TENSILE STRENGTH AND ELECTRICAL CONDUCTIVITY OF ACTIVATED CARBON FIBERS

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Introduction

There is interest in the use of activated carbon fibers for various adsorptive duties. Although the adsorptive properties are of paramount importance, the physical properties of the fibers influences their application in, for example, permeable composites [1]. Such composites can capitalize upon the high diffusion rates which result from the small fiber diameter but without the containment and pressure drop problems associated with fine powders. Also, the electrical conductivity of such composites may be utilized in temperature swing adsorption applications [2]. In recent work carbon fibers have been produced from Egyptian coal tar pitch via filtration, distillation, melt spinning, stabilization in air, and carbonization in nitrogen. Some of these fibers have been steam activated and this paper reports on the tensile strength and the electrical conductivity of individual fibers as a function of weight loss during activation.

Experimental

The electrode pitch, Table 1, was supplied by the Al Nasr Company for Coke and Chemicals from their Russian-built plant running mainly on American coal. Solids that would have interfered with spinning and weakened the final fibers were removed form the pitch by filtration using a 0.12 m diameter stainless steel vessel containing a metal screen and operated at a temperature of 235 °C and a differential pressure of 200 kPa (30 psi). Vacuum distillation was used to remove low boiling material from the filtered pitch to give a product with a softening point of 235 °C with a yield of 64 %.

A single hole spinneret consisting of a stainless steel body with a threaded cap containing a 0.3 mm diameter, 1 mm long hole was used to form the fibers. The spinneret was electrically heated and the temperature monitored using an internal thermocouple. By controlling the temperature of the melt to a value in the range of 270 - 285 °C the feedstock could be extruded through the spinneret hole under nitrogen pressure and the fiber strand attached onto a 0.13 m diameter wind-up drum. With drum speeds of up to 1300 rpm, continuous fibers were produced for periods of up to 20 minutes. Under these conditions the fiber diameters were typically around 20 μm. The fibers were cut from the drum and the bundles stabilized by heating in air at temperatures of up to 310 °C and thereafter carbonized by heating in nitrogen at 1100 °C.

One gram samples of the bulk batch carbonized fibers were activated in a steam-nitrogen mixture at 830 °C for times ranging from 5 minutes to 2 hours. Tensile load and elongation at failure were measured on selected carbonized fibers using an Instron apparatus (ASTM 3379-75). The diameters of the single broken fibers were measured using an optical microscope and the tensile strength calculated. The electrical conductivity was measured by mounting individual fibers on glass slides using a conducting cement (colloidal graphite). A known electrical current was passed through the fiber and the voltage gradient determined. From these values and the measurement of fiber diameter the electrical conductivity was calculated. Nitrogen BET surface area was measured on the activated carbon fibers using an Omnisorp (model 610) apparatus operating at a temperature of 77 K.

Results and Discussion

During stabilization there was a 5.2 % gain in weight followed by a 19.6 % loss during carbonization giving an overall yield of 84.6 %. There was a 3 % shrinkage in fiber length during stabilization and a further 13 % shrinkage during carbonization. These coal tar based carbon fibers are similar to commercially available general purpose fibers (e.g., Carboflex) in tensile strength and electrical conductivity (Table 2).

During activation, tensile strength and conductivity are apparently reduced, but the interpretation of the data is made more complex by the progressive development of porosity (and hence high surface areas) in the fibers, Figure 1. Simplistically, both of these parameters, strength and conductivity, are calculated from the envelope dimensions of the activated fiber, but where porosity becomes significant, allowance should be made for the voidage within the fiber structure. The observed

dimensional changes and the corresponding mass loss during activation, are similar to those observed for Carboflex [1] and enabled the changes in density relative to the original carbonized fiber to be determined, Table 2.

The ratio of tensile strength to relative density shows only a small decrease as activation proceeds, Figure 2. This would indicate that the loss of mass does not introduce significant defects in the fibers and most of the remaining material contributes to the overall fiber strength (the standard deviations of the quoted strengths for the activated fibers were 15-20 %).

Electrical conductivity (Figure 3) is distinctly non-linear with large reductions for relatively small weight losses, and follows a form reflecting the increased tortuosity and length of the conductive path through the fiber, e.g., a tortuosity factor of about 5 for a 64 % weight loss.

Conclusions

During activation of these coal tar pitch based isotropic carbon fibers, the tensile strength reduces only slightly more than the mass removal, whereas electrical conductivity reduces much more dramatically.

Acknowledgments

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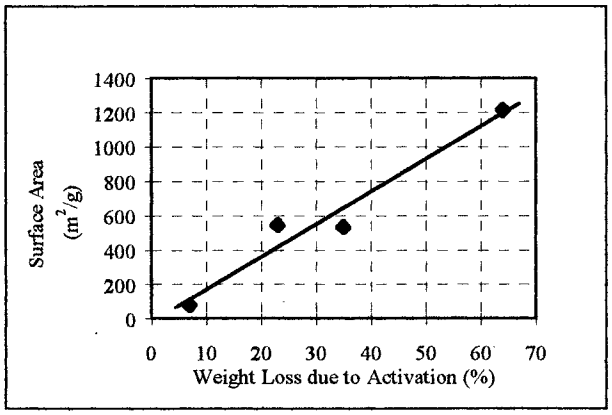

Figure 1. Development of Surface Area

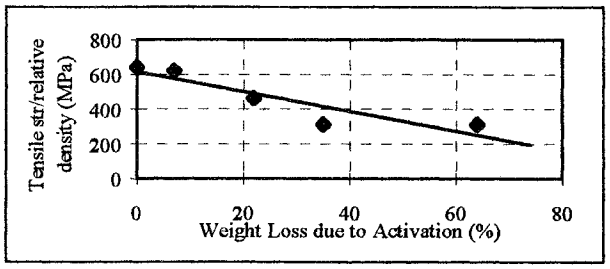

Figure 2. Tensile strength/relative density vs. Burn off

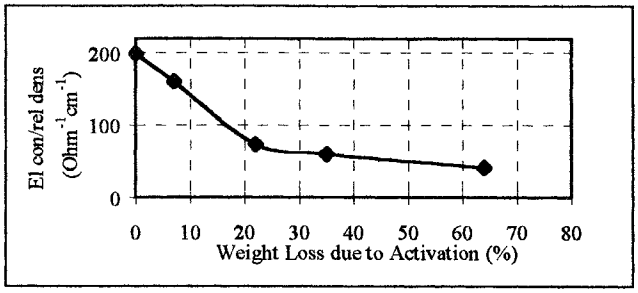

Figure 3. Electrical cond/relative density vs. Burn off

TABLE 1
Feedstock Pitch Analysis

Property		Electrode Pitch (E)
Softening Point	°C	100 - 105
Toluene Insolubles	%	> 31
Quinoline Insolubles	%	< 12
Ash Content	%	< 0.3
Volatile Matter	%	< 50
Water Content	%	< 0.5
Specific Gravity	g/cc	> 1.31

TABLE 2
Physical Properties of Carbonized and Activated Fibers

Sample No.	Mass % of original	Relative Density	Tensile strength (MPa)	Electrical Conductivity ($Ohm^{-1}cm^{-1}$)
Carboflex	100		400-600	147-192
80	100	1	640	199
80/250	93	0.93	580	149
80/248	78	0.82	370	60
80/246	65	0.74	230	44
80/249	36	0.49	150	20

References

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2. Kimber, G.M. and Johnson, A., Carbon 96, Extended Abstracts 52-53, Newcastle, UK, 1996.