

POLYETHERIMIDE NANOFOAMS USING CARBON DIOXIDE

G.W. Hofland*, Ch. Kersch, G.F. Woerlee

FeyeCon Development & Implementation,
Rijnkade 17A 1382GS Weesp, The Netherlands
Email: gerard@feyecon.com Fax: +31 294 45 88 66

Nanofoams may be interesting media for transparent insulation of glazing insulation. Nanofoams of polyetherimide were produced by using carbon dioxide as a blowing agent. Bicontinuous nanoporous foams were formed when the process variables were well chosen. The effect of using saturation pressures higher than 60 bar had limited effect of the density reduction.

INTRODUCTION

Foams with nano-sized pores have been subject of investigation for several applications. Krause and Wessling et al. produced foams to be used in membrane separations [1,2]. Hedrick et al. [3] aimed at making foams with low dielectric properties. A more common application of polymeric foams is as an insulating material [4]. It is however not common when the foam must be transparent.

A large part of the energy required for heating of houses, utility buildings and green houses is lost via the windows. Increase of the thermal isolation could be performed by using transparent nanofoam materials. These nanofoams must suffice stringent demands to the light transmission (high) and thermal conductivity (low). A small pore size assists in the first of these goals. To achieve the second simultaneously using foaming with carbon dioxide as a blowing agent, the density of the foam must be significantly lower than reported up to now. Krause [1] worked at a maximum pressure of 60 bar. For this paper, foaming was performed both at pressures of 60 and 160 bar to show the effect of higher pressure.

MATERIALS AND METHODS

Materials

Polyetherimide plate and fibre materials were received from General Electric Plastics, The Netherlands. Organic solvents were purchased from Sigma-Aldrich (analytical grade). Carbon dioxide was purchased from Hoek Loos and had a purity of > 99.5%.

Foaming process

The foaming was performed via a pressure cell technique (Krause, 2001). Pieces of the plate and fibre material (thickness 1 and 0.35 mm) were placed in a pressure vessel connected to a pump providing the carbon dioxide. The material was saturated with carbon dioxide at pressures of 60 and 160 bar at room temperature. Fibre material was

equilibrated during a least 6 hours. Plate material was equilibrated overnight. The pressure was quickly released from the pressure vessel (< 4 sec). After removing the gas-saturated polymer from the pressure vessel, the sample was immersed in a glycerol bath maintained at the desired temperature for period of 30 s (foaming time). The samples were next quenched in a 1-1 (vol.) ethanol-water mixture and washed in ethanol during at least one hour.

Polymer foam characterisation

Expansion of the polymers was measured by comparing the thickness before and after the foaming. The morphologies of the foamed samples were investigated using a Joel scanning electron microscope (SEM). The samples sputter coated with gold before analysis.

RESULTS AND DISCUSSION

First a series was done using PEI fibre. The results of the foaming of PEI confirmed earlier experiments of Krause [1]. PEI foaming occurred at temperatures between 125°C and 205°C. The expansion of the PEI was determined and the density calculated from the expansion ratio is shown in Figure 1.

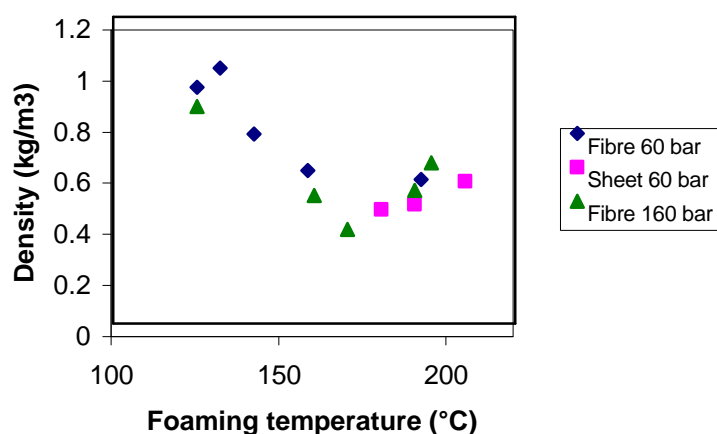


Figure 1 Density calculated from the measured expansion of the polymer at different foaming temperatures.

The values that were found in this study differ little from those found by Krause [1] which may be due to the use of an other measurement technique. Despite the limited number of experiments it can be concluded that the effect of the pressure on the density is small.

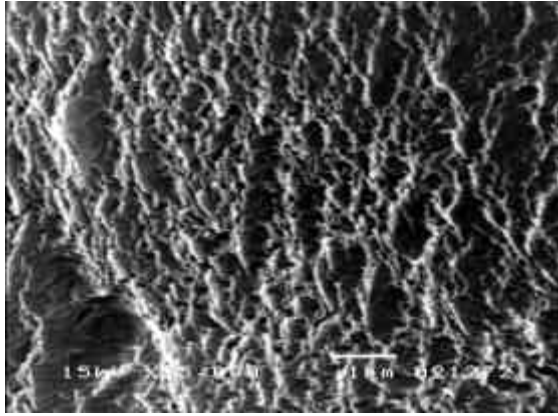


Figure 2. SEM micrograph of nanoporous polyetherimide, foamed at 185°C after saturation during 24 hours at 60 bar.

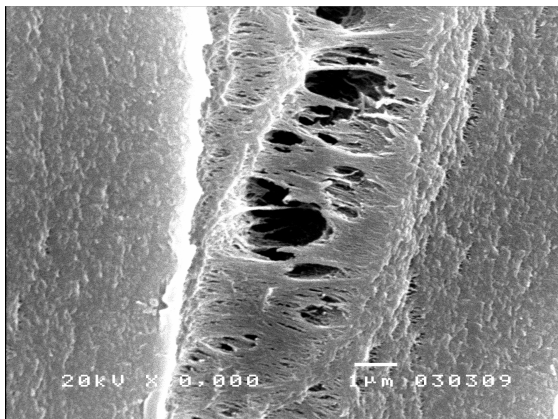


Figure 3. SEM micrograph of nanoporous polyetherimide fibre, foamed at 192°C after saturation during 6.5 hours at 60 bar.

The pore size of the foams decreased when the foaming temperature was higher. A bicontinuous morphology was to be seen on the SEM photo's (Figure 2), when the saturation time was long enough, both at pressures of 60 bar and 160 bar. However, cracks occurred, which can be the cause for the material to be non-transparent.

CONCLUSIONS

Polyetherimide was foamed using carbon dioxide as a blowing agent. The effect of saturation pressure and foaming temperature was determined. Bicontinuous nanofoams were produced with pore size in the desired range. Increasing the pressure resulted in a slight decrease of the foam density. Transparency can still be improved.

ACKNOWLEDGEMENT:

The authors want to thank the EET program of Senter and Novem for their support.

REFERENCES :

[1] KRAUSE, B., Polymer nanofoams Thesis University of Twente **2001**.

[2] WESSLING, M., BORNEMAN, Z., BOOMGAARD, A VAN DEN, SMOLDERS C.A.J. Applied Polymer Science, **1994**, 1497-1512.

[3] KUMAR, V., Cellular Polymers, **1993**, 12, 207-223.

[4] HEDRICK, J.L., CARTER, K.R., CHA, H.J., HAKER, C.J., DI PIETRO, R.A., LABADIE, J.W., MILLER, R.D., RUSSELL, T.P., SANCHEZ, M.I., VOLKSEN, W., YOON, D.Y., MECERREYES, D., JEROME, R., MCGRATH, J.L., Reactive & functional polymers, **1996**, 43-53.