second meridional interference, which after the second period becomes increasingly distinct, is not produced by interferences between micro-paracrystallites, but is the first subsidiary maximum of their Fourier-transform (shape- or particle-factor). Herefrom it can be concluded that in the one carefully studied case the amorphous region has a thickness of about 10 Å, and the crystallites a length of about 260 Å in the fibre direction. However, using the conventional densities of both phases, the calculated density is much too high. From this it must be concluded that there are lateral interfaces of lower density between adjacent microparacrystallites similar to the grain boundaries observed in PE single crystals. For these reasons the "two-phase-model" is only a first rough approximation.

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The Mechanical Properties of Carbon Fibres Coated with Titanium Carbide

The mechanical properties of carbon fibres are degraded by nickel or cobalt coatings following thermal treatment [1] and by silicon deposition [2]. A possible way of protecting the fibres from such an attack is to sheath them in a non-reacting material. Carbides are possible candidates for this role provided that they do not themselves affect the fibres during the deposition process.

We have studied Courtaulds "Grafil HT" fibres, thinly coated with titanium carbide by chemical vapour-deposition (CVD) from a mixture of hydrogen, methane and titanium tetrachloride vapour at high temperature [3].

The mechanical properties are compared in fig. 1 with the curves obtained previously for uncoated fibres using the same experimental technique [4]. In accord with the established diameter dependence of the properties of type "HT" fibres [5], diameter is used as abscissa.

Although there is scatter in the data, typical of carbon fibres, it is apparent that Young's Modulus of the coated fibres is not significantly different from that of the uncoated fibres shown by the continuous line in fig. 1. The thin coatings applied here (about 0.1 μm thick or amounting to some 4 vol % on a 8 μm diameter fibre) could increase the modulus of the fibres. Using the law of mixtures, the upper limit of this effect may be estimated as about 3 % or within the scatter band of results. An exact estimate of the upper limit cannot be given, partly because data for the variation of modulus of elasticity of TiC with carbon content are not available. In the above calculation a modulus of 4.8×10^4 kg/mm^2 was used for TiC, the average for $TiC_{0.95}$ [6] and $TiC_{0.91}$ [7], however, the composition of the carbide coating was deduced as about $TiC_{0.6}$ (measured by X-ray diffraction and using the reported variation of lattice parameter with carbon content [8]). Contrary to the trend shown by the modulus, the fracture strength and strain both appear to be somewhat reduced by the presence of the carbide coating. The reduced fracture strength of the coated fibres is believed to be related to the cracking of the coating – at a sufficiently high load the shock induced by the cracking might lead to catastrophic failure of the fibres. On some load-extension curves, "kinks" – small load drops – were noted, and were shown to be associated with local cracking in the carbide coating (fig. 2a). Not all specimens showed this effect, whilst some samples which "kinked" at a low strain showed a second "kink" at higher strain.

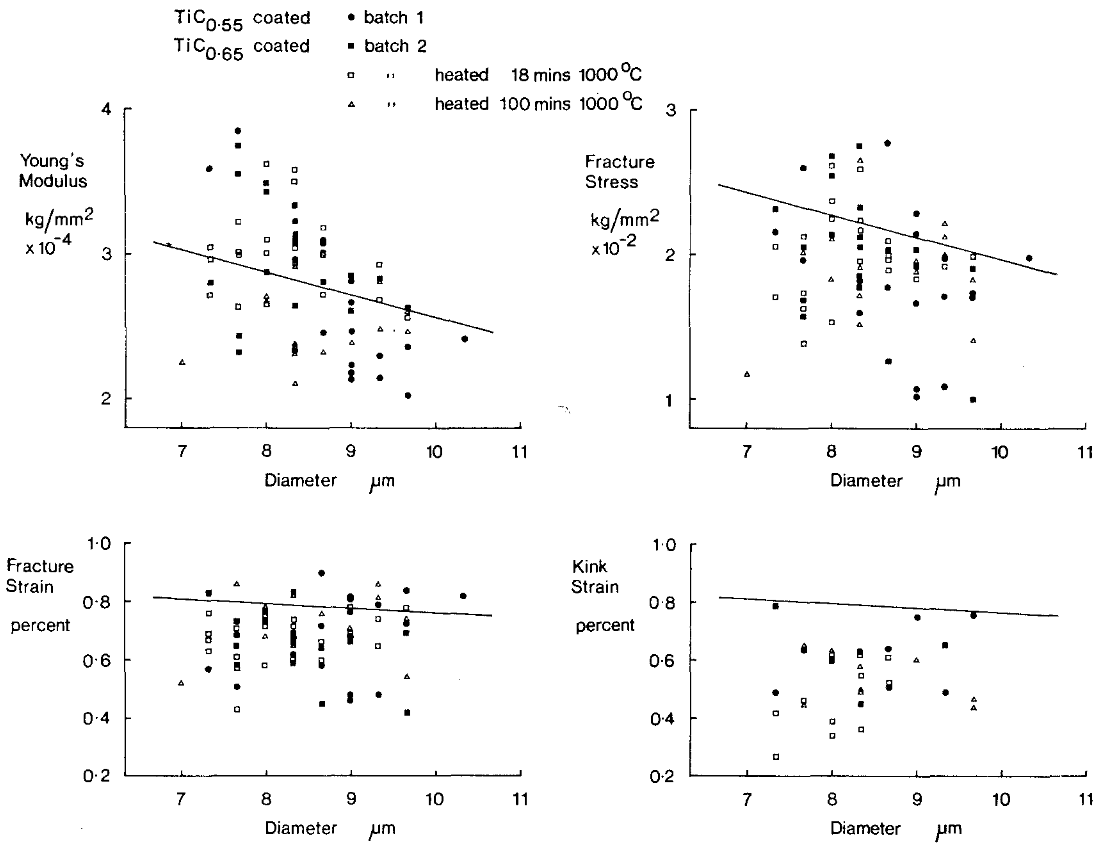

Figure 1 The mechanical properties of "Grafil HT" carbon fibres coated with titanium carbide of the indicated composition in the as-received and heat-treated conditions. A comparison is made between the present moduli and fracture stresses and the least-squares curve fitted to the uncoated fibre data reported previously [6]. The strains at which fracture and "kinks" (see the text) were observed here are both compared with the earlier fracture strain curve [6].

The thermal stability of carbide coated fibres is of extreme importance when such fibres are incorporated into a metal matrix by some method such as liquid infiltration. The effect of a typical temperature cycle on the structure and properties of the fibres was also investigated. In fig. 1, measurements of mechanical properties are included for coated fibres which have been heat treated at 1000°C in a vacuum of 10^{-5} torr for 18 min and for 100 min. After the short annealing time, little change in properties was observed. Even more extended annealing treatments, e.g. 100 h at 1000°C, do not degrade properties further.

Although the properties of carbon fibres appear to be slightly degraded by the presence of a titanium carbide coating, the deterioration is not as significant as that observed for nickel, cobalt or silicon coatings. The bond between fibre and coating appears to be good since more than one crack is observed locally at fracture in tensile tests, figs. 2a and b, although interfacial delamination was occasionally observed, fig. 2c. Fracture characteristics are unchanged after annealing treatments, suggesting that recrystallisation has not taken place. Indeed, even after the more extreme annealing treatment, microprobe analysis shows that titanium does not diffuse from the carbide into the bulk of the fibre, fig. 2d. Also, the coatings do not show measurable increases in lattice parameter or cracking which could be attributed to epitaxial stresses resulting from a volume increase, which suggests that carbon does not diffuse significantly into the carbide.

The results presented here indicate that titanium carbide coated carbon fibres may prove to be advantageous when such fibres are

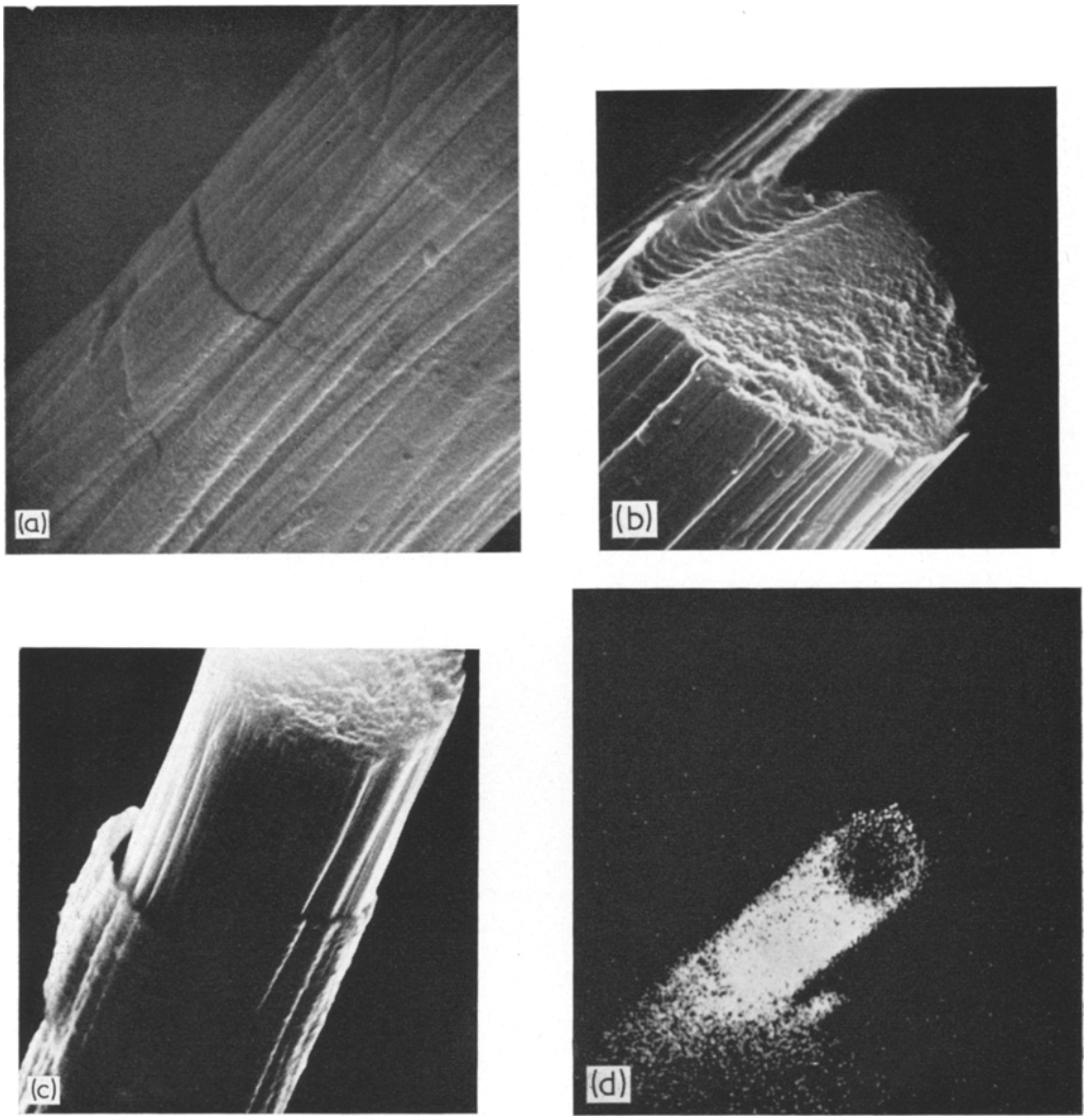

Figure 2 Scanning electron-micrographs of titanium carbide-coated carbon fibres in the as-received condition showing the following effects in the coating: (a) local cracking associated with "kinks" in the load-extension curves (× 7500); (b) local cracking near a fracture surface (× 5500) and (c) peeling away near a fracture surface (×3300). An electron-microprobe scan for titanium across a fracture surface is also reproduced in (d) showing the lack of penetration of titanium into the body of the fibre (× 1250).

considered as components of metal matrix composites because: (*a*) fabrication is not difficult by a method such as chemical vapour-deposition, although the process needs development so that more stable, fully stoichiometric carbides can be produced and, (*b*) fibre properties do not significantly deteriorate as a result of the coating even after extended heat treatment.

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Short Notice

Lectures on the Electrical Properties of Materials

L. Solymar and D. Walsh
Oxford University Press (1970), £4·00

This is an interesting book because the authors have attempted to combine a discussion of the basic electrical properties of materials with a description of the devices, whose operation is based upon these properties. This is of course a major undertaking and the authors have not made the task any easier by starting many of their discussions at an extremely elementary level. For example, no prior knowledge of crystallography or of atomic bonding appears to be assumed, and the *p-n* junction is introduced from the concept of putting a piece of *p* type and a piece of *n* type material together.

In contrast to this, the reader is expected to be familiar with such quantities as Maxwell's equations of electromagnetism and Gibbs free energy and readily able to manipulate matrices and differential equations. These combine to give the book a rather odd balance and I find it difficult to appreciate the type of 2nd year engineering student at whom it is aimed. For 2nd year electronic or electrical engineers, the section on semiconductors and semiconductor devices is not really sufficient, and in any case would be dealt with in other courses, whilst for civil and mechanical engineers, such topics as energy band theory and super-conductivity, are perhaps taken too far.

However, the book is written in a light hearted informal manner that is very refreshing. This, coupled with the liberal use of analogies and simple models, makes it a very "readable" book, and I consider that all students would find it acceptable.

In conclusion, I feel that the book has suffered from the authors setting themselves the extremely difficult task of trying to explain both the electrical properties of materials and the operation of many devices in one text. In spite of this, it would be a useful book for most engineering students and I would not hesitate to recommend it to them.

D.R.L.