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Chemical Vapour Deposition of Silicon Carbide on Non-circular Carbon Fibers

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I. Introduction

Pitch based carbon fiber is melt spun and it has the potential of easily producing of variety of different shapes of non-circular fiber. The increased surface area to volume ratio of non-circular fibers as compared to circular ones might result in increased fiber wetting through capillary action[1]. Thus, carbon fibers with non-circular shapes might provide improved fibre-matrix bonding in composites. The use of hollow fiber is another alternative to produce composites with improved properties. It has been shown[2], that the bending stiffness of composites reinforced with hollow carbon fibers is much better than those reinforced with solid round fibers. Therefore, carbon fibers with hollow as well as non-circular cross sections are promising reinforcing materials for producing of advanced composites. For high temperature applications in oxidizing atmosphere, however, the use of a protective barrier layer is nessessary due to the sensitivity of the carbon materials to oxidation. Thin layers of silicon carbide are known to provide a good oxidation protection for carbon fibers[3,4,]. The coating is generally deposed by chemical vapour deposition (CVD). This technique affords an easy process for high rates of deposition and good control of the reaction parameters[5].

In this study, non-circular carbon fibers from isotropic pitch were coated with silicon carbide for oxidation behaviour. Furthermore, the surface free energy of the carbon fibre surfaces before and after coating have been determined.

II. Experimental

The deposition of silicon carbide from methyltrichlorosilane (MTS, CH_3SiCl_3) was performed in a resistance-heated turbular flow reactor under reduced pressure (P_{total}=250 mbar) at 850℃ using hydrogen as carrier gas.

As substrate isotropic pitch based carbon fibers with hollow and C-shaped cross sections, manufactured on a laboratory scale by one of the authors(B.S.Rhee)[6], were used. The carbon fibres as a tow (2000 monofilaments) with a length of ca. 15 cm were coated with silicon carbide. The thickness of the SiC layer was determined using scanning electrone microscope(SEM).

Both, the uncoated and the coated fibres were characterized by

● mechanical properties (tensile strength and Young's modulus) measured in a monofilament test with a gauge length 30 mm and cross-head displacement of 0.5 mm/min.

● oxidation behaviour measured in a thermal balance and expressed as the weight change during heating in air flow with a constant heating rate of 5K/min.

III. Results and discussion

3.1 Mechanical properties of the coated fibers

The results of the measurments of the mechanical properties of the uncoated and coated isotropic pitch-based carbon fibers are presented as follows. The tensile strength of the carbon fibers is strongly negative influenced by the SiC-layer. This effect has to be explained in terms of differences inthe coefficient of thermal expansion as well as different mechanical properties of fibre and coating. Therefore, a layer thickness of more than 100-150 nm seems to be unacceptable, because of the strongly decreasing of the initial tensile strength. As a contrast, the influence of the SiC-coating on the Young's modulus of the carbon fibers is very weak. The difference in the stiffness of ceramic materials and carbon fiber is too significant, so that the coating takes all the applied stresses over.
An increase of the values for the torsional rigidity modulus has been found for the coated fibers and this effect is strongly marked in the case of the hollow fiber.

3.2 Oxidation behaviour of the carbon fibers after coating with SiC

The results of the oxidation tests are summarized in terms of the relative mass change as a function of the heating temperature. The samples, carbon fibers with hollow and C-shaped cross sections coated with 100 nm SiC-layer as well as the uncoated fibers, were heated in a thermal balance with a constant heating rate of 5 K/min in air flow.
There is a considerable mass loss for all the samples investigated. The coating with SiC, however, leads to a shift of the temperature for the start of the burn-off and the residual mass at 1200℃ to higher values. The form of the curves leads to the conclusion, that the oxidation of carbon fibers is strongly slowed down by coating with 100nm of silicon carbide.

IV. Conclusions

○ The deposition of thin layer of silicon carbide (100-150nm) by chemical vapour deposition technique doesn't significantly affect the tensile strength and Young's modulus of the fibres. However, the torsional rigidity modulus increases strongly after coating.
By coating the carbon fibres with SiC, the oxidation process starts at higher temperatures and the rate of burn off is slowed down.

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