UNIVERSITI PUTRA MALAYSIA

SURFACE WHISKERIZATION OF CARBON FIBERS WITH CARBON NANOTUBES

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CHRISTINA VARGIS **MASTER OF SCIENCE** **2007**

SURFACE WHISKERIZATION OF CARBON FIBERS WITH CARBON NANOTUBES

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the degree of Master of Science

September 2007

DEDICATED TO

Papa and Ama,

Who showered me with the love, support and confidence that help me come this far….

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

SURFACE WHISKERIZATION OF CARBON FIBERS WITH CARBON NANOTUBES

By

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September 2007

Chairman : Suraya Abdul Rashid, PhD

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Carbon fibers are the main reinforcing fibers used in high performance polymer matrix composites in various applications such as manufacturing of aerospace vehicles and high quality sports gear. Composite performance can be enhanced by applying an optimum level of fiber surface treatment. Surface treatments may be classified into oxidative and non-oxidative treatments. In this study, whiskerization which is a type of non-oxidative treatment was employed. This treatment involved the coating of untreated carbon fibers with carbon nanotubes (CNTs).

There are three main objectives in this study. The first objective was to design and fabricate a chemical vapour deposition (CVD) reactor system that enables the growth of CNTs from carbon fiber surface. The second objective was to carry out whiskerization

treatment at various conditions and to characterize the CNT-coated fibers at these conditions. Characterization of CNT-coated fibers was conducted at varying regions within the reaction tube; at reaction temperatures between 800-1000^{o}C and carrier gas (hydrogen) flow rates between 100-500ml/min. Characterization of the CNTs formed on the carbon fibers was also conducted. The third objective was to investigate the flexural properties of composites made from untreated and CNT-coated carbon fibers.

A CVD reactor system, referred to as CVD rig was successfully designed and fabricated to grow CNTs on untreated carbon fiber. CNTs grew on carbon fiber at region 1 for all treatment conditions. The CNTs grown on the carbon fibers increased in length and distinctness of parallel graphitic sheets alignment as the reaction temperature increased from 800 to 1000^{o}C. As the hydrogen flow rate increased from 100 to 500 ml/min, the CNT coatings on the fibers were relatively more even and the amorphous carbon impurities (indicated by clumps) on the CNT-coated fibers disappeared (only observed at 800^{o}C). “Whisker-like” morphology and bi-directional growth were the two types of CNT conformations produced in this study. The CNTs grown was identified as multi-walled carbon nanotubes (MWCNTs).

Whiskerization treatment on carbon fibers increases the flexural strength of composites between 44-122%. Higher reaction temperature and hydrogen flow rate during carbon fiber whiskerization treatment lowers the flexural strength of its composite. Hydrogen

flow rate has lesser impact on the flexural strength as compared to the reaction temperature. Observation of carbon fiber-epoxy composite fracture surface indicated CNT-coated carbon fiber bonds better with epoxy matrix compared to untreated carbon fiber.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENGHABLURAN SUNGUT PERMUKAAN GENTIAN KARBON DENGAN NANOTIUB-NANOTIUB KARBON

Oleh

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Gentian karbon merupakan penguat utama yang digunakan dalam komposit matriks polimer berprestasi tinggi dalam pelbagai aplikasi seperti pengeluaran kenderaan angkasa lepas dan peralatan sukan berkualiti tinggi. Prestasi komposit dapat dipertingkatan dengan mengaplikasi rawatan permukaan gentian tahap optima. Rawatan permukaan boleh diklasifikasikan kepada rawatan beroksigen dan tak beroksigen. Dalam kajian ini, penghabluran sungut yang merupakan sejenis rawatan tak beroksigen digunakan. Rawatan ini melibatkan penyalutan gentian karbon yang belum dirawat dengan nanotiub-nanotiub karbon (CNTs).

Terdapat tiga objektif utama dalam kajian ini. Objektif pertama adalah untuk merekabentuk dan membina sebuah sistem reaktor pemendapan wap kimia (CVD) yang membolehkan pertumbuhan CNTs pada permukaan gentian karbon. Objektif kedua ialah untuk menjalankan rawatan penghabluran sungut dalam pelbagai keadaan dan mencirikan gentian-gentian yang disaluti CNTs dalam keadaan-keadaan ini. Pencirian gentian yang disaluti CNTs dijalankan pada pelbagai bahagian di dalam tiub tindakbalas, pada suhu tindakbalas antara 800-1000^{o}C dan kadar aliran gas pengangkut (hidrogen) antara 100-500 ml/min. Pencirian CNTs yang terbentuk di atas gentian karbon juga dijalankan. Objektif ketiga ialah untuk menyiasat sifat-sifat lenturan komposit yang diperbuat daripada gentian-gentian karbon yang belum dirawat dan yang disaluti CNTs.

Sistem reaktor CVD yang dipanggil rig CVD telah direkabentuk dan dibina dengan jayanya untuk pertumbuhan CNTs di atas gentian karbon yang belum dirawat. CNTs tumbuh di atas gentian karbon pada kawasan 1 untuk untuk semua kondisi rawatan. CNTs yang tumbuh di atas gentian karbon bertambah panjang dan barisan kepingan grafit selari CNTs bertambah ketara apabila suhu tindakbalas meningkat dari 800 ke 1000^{o}C. Apabila kadar aliran hidrogen meningkat dari 100 ke 500 ml/min, salutan CNTs di atas gentian-gentian bertambah sekata secara relatif dan bendasing karbon amorfus (ditunjukkan oleh kelompok) di atas gentian yang disalut CNT hilang (hanya diperhatikan pada 800^{o}C). Morfologi ‘whisker-like’ dan ‘bi-directional growth’ merupakan dua jenis bentuk CNT yang dihasilkan dalam kajian. CNTs yang telah

bertumbuh dikenalpasti sebagai nanotiub-nanotiub karbon menjajar pelbagai dinding (MWCNT).

Rawatan penghabluran sungut di atas gentian karbon meningkatkan kekuatan lenturan komposit antara 44-122%. Peningkatan suhu tindakbalas dan kadar aliran hidrogen semasa gentian karbon mengalami rawatan penghabluran sungut merendahkan kekuatan lenturan kompositnya. Kadar aliran hidrogen mempunyai kesan yang kurang ke atas kekuatan lenturan berbanding dengan suhu tindakbalas. Pemerhatian ke atas permukaan retak komposit gentian karbon-epoksi menunjukkan gentian karbon yang disalut dengan CNT terikat dengan lebih baik dengan matriks epoksi berbanding gentian karbon yang belum dirawat.

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I certify that an Examination Committee has met on 14 September 2007 to conduct the final examination of Christina Vargis a/p Jones @ John Vargis on her Master of Science thesis entitled “Surface Whiskerization of Carbon Fibers by Carbon Nanotubes (CNT)” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the degree of Master of Science.

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

_____

CHRISTINA VARGIS

Date: 29 October 2007

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