POSTER

COMPARISON OF THE EFFECT OF AN OXYGEN PLASMA TREATMENT ON DIFFERENT TYPES OF CARBON FIBERS

M. C. Paiva[1], M. A. Montes-Morán[2], A. Cuesta[2], A. Martínez-Alonso[2], J. M. D. Tascón[2] and C. A. Bernardo[1]

1. Departamento de Engenharia de Polímeros, Universidade do Minho
Azurém, 4810 Guimarães, Portugal.
2. Instituto Nacional del Carbón, CSIC, Apartado 73, 33080 Oviedo, Spain.

1. INTRODUCTION

Plasma oxidation of carbon fibers is a promising method to improve the fiber-matrix adhesion in carbon fiber-reinforced composites [1-4]. However, there is little knowledge on how this treatment affects different types of carbon fibers, and also on its effect on the interfacial behaviour of thermoplastic matrix composites. In the present work, two types of carbon fibers, with very different structures, were plasma treated under identical conditions. Mechanical properties of these fibers, and of the composites made from them, were determined. The results obtained are interpreted on the basis of the structural characteristics of the fibers.

2. EXPERIMENTAL

Ultra-high modulus, P120J Amoco pitch-based carbon fibers (FU1 sample) and high-tensile strength, Sigrafil C320 PAN-based carbon fibers (FT2 sample) were used in this work, both samples being untreated and unsized. Oxygen plasma treatments were carried out in a Technics Plasma 200-G reactor under identical conditions (75 W, 1 mbar, 3 min). Tensile strength tests were performed on fiber monofilaments using an Instron 1122 apparatus. Monofilamentar composites were produced by compression moulding for all fibers, treated and untreated, using a polycarbonate matrix. The fragmentation technique was used to evaluate the interfacial stress transfer ability on the different systems, following a well established procedure [5]. The methodology for the various fiber characterisations, namely XRD and XPS, and the experimental details of the plasma reactor are described in detail elsewhere [6].

3. RESULTS AND DISCUSSION

Figure 1 shows the variation of the tensile strength (σ) with gauge length for the FU1 (untreated), and FT2 (treated) fibers. The results of tensile tests performed with the other fibers, at a gauge length of 20 mm, were not significantly different from those shown in Figure 1. As a first approximation, it may thus be assumed that plasma treatments under mild conditions do not affect appreciably the tensile strength of the fibers under study.

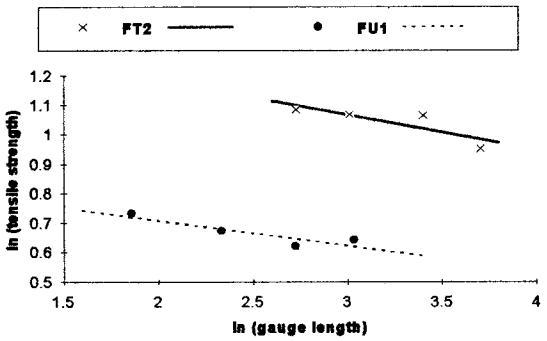

Figure 1. ln (σ) vs. ln (gauge length) for FT2 and FU1 fibers.

Results of the fragmentation tests carried out with the monofilamentar composites are shown in Table I. No decrease in fiber diameter is observed following the plasma treatment. The interaction between the fiber and the matrix is assessed by means of the interfacial shear strength, τ [5]. The most significant result is the increase in τ as a consequence of the plasma treatment, the effect being more pronounced for the FU1 sample. The measured values of l_c, the critical length of the fibers [5], are also included in the table. The greater efficiency of the plasma treatment for the ultra-high modulus fibers could be due to either incorporation of more functional groups favouring further bonding with the matrix, or to the development of a more irregular surface favouring mechanical interlocking. The absence of flaws in the plasma-treated fibers, as suggested by SEM

Table I. Results from the fragmentation tests.

Sample	Diameter (μm)	l_c (μm)	τ (MPa)
FT2	8.3±0.8	835	20.9
FT2, 75W/3min	7.9±0.6	641	26.5
FU1	9.6±1	1353	10.3
FU1, 75W/3min	9.6±1	509	33.0

examination, seems to rule out the second possibility. On the other hand, as Figure 2 shows, there is a good correlation between the oxygen concentration at the fiber surface and the interfacial shear strength of the resulting composites. This indicates that oxygenated functionalities present at the fiber surface after plasma treatment may be responsible for the improvement in fiber-matrix adhesion in the composites.

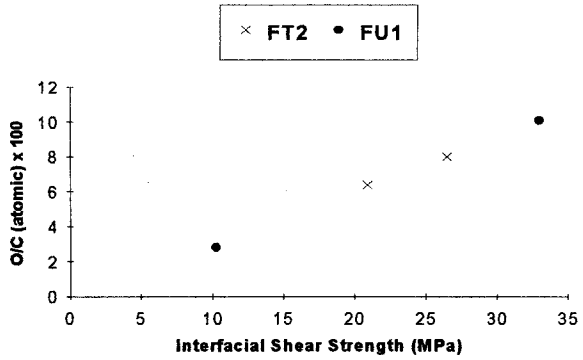

Figure 2. Correlation between oxygen concentration (XPS) and fragmentation results.

Due to its inherent high reactivity, cool oxygen plasma seems to be much less sensitive than O_2 to the carbon structural features. A recent comparative study covering many types of carbon materials [6] has shown that the main factor controlling carbon reactivity in an oxygen plasma is the surface area available for the reaction. Due to the very low surface area of carbon fibers, the small differences found for this parameter are not significant when purporting to explain trends in plasma reactivity. Nevertheless, the observed reactivity sequence is not unexpected, as some authors [3,7] have suggested that oxygen plasma preferably attacks basal planes. In addition to neat structural differences detected by XRD, Raman microprobe spectrometry has shown [8] that FU1 fibers are highly graphitized at the surface. Consequently, under the conditions used in this work, the ultra-high modulus fibers would be more deeply oxidised than the high tensile strength ones. This may explain the comparatively higher efficiency of the plasma treatment of the FU1 fibers despite their lower oxygen content in the untreated form.

4. CONCLUSIONS

Oxygen plasma treatment does not seem to modify appreciably the tensile strength nor the diameter of the two types of fibers studied. The increase in the surface concentration of oxygenated functional groups generated by the fiber treatment correlates well with the interfacial shear strength in the composites. The plasma treatment is more efficient for the ultra-high modulus fibers, which could be explained by their structural characteristics.

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