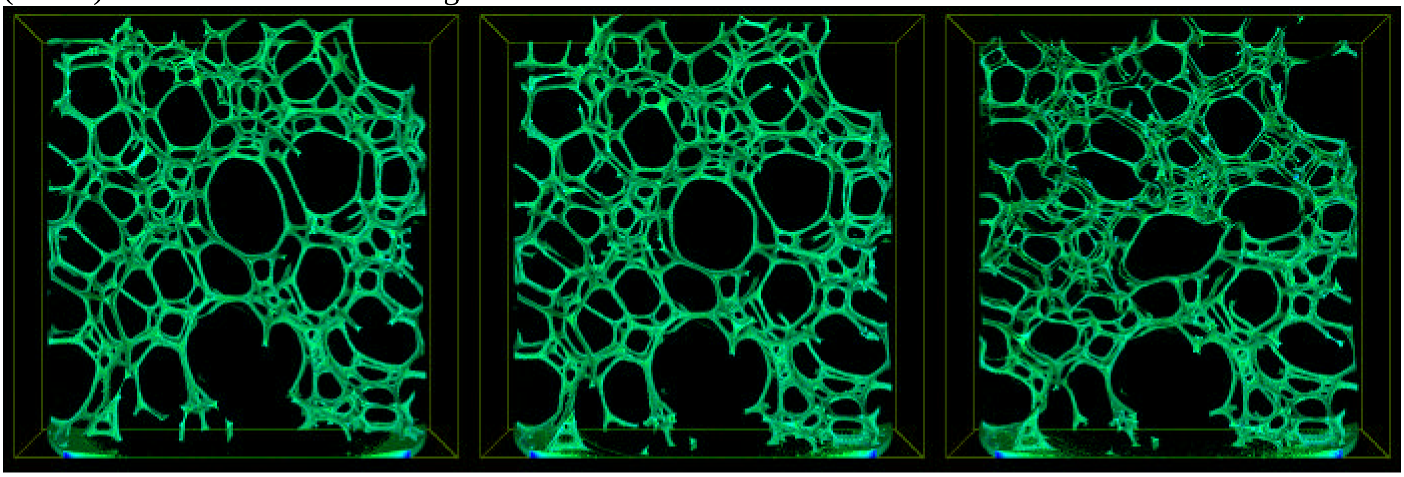

Figure 1: Reconstructed images at 0%, 6% and 12% compression. It is visually clear that a collapse has occurred prior to the 12% strain image.

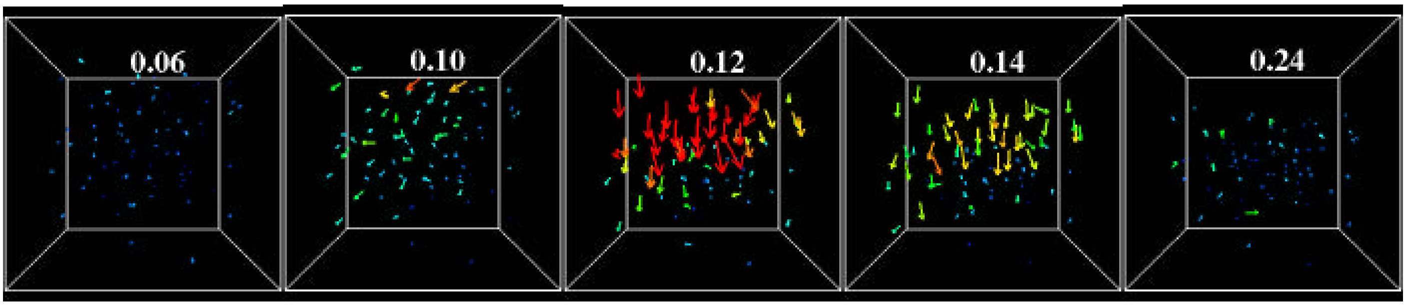

Figure 2: Deviation of local strain from affine deformation. At low strains the deformation is affine (evenly distributed across the sample). At 12% macroscopic strain a massive, cooperative departure from affine deformation occur as shown by the red arrows. In the imaged region the deformation has returned to affine by 24% strain although areas outside the imaged region may be undergoing collapse.

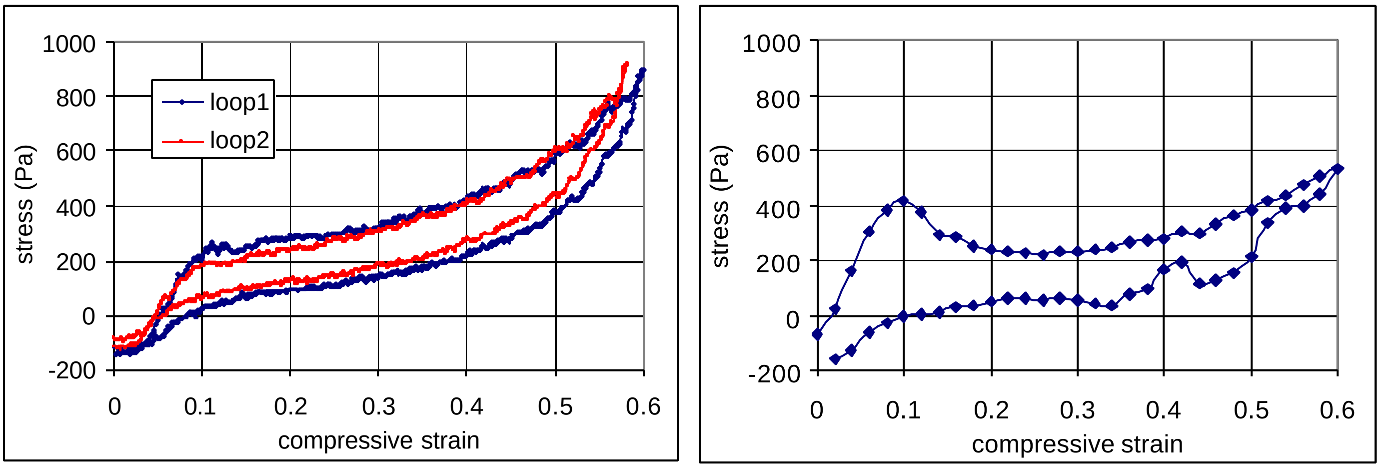

Figure 3: Load/deflection curve measured using in-situ stress transducer during fast compression experiment and slow compression experiment. Note that in the slow compression significant relaxation occurs. In both experiments a significant plateau or even drop in stress occurs after 10% strain and the mechanism of this collapse is observed in images and data analysis above.

These experiments have allowed the mechanism of foam deformation to be examined in unprecedented detail. The plateau in the stress-strain curve at ~10% strain is clearly identified as occuring at the same strain level as a cooperative collapse across a lateral band in the foam.