

Electrical resistivity of carbon fibres and their structural correlation by Mirage-FTIR spectroscopy

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The electrical resistivity of carbon fibres prepared at different carbonisation temperatures has been reported. The resistivity data have been analysed in the light of microstructural changes occurring at different stages of carbonisation as revealed by Mirage-FTIR spectroscopic technique. The low resistivity of high modulus carbon fibre has been attributed to the increased graphitisation.

The wide ranging applications of carbon fibres^{1,2} from the hi-tech areas like defence, aviation, space, etc. to industrial and domestic sectors have led to a variety of studies on this material. The specific applications of such materials are decided by their quality (i.e. physico-mechanical properties) which, in turn, are influenced by the quality of raw material and the processing conditions³⁻⁶. In an attempt to demonstrate such dependence, a preliminary study on IR spectroscopic and electrical resistivity measurements on carbon fibres treated at different carbonization temperatures has been reported. The results have been analysed in the light of microstructural changes as revealed by infra-red spectroscopic measurements made by using novel combination set-up of Mirage-FTIR recently developed.

Experimental Procedure

Electrical resistivity measurements—Fibre was stretched properly on a cleaned glass slide which was then deposited with four electrodes. A constant current of low magnitude was passed through the two outer electrodes and the corresponding voltage drop was measured across the inner two electrodes with the help of digital voltmeter. All the measurements were made at room temperature. The diameter of fibre was measured by optical microscope.

IR spectral measurements—Carbon fibre being

black and highly absorbing in nature, it was difficult to record a good quality IR spectrum by conventionally available techniques^{7,8}, which detect mainly transmitted or reflected radiations. A newly developed technique "Mirage-FTIR" has been used to record IR spectrum of carbon fibres. The principle, experimental set-up and other working details of Mirage-FTIR technique has been described elsewhere⁹⁻¹¹.

Results and Discussion

The carbon fibres used in the present study were produced from special acrylic fibre (SAF), a polyacrylonitrile (PAN) based fibres¹¹.

Electrical resistivity data on different carbon fibres are reported in Table 1. An analysis of data indicates that the resistivity of first two carbon fibres (i.e. CF-1 and CF-2) are nearly same and fall in the expected range. The minor variations in resistivity values of the two samples could be attributed to the difference in the extent of thermal treatment or sizes (known to contain non-carbon elements^{12,13}).

The considerable decrease in the resistivity of the third sample (CF-3), a high modulus carbon fibre

Table 1—Electrical resistivity (RT) of carbon fibre

Sample	Carbonisation temperature	Resistivity $10^{-4} \Omega \text{ cm}$
CF-1	$\approx 1200^\circ\text{C}$	13.9
CF-2	$\approx 1200^\circ\text{C}$	16.3
CF-3	$\approx 2500^\circ\text{C}$	8.16

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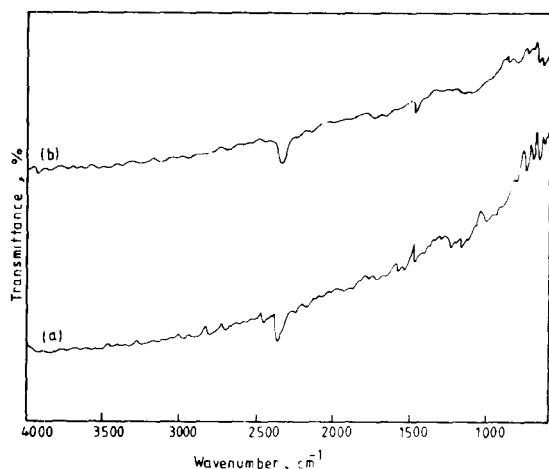


Fig.1—Mirage-FTIR spectra (a) CF and (b) HMCF

treated at 2500°C or above, is expected to be due to the loss of non-carbon elements from the carbon fibres as a result of treatment at very high temperature leading to framework structure similar to that of graphite. This is further supported from the facts that (a) the resistivity of HMCF is similar to that of graphite and (b) the micro-structural difference between the two fibres, viz., CF and HMCF as revealed from their infra-red spectral analysis discussed below.

Comparative analysis of IR spectra of CF and HMCF, shown in Fig.1, reveals that weak and broad bands = 1360 cm^{-1} and $\approx 1150\text{ cm}^{-1}$ (mix bending mode $\gamma_{\text{CN}} + \gamma_{\text{NH}}$)^{11,14} in case of HMCF tend to decrease and change into a nearly flat plateau indicating the loss of residual hetero-atoms from the framework structure, making it almost totally a graphitic structures. The low resistivity of HMCF may also be attributed to preferential alignment of graphitic crystallites along the fibre axis or

increased graphitisation which makes carbon fibre a fairly good conductor.

It may be mentioned that such a correlation has possibly been attempted for the first time mainly due to inability to record a well resolved IR spectrum of such high absorptivity (black) material like carbon fibre by conventional techniques.

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