MESOPHASE AR PITCH DERIVED CARBON FOAM: EFFECT OF TEMPERATURE, PRESSURE AND PRESSURE RELEASE TIME

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Introduction

One of the fields of recent developments of advanced materials technology has been driven by the requirements for improved strength, low-weight and low-cost in structural engineering materials.

Research related to carbon foams started in 1960's [1]. Mesophase pitch-based carbon foams are proving to be popular in the field of carbon materials, due to their high pore structure, high thermal conductivity and low density.

Carbon foam is widely used in many industrial areas such as; in aerospace and defense industries, optical benches and lightweight mirrors, thermal protection systems, heat transfer systems, lightweight antennas, stealthy materials and lightweight armor. Moreover, commercial carbon foam is used in composite tooling, abrasive tools, battery and fuel cell electrodes, brake disks, engine components, catalytic converters, heat exchangers, energy absorbing crash barriers, structural insulated panels, high temperature insulation, fire doors and blocks, bone surgery material and tooth implants [2].

In this study, effect of temperature, pressure and pressure release time on the properties of mesophase pitch based carbon foams are investigated.

Experimental

In the experiments, Mitsubishi AR naphthalene-based mesophase pitch with a softening point of 283ºC was used to produce carbon foam.

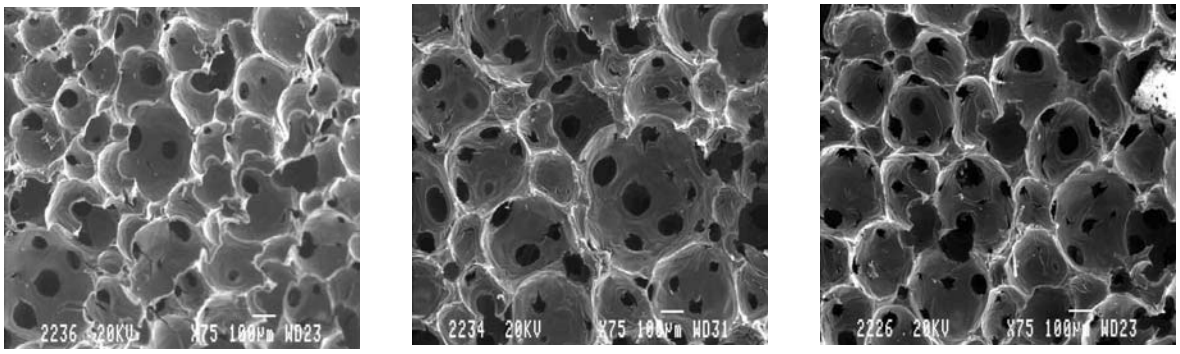
For the foam production mesophase pitch pellets are introduced into a cylindrical aluminum mold. The samples were heat treated, pressurized to various temperature and pressure levels and finally pressure was released in order to obtain green carbon foam samples. The green foams were removed, stabilized by heating up to 310ºC and carbonized by heating to 1050ºC under nitrogen atmosphere. Process temperatures of 280, 293 and 300ºC, and pressures of 38, 58 and 78 bars, and pressure release times of 5, 80 and 190 sec. were selected as process parameters and the effects of those parameters on carbonized carbon foam were investigated.

The samples were characterized by scanning electron microscopy (JEOL JSM-840). Compressive testing was conducted by an Instron Model 1195 Tension/Compression tester. Densities of all samples were also determined.

Results and Discussion

Effects of Temperature

The scanning electron microscopy photographs of the carbon foams produced at three different temperatures are given in Figure 1.



280°C 293°C 300°C

Figure 1 SEM photographs of carbon foam samples produced at various temperatures.

As can be seen from SEM photographs of carbon foams, process temperature affected the cell structure and porosity of the samples. In the range used in these experiments as the temperature is increased cell formation became more regular and uniform.

Densities and compressive strengths of carbon foams obtained at three different temperatures are compiled in Table 1.

Table 1 Densities and compressive strengths of carbon foam samples produced at different temperatures.

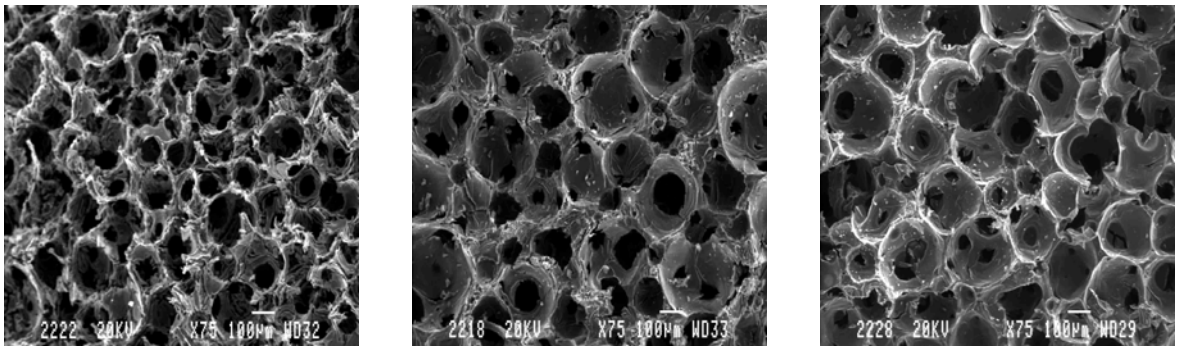
Temperature (°C)	Density (g/cm^3)	Compressive Strength (MPa)
280	0.38	1.5
293	0.41	2.1
300	0.56	3.3

The densities of carbon foam increase with increasing temperature. Bubble growth is an effective mechanism affecting foam formation together with viscosity [3, 4, 5]. As the temperature is increased more volatiles are evolved and kept under pressure. When the pressure is released volatiles are released to finalize geometry and interconnection between cells. At the same time, the remaining foam shrinks due to relief of stress after the loss of volatiles resulting in to more compact structure at higher temperatures.

The compressive strengths of the three samples increased with increasing temperature which is in parallel behavior with the density increase with increasing temperatures.

Effects of Pressure

The scanning electron microscopy photographs of the carbon foams produced at three different pressures are given in Figure 2.



38 bar 58 bar 78 bar

Figure 2 SEM photographs of carbon foam samples produced at various pressures.

As it can be observed from the SEM photographs of carbon foams obtained at three different pressures that, a more open-celled interconnected porous structure will be reached at high operating pressures.

Densities and compressive strengths of carbon foams obtained at three different pressures are compiled in Table 2. It is observed the densities of the carbon foam increased with increase in operating pressure.

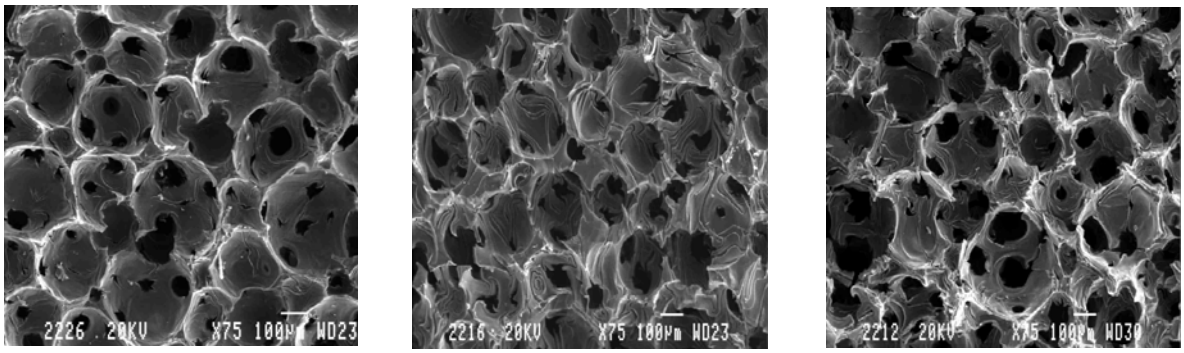
Table 2 Densities and compressive strengths of carbon foam samples produced at different pressures.

Pressure (bar)	Density (g/cm^3)	Compressive Strength (MPa)
38	0.50	1.9
58	0.54	2.5
78	0.58	3.5

The foams became denser which partly caused as a result of compaction due to developed foam structure. These are the main reasons behind the enhancement of the mechanical properties for the increasing operating pressure. Low-pressurized carbon foams, having an undeveloped texture with cracks, have relatively low compressive strengths. Since the high content of cracks in the foam structure will adversely affect mechanical properties [6].

Effects of Pressure Release Time

The scanning electron microscopy photographs three different pressure release time are given in Figure 3.



5 sec. 80 sec. 190 sec.

Figure 3 SEM photographs of carbon foam samples produced at various pressure release times.

The changes in pressure release time basically affect the formation of porous structure. All carbon foam samples exhibit, changing degree of interconnected, open-celled and spherical porous morphology. Typical porous structure of carbon foam can be significantly observed for the carbon foam obtained for pressure release time of 5 sec. On the other hand, with increasing pressure release time deviations from spherical structure and an increasing number of cracks in the foam structure are observed.

Densities and compressive strengths of carbon foams obtained at three different pressure release times are compiled in Table 3.

Table 3 Densities and compressive strengths of carbon foam samples produced at different pressure release time.

Pressure Release Time (sec.)	Density (g/cm^3)	Compressive Strength (MPa)
5	0.56	3.3
80	0.51	2.9
190	0.37	2.6

With increased pressure release times the structure became undeveloped so that carbon foams became weak in strength as well when compared to more rapidly depressurized foam samples. This further realized with the increased number of cracks in the foam structure.

Conclusions

Increase in process temperatures resulted in more homogeneous, interconnected, better structured, higher density, higher compressive strength carbon foams.
Operating pressure and pressure release time affect foam properties such as pore structure, density and compressive strength of the carbonized foams. Higher density, increased compressive strength and a more interconnected open celled porous structure are obtained at higher pressures. A more interconnected open-celled porous structure is formed for shorter pressure release times.

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