Title of collaborative project: Studies on enhancing transverse thermal conductivity in carbon/carbon composites

Contract Number : FA5209-06-P-0074

Name and address of Principal Investigator from India : Dr. Lalit Mohan Manocha
Coordinator
Sophisticated Instrumentation Centre for Research and Testing (SICART)
Vallabh Vidyanagar – 338120, INDIA
Phone: 91 2692 234966
e.mail: manocha1@rediffmail.com

Name and address of Co- Investigator from India : Dr. (Mrs.) Satish M Manocha
Professor
Department of materials Science
Sardar Patel University
Vallabh Vidyanagar – 388120, INDIA
Telefax: 91 2692 235183
e.mail: sm_manocha@rediffmail.com

Name and address of Principal Investigator from USA: Dr. Ajit Roy
Research Leader
Structural Materials Branch
Air Force Research Laboratory
Wright Patterson Air Force base
OH 45433-7750, USA
Phone: 937 – 255 – 9034
e.mail: ajit.roy@wpafb.af.mil

Total cost of the proposal: USD 18,000=00

Objective: To carryout in-depth study on the factors influencing out-of-plane thermal conductivity of carbon –carbon conductivity.

To enhance out-of-plane conductivity of carbon-carbon composites through addition of carbon nanomaterials.

To study effect of carbon nanomaterial addition on the microstructure of the carbon matrix and correlate it with the thermophysical and mechanical properties of the end products.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **06 JUL 2007**	2. REPORT TYPE **FInal**	3. DATES COVERED **03-03-2006 to 01-03-2007**
4. TITLE AND SUBTITLE **Studies on enhancing transverse thermal conductivity carbon/carbon composites**		5a. CONTRACT NUMBER **FA520906P0074**
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Lalit Mohan Manocha**		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Sophisticated Instrum. Cntr. for Adv Res & Test (SICART),Mota Bazzar,Vallabh Vidyanagar, Gujrat 388120 India,IN,388120**		8. PERFORMING ORGANIZATION REPORT NUMBER **N/A**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **AOARD, UNIT 45002, APO, AP, 96337-5002**		10. SPONSOR/MONITOR’S ACRONYM(S) **AOARD**
		11. SPONSOR/MONITOR’S REPORT NUMBER(S) **AOARD-054092**
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		

14. ABSTRACT

The structure derived potential properties of Graphite such as high stiffness coupled with high thermal conductivity and low coefficient of thermal expansion have been better achieved in Carbon fibers and Carbon-Carbon composites. Consequently, the application domain of carbon-graphite based materials has increased to thermostructural components. During last few decades there has been great interest in the development and performance studies of carbon fibers and carbon-carbon composites, especially for thermal management systems. These composites are prepared with wide range of reinforcing fibers, high strength carbon fibers to high modulus prepared from PAN, Pitch as well as CVD carbon fibers and carbonaceous material with different compositions as matrix precursor. Both fibers and matrix influence the structure and ultimate properties of carbon/carbon composites. As far as mechanical properties of carbon/carbon composites are concerned the reinforcing carbon fibers are the major load bearing component in carbon-carbon composites. However, the load distribution amongst the fibers through matrix system, the ultimate fracture behaviour and mechanical properties of the composites require judicial control of fiber/matrix interface. Similarly the transport properties like thermal and electrical conductivity depend more on structure and properties of fibers, more so in the direction of the fiber whereas the matrix controls transport properties in the direction perpendicular to reinforcement. For last two decades, the focus of research has been on influence of various parameters such as fiber type, matrix type and processing conditions etc on ultimate properties of carbon/carbon composites, specifically relation between structure, processing conditions and thermal properties of the composites. Most of the work reported in the literature has been done with mechanical properties in focus. The present investigations were undertaken to study thermal properties of the composites and to enhance thermal conductivity of the composites in the direction perpendicular to the fibers through control of matrix microstructure and to study influence of nanocarbon reinforcement addition to the carbonaceous precursors on the microstructure of the matrix as well as on the thermal properties of the ultimate composites. The work incorporated in this report elucidates the thermal conductivity of different types of carbon-carbon composites prepared by the Investigators using different types of carbon fibers and matrix systems.

15. SUBJECT TERMS

Carbon-Carbon Materials, Ceramic Matrix Composites

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

PROGRESS REPORT

The structure derived potential properties of Graphite such as high stiffness coupled with high thermal conductivity and low coefficient of thermal expansion have been better achieved in Carbon fibers and Carbon-Carbon composites. Consequently, the application domain of carbon-graphite based materials has increased to thermostructural components. During last few decades there has been great interest in the development and performance studies of carbon fibers and carbon-carbon composites, especially for thermal management systems. These composites are prepared with wide range of reinforcing fibers, high strength carbon fibers to high modulus prepared from PAN, Pitch as well as CVD carbon fibers and carbonaceous material with different compositions as matrix precursor. Both fibers and matrix influence the structure and ultimate properties of carbon/carbon composites. As far as mechanical properties of carbon/carbon composites are concerned the reinforcing carbon fibers are the major load bearing component in carbon-carbon composites. However, the load distribution amongst the fibers through matrix system, the ultimate fracture behaviour and mechanical properties of the composites require judicial control of fiber/matrix interface. Similarly the transport properties like thermal and electrical conductivity depend more on structure and properties of fibers, more so in the direction of the fiber whereas the matrix controls transport properties in the direction perpendicular to reinforcement. For last two decades, the focus of research has been on influence of various parameters such as fiber type, matrix type and processing conditions etc on ultimate properties of carbon/carbon composites, specifically relation between structure, processing conditions and thermal properties of the composites. Most of the work reported in the literature has been done with mechanical properties in focus. The present investigations were undertaken to study thermal properties of the composites and to enhance thermal conductivity of the composites in the direction perpendicular to the fibers through control of matrix microstructure and to study influence of nanocarbon reinforcement addition to the carbonaceous precursors on the microstructure of the matrix as well as on the thermal properties of the ultimate composites.

The work incorporated in this report elucidates the thermal conductivity of different types of carbon-carbon composites prepared by the Investigators in India using different types of carbon fibers and matrix systems.

These are categorized as:

Series A : 2D Carbon/carbon composites made with

High strength PAN, intermediate modulus pitch and Rayon based carbon fibers as reinforcement.

Phenolic as performing and pitch as impregnating (densifying) matrix precursor. These composites were heat treated in the temperature range of 1200 to 2700°C. These composites have undergone densification under low pressure impregnation and carbonization.

Series B. UD/2D Carbon/carbon composites made with

High strength PAN, intermediate modulus pitch and High modulus pitch based carbon fibers as reinforcement.

PFA as performing and pitch as impregnating (densifying) matrix precursor. These composites were heat treated in the temperature range of 1200 to 2700°C. These composites have undergone densification under low pressure impregnation and carbonization. as well as under High Pressure Impregnation/Carbonization conditions.

. In some of the composites milled carbon fibers were added in order to study the presence of milled fibers on the structure of matrix systems.

.

The microstructure of the composites was studied using optical microscope (Laborlux 12 POLS), XRD (Phillips) and scanning electron microscope (Hitachi S-3000N) and densitometer (Mettler Toledo AG204). Thermal conductivity were measured by laser flash method.

Data on composites A is presented in this report.

It is found that thermal conductivity both in plane as well as in direction perpendicular to lay upis influenced by the type of the fibers (in fact on graphitic content) as well as on final heat treatment temperature. The variation of thermal conductivity with measurement temperature is also found to be dependent on the degree of graphitic content in the composites.

Composites with low graphitic content (either made with PAN based carbon fibers or heat treated to 1200 C) are found to exhibit lower thermal conductivities. The conductivity is found to increase with test temperature.

Composites with high graphitic content (either made with pitch based carbon fibers or heat treated to 2700C) exhibit high thermal conductivity in both the direction. The ratio of conductivity in the two direction is found to increase with extent of graphitic content.

Composites having high graphitic content show a dip in the conductivity versus temperature plot when measured in perpendicular direction. It is not observed in composites with low graphitic content.

Composites made with same fiber system and matrix and heat treated to same temperature but differing in densities also exhibit difference in thermal conductivities. Composites having lower density exhibit lower thermal conductivity.

Same trend is seen in composites of series B