



Effects of High Temperature Argon Heat Treatment on Tensile Strength and Microstructure of BN/SiC Coated SiC Fiber Preforms

Ramakrishna T. Bhatt
U.S. Army Research Laboratory, Glenn Research Center, Cleveland, Ohio

Yuan L. Chen
Dynacs Engineering Corporation, Inc., Brook Park, Ohio

19990707 088

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

DTIC QUALITY INSPECTED 4

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the Lead Center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.

- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized data bases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at <http://www.sti.nasa.gov>
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at (301) 621-0134
- Telephone the NASA Access Help Desk at (301) 621-0390
- Write to:
NASA Access Help Desk
NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076



Effects of High Temperature Argon Heat Treatment on Tensile Strength and Microstructure of BN/SiC Coated SiC Fiber Preforms

Ramakrishna T. Bhatt
U.S. Army Research Laboratory, Glenn Research Center, Cleveland, Ohio

Yuan L. Chen
Dynacs Engineering Inc., Brook Park, Ohio

Prepared for the
ICCM-12
sponsored by the L' Association pour les Materiauz Composites
Paris, France, July 5-9, 1999

National Aeronautics and
Space Administration

Glenn Research Center

Trade names or manufacturers' names are used in this report for identification only. This usage does not constitute an official endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

Available from

NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076
Price Code: A03

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22100
Price Code: A03

EFFECTS OF HIGH TEMPERATURE ARGON HEAT TREATMENT ON TENSILE STRENGTH AND MICROSTRUCTURE OF BN/SiC COATED SiC FIBER PREFORMS

Ramakrishna T. Bhatt
U.S. Army Research Laboratory
NASA Glenn Research Center
Cleveland, Ohio 44135

and

Yuan L. Chen
Dynacs Engineering Corporation, Inc.
2001 Aerospace Parkway
Brook Park, Ohio 44142

ABSTRACT

Preforms of BN/SiC coated Hi-Nicalon and Sylramic SiC fibers were heat treated under 0.1 MPa argon pressure between 1000^o to 1800^o C for 1 and 100h. The effects of high temperature exposure on physical dimensions, weight, room temperature tensile strength, and microstructure of preforms have been studied. Both preforms showed shrinkage and weight loss, and microstructural changes beyond 1000^o C. After 100 hr exposure, the Hi-Nicalon preforms showed strength degradation beyond 1200^o C. The mechanisms of the strength degradation appear to be grain growth of the SiC fibers and crystallization of the BN coating. After 100 hr, the Sylramic preforms heat treated to 1000^o C retained their as-produced strength while some of those heat-treated between 1000^o and 1800^o C showed strength degradation and others did not. At 1800^o C, the ultimate tensile strength decreased with increasing time of exposure. Reasons for strength degradation of Sylramic preforms are being investigated.

INTRODUCTION

Preforms of boron nitride/silicon carbide (BN/SiC) coated Hi-Nicalon and Sylramic SiC fibers are used as building block for the fabrication of silicon carbide based composites by the melt infiltration (MI) approach. The composite fabrication involves two steps. In the first step the preform is infiltrated with carbon foam derived from a polymer, or with a SiC slurry. In the second step the filled preform is infiltrated with molten silicon. The MI fabrication approach offers two main advantages over other methods of fabricating SiC/SiC composites: Minimal fiber damage during fabrication, and near net shape capability. The current generation SiC/SiC composites show high thermal conductivity and have performance potential up to 1320^o C.

However, because of the large scatter in mechanical properties, poor oxidation resistance of the BN interface coating at intermediate temperatures, high surface recession rate in combustion environments, and the presence of high amounts of residual silicon in the SiC matrix, current generation SiC/SiC composites are restricted to below 1200 °C applications [1]. The large scatter in mechanical properties is partly due to variation in mechanical properties of the preforms, or to poor microstructural control during processing. Since performance and properties of the composites are controlled by the preforms, the factors that affect preforms will have a major effect on reliability, reproducibility, and maximum use capability of the composites.

The objective of this study is to determine the microstructural and strength stability of commercially available BN/SiC coated SiC fiber preforms in argon to simulate processing and application temperature exposures.

EXPERIMENTAL

The BN/SiC coated Hi-Nicalon™ and Sylramic™ SiC fiber preforms were purchased from AlliedSignal Composites, Delaware. Hi-Nicalon™ and Sylramic™ are the trade names of the SiC fiber manufactured by The Nippon Carbon Company, Japan, and The Dow Corning Company, Midland, Michigan, respectively. For conciseness, henceforth, these two preforms will be referred to as Hi-Nicalon and Sylramic preforms. The preforms were prepared by stacking eight layers of 2-D woven 5-harness-satin (5HS) SiC fiber mats (152 mm x 229 mm) and then infiltrating the assembly with the BN and SiC coatings by a proprietary chemical vapor infiltration (CVI) process. Typical dimensions of the as-processed preforms were 152 mm x 229 mm x 2 mm. The preforms consist of ~40 vol. % SiC fiber, ~3-8 vol. % BN, ~18-30 vol. % SiC, and ~20-40 vol. % open porosity. The rectangular specimens of dimensions 152mm x 13mm x 2mm were cut from the larger preforms using a diamond impregnated metal bonded cut-off wheel.

The specimens were heat-treated in a box furnace in 0.1 MPa argon for 1 and 100 hrs at 200 °C temperature intervals between 1000 °C and 1800 °C. At each exposure condition at least 3 to 5 specimens were heat-treated. The specimen dimensions and weight were measured before and after heat treatment at room temperature.

To avoid possible delamination and compressive failure within the grip area during tensile testing, the entire heat-treated preform was infiltrated with a low strength, low modulus epoxy. An infiltration procedure similar to that developed for ceramographic specimens was used. The epoxy infiltrated specimens were machined to dog-bone shape in the gauge section using an ultrasonic impact machine and SiC slurry. For tensile testing, two glass fiber reinforced epoxy tabs of dimensions 38mm x 13mm x 2mm were glued at each specimen end. A spring loaded contact extensometer was attached to the specimen in the gauge section to monitor strain. The tensile tests were conducted at room temperature at a cross-head speed of 1.3 mm/sec.

For the preparation of transmission electron microscope (TEM) specimens, the preform specimens were sectioned using a diamond saw, vacuum degassed in a mixture of epoxy, and sandwiched between two silicon wafers. The sandwich specimens were sliced to a size of 2.5mm x 2mm x 0.5mm. These specimens were thinned to electron transparency using tripod

polishing and argon ion-beam milling. Diffraction contrast images, selected-area and micro diffraction data were recorded using a Philips CM200 electron microscope operated at 200 kV. The TEM is coupled to an energy dispersive X-ray (EDX) spectrometer for chemical identification. The present transmission electron microscopy results include analyses from cross-sections of preforms. In this mode, the fibers were observed 'end-on'.

RESULTS

The optical micrographs of the cross-section of the epoxy infiltrated Hi-Nicalon and Sylramic fiber preforms are shown in Figs. 1 and 2. These cross-sections show similarities and

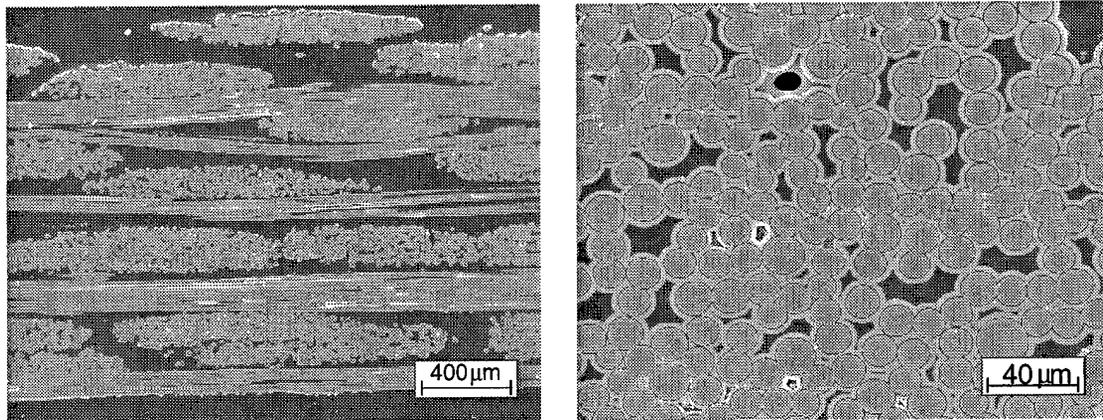


Fig. 1: Optical photographs of the cross-section of an epoxy infiltrated BN/SiC coated Hi-Nicalon SiC preforms showing fiber distribution and CVI coating thickness variation.

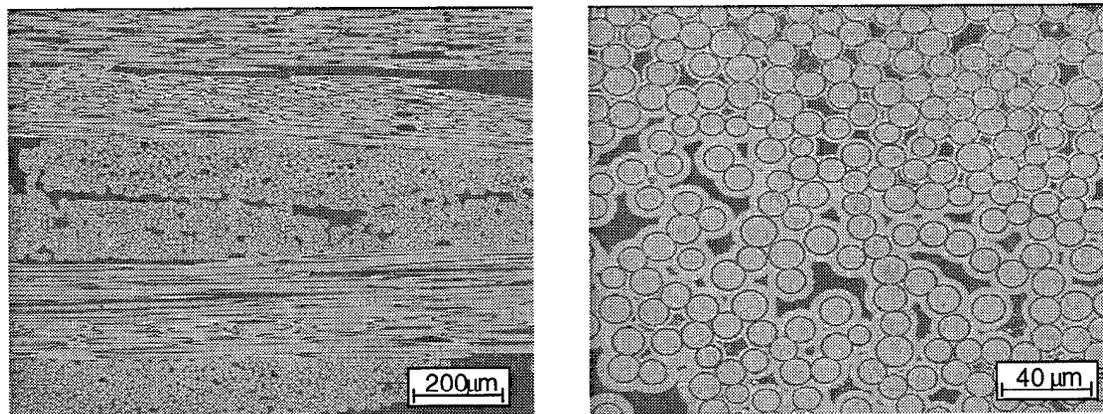
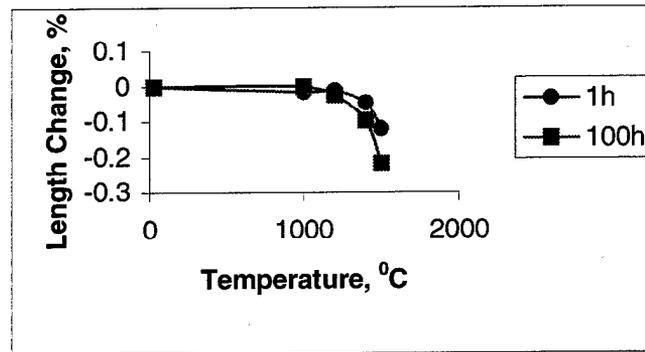


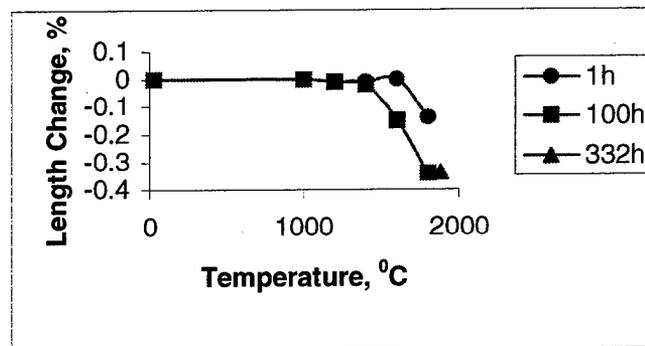
Fig. 2: Optical photographs of the cross-section of an epoxy infiltrated BN/SiC coated Sylramic SiC preforms showing fiber distribution and CVI coating thickness variation.

differences between preforms. In these figures, the dark ring around the fibers is the BN coating and the light grayish region on top of the BN coating is the SiC coating. For both Hi-Nicalon and Sylramic preforms, the SiC coating thickness varies from tow to tow as well from the middle to the periphery of the tow. There are also several differences noticed between preforms. The fiber diameters in the Hi-Nicalon preforms are ranging from 9 to 15 μm , while those in Sylramic preforms are all $\sim 10 \mu\text{m}$. The fiber tows in Hi-Nicalon preforms are loosely woven, whereas in Sylramic, they are tightly woven. Closed porosity in Hi-Nicalon preforms is $< 2 \text{ vol. } \%$, and $\sim 2\text{-}5 \text{ vol. } \%$ in Sylramic preforms. The Sylramic preforms show a thick layer of SiC on the outer periphery of the tows.

Both types of preforms showed shrinkage in length and weight loss at high temperatures. Shrinkage observed in preforms after 1 and 100 hr heat treatments in argon at temperatures to $1800 \text{ }^\circ\text{C}$ is plotted in Fig. 3 along with a specimen heat treated at $1800 \text{ }^\circ\text{C}$ for 332 hr. According to figure 3(a) the length of the Hi-Nicalon preforms remained nearly the same up to $1200 \text{ }^\circ\text{C}$. Beyond this temperature, the length decreased with increasing heat treatment temperature at a



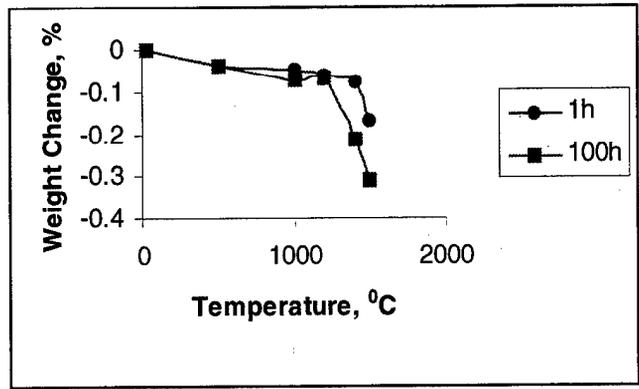
(a)



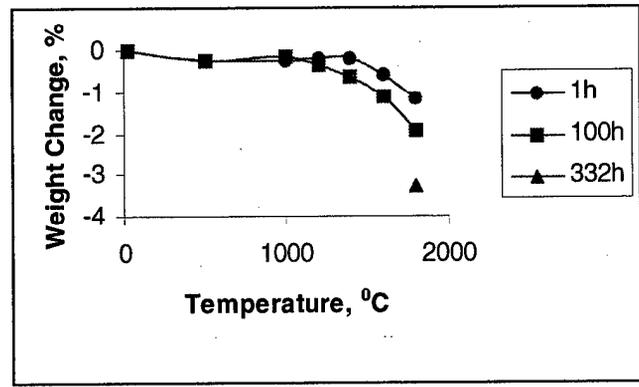
(b)

Fig. 3: Variation of length change with temperature for the BN/SiC coated SiC preforms. (a) Hi-Nicalon; (b) Sylramic.

fixed exposure time, or with increasing time at a given temperature. The Sylramic preform showed shrinkage in length beyond 1600 °C (Fig. 3(b)). Figure 4 shows variation of weight loss with heat treatment temperature. Two weight loss regions were observed in the figure: An initial region where weight loss is independent of exposure condition followed by a region where weight loss is dependent on time and temperature. The initial region lasted up to 1200 °C for both preforms. In this region ~ 0.07 % and ~0.29 % weight losses were observed respectively, in Hi-Nicalon and Sylramic preforms. Above 1200 °C, the weight loss increased with increasing temperature at constant time, or with increasing time at a given temperature.



(a)

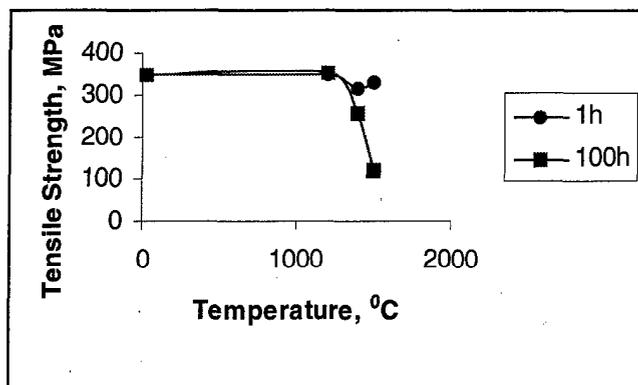


(b)

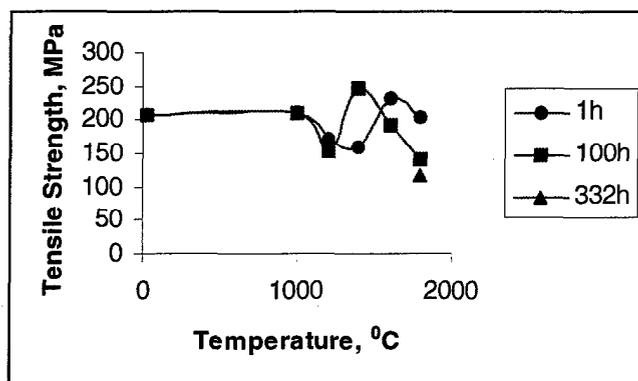
Fig. 4: Variation of weight loss with temperature for the BN/SiC coated SiC preforms. (a) Hi-Nicalon; (b) Sylramic.

The effects of heat treatment temperature and time on ultimate tensile strength of the Hi-Nicalon and Sylramic preform specimens are plotted in figure 5. Each data point represents an average of 3 to 5 specimens. The scatter in the strength data is ~ 25 MPa. The Hi-Nicalon preforms heat treated at temperatures to 1500 °C for 1hr and those heat treated for 100 hr at temperatures to 1200 °C showed no loss in ultimate tensile strength when compared with the UTS values of the as-received specimens. Between 1200° and 1500 °C, the UTS values of the 100hr heat-treated specimens decreased with increasing exposure temperature. On the other hand, the Sylramic

preforms are relatively stable up to 1000 °C after 1 and 100h. Between 1000 and 1600 °C both at 1 and 100 hr exposures, some preforms showed strength degradation and others did not. In addition, the UTS of the preforms appears to decrease with increasing time of exposure at 1700⁰ and at 1800 °C.



(a)



(b)

Fig. 5: Effect of heat treatment temperature and time on ultimate tensile strength of the BN/SiC coated SiC preforms. (a) Hi-Nicalon; (b) Sylramic.

The TEM micrographs and selected area diffraction (SAD) pictures of the as-fabricated Hi-Nicalon and Sylramic preforms are shown in Fig. 6. Results indicate that for as received condition, the BN interface is nearly amorphous and the SiC coating is crystalline in both preforms. The SiC grains are columnar and grow radially. The boundary between the SiC fiber and BN coating or between the BN and SiC coatings is sharp and distinct suggesting no interdiffusion between the zones. However in few cases a graded zone of fine grained SiC and amorphous BN was noticeable at the BN/SiC coating interface as shown in figure 6(a). The EDX analysis shows that the BN coating contains small amounts Si, C, and O. The Hi-Nicalon fiber is microcrystalline with an average grain size of 2 nm (Fig. 6(a)). The Sylramic SiC fiber contained randomly oriented SiC grains of nominal diameter of ~100 nm, and TiB₂ particles.

After argon heat treatment beyond 1000 °C, the Hi-Nicalon and Sylramic preforms showed coarsening of grains in the SiC fibers and crystallization of the BN coating. However only major microstructural changes observed in the heat-treated preforms will be described here. The TEM micrograph of the Hi-Nicalon preform heat treated at 1500 °C for 100 hr is shown in Fig. 7.

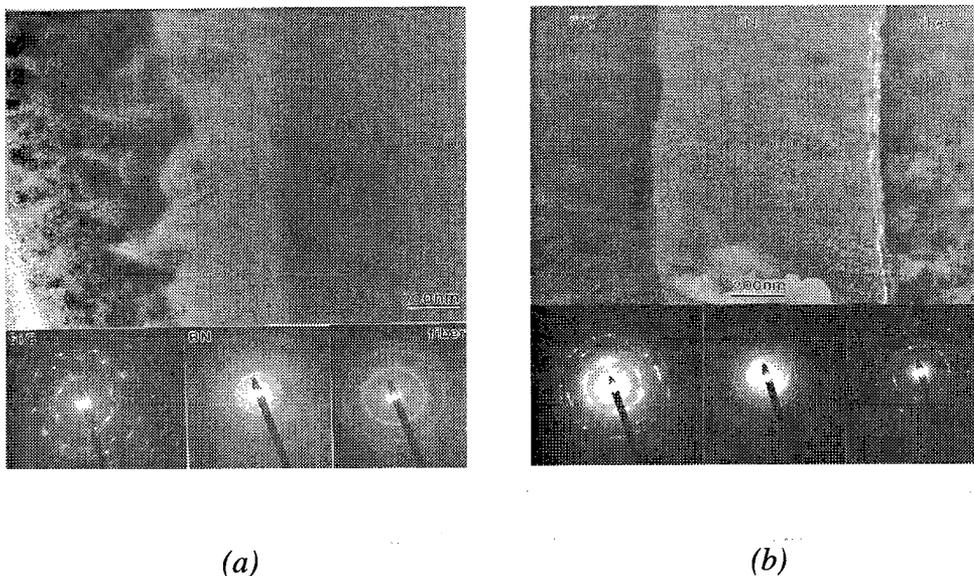


Fig. 6: TEM micrographs of the cross section of as-received BN/SiC SiC coated preforms showing interface microstructures. (a) Hi-Nicalon; (b) Sylramic.

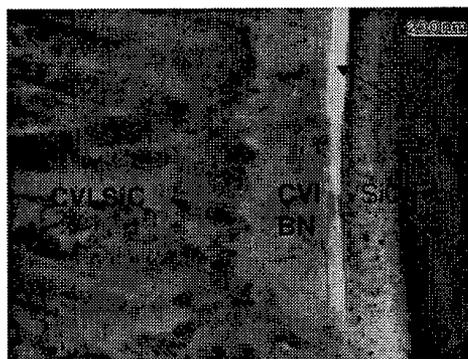


Fig. 7: TEM micrograph of the interface zone of the BN/SiC coated Hi-Nicalon preform heat treated at 1500 °C for 100 hr in argon showing grain growth in SiC fiber.

Several microstructural changes are noticed, when comparing Fig. 7 with Fig. 6(a): Crystallization of the BN interface, grain growth in SiC fibers, coarsening of SiC grains in the CVI SiC coating, and a gap at the BN/SiC fiber interface. Gap formation could be due to fiber shrinkage or due to differential etching during TEM specimen preparation. The EDX analysis across the interface indicates O₂ enrichment in the BN coating and at the interface of the BN/SiC coating, and carbon segregation at the surface of the SiC fiber. Figure 8(a) shows the

TEM micrograph of the Sylramic preform heat-treated at 1420 °C for 2 h in argon. Noticeable features in the micrograph are coarsening of SiC grains in the fiber, and partial recrystallization of amorphous BN coating. The SiC grains grew from ~100 nm (as-fabricated condition) to ~200 nm (heat-treated preforms). The BN coating contains rod like BN grains. Figure 8(b) is the TEM micrograph of the preform heat treated for 1 h at 1800 °C. When compared with the BN interface in Fig. 8(a), Fig. 8(b) shows greater amounts of the crystallized grains in the BN coating, larger SiC grains, migration of TiB₂ particles from the interior of the SiC fibers to the BN/SiC fiber interface, and Si-B-C islands in the Sylramic fibers.

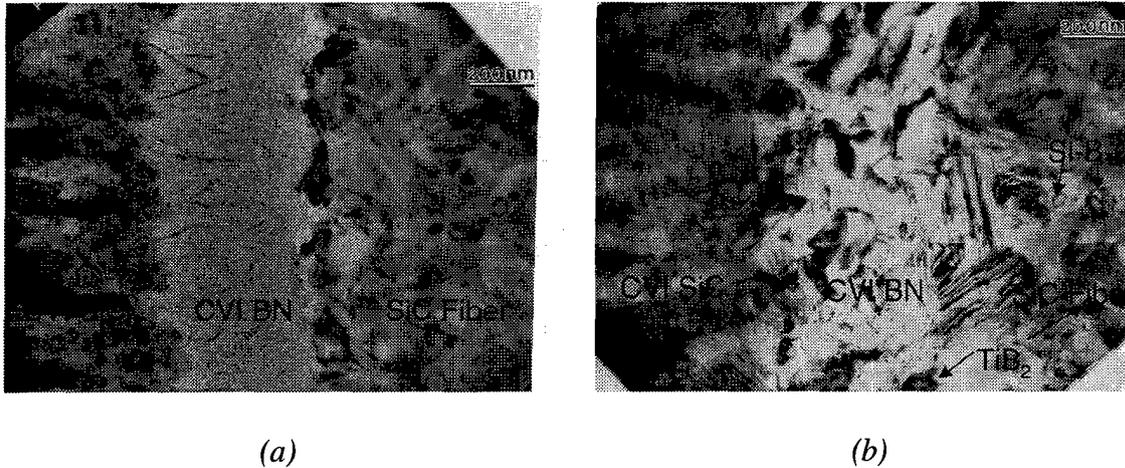


Fig. 8: TEM micrographs of the interface zone of the heat treated BN/SiC coated Sylramic preforms showing crystallization of BN coating and coarsening of SiC grains in the fibers. (a) 1420 °C for 2 hr; (b) 1800 °C for 1 hr.

DISCUSSION

Results of this investigation indicate that heat treatment of Hi-Nicalon and Sylramic preforms in argon above 1000 °C resulted in shrinkage, weight loss, microstructural changes in the constituents, and strength degradation. Although preform strength degradation mechanisms are not clearly understood, an attempt is made to explain weight loss and shrinkage based on the composition, microstructure, and processing temperatures of the preform constituents.

The Hi-Nicalon SiC fibers used in the preforms were processed by the melt spinning of polycarbosiline, followed by radiation curing and pyrolysis at ~ 1200 °C [2,3]. Based on the elemental analysis, the chemical composition of fiber can be represented as 91 wt% SiC and 9 wt% C [4]. The reported value of the C/Si atomic ratio is 1.3 [4]. Naslain et al [5] reported that the fiber contains β -SiC as 2-20 nm crystallites and excess elemental carbon. This is in agreement with the TEM results shown earlier in Fig. 6(a). On the other hand, the Sylramic fiber is processed at a temperature > 1600 °C and contains 95 wt% SiC, 3 wt% TiB₂, 1.3 wt% B₄C and 0.7 wt% O [5]. The fiber contains 0.1 to 0.5 μ m grains of β -SiC. The BN/SiC interface coatings of the Hi-Nicalon and Sylramic preforms were deposited by CVI at <1200 °C [6]. Physical property characterization results indicate that the preforms contain ~40 vol.% SiC fibers,

3-5 vol.% BN and 18-32 vol.% SiC coatings, and 20-40 vol.% open porosity. The BN coating is porous and the SiC coating is fully dense.

Microstructure of the constituents, physical dimensions, and strength of Hi-Nicalon and Sylramic preforms after 1 and 100 hr heat treatment up to 1200⁰ C remained nearly the same as those of the as-fabricated preforms. The only change observed under these exposure conditions is a small weight loss. This weight loss is probably related to moisture desorption. Large amounts of interconnected open porosity, and the porous BN coating in the preforms favor moisture adsorption. Although physical dimensions and pore volume are nearly the same, the Sylramic preforms show a greater tendency for moisture adsorption than the Hi-Nicalon preforms (cf Fig. 4). One possible reason is that TiB₂ and other silicon borides present in the fibers are more susceptible to moisture adsorption and dehydration than the SiC and carbon.

Upon heating the preforms above the processing temperature of the BN/SiC coatings or the SiC fibers, microstructural changes can occur. Time and temperature dependent shrinkage and weight loss, crystallization of the BN coating, and slight coarsening of grains in the SiC fibers and the SiC coating were the observed changes after exposing the preforms in argon at temperatures > 1000⁰C. Some of the suggested mechanisms for the weight loss and shrinkage are dissociation of chemically bound O₂ from the BN coating as volatile B₂O gas, dissociation of silicon carbide into silicon vapor and carbon on the surface of the SiC coating, and sintering of the constituents. Previous heat treatment studies have reported shrinkage, and strength degradation in Hi-Nicalon SiC fibers heat treated in inert environments for 1 hr at temperatures >1200⁰C [7,8]. The strength degradation in these fibers is primarily attributed to grain growth. On the other hand, the Sylramic fibers heat-treated in argon up to 1550⁰C for 10 hr do not show weight loss or strength degradation [5]. The weight loss seen in both preforms at least up to 1500⁰C appears to be related to dissociation of the BN/SiC coating by mechanisms as suggested earlier. Based on limited data, the strength degradation mechanism of Hi-Nicalon preforms appears to be related to grain growth in the fibers and crystallization of the BN interface. Although microstructural changes, weight loss, and shrinkage were observed in the Sylramic preforms heat-treated above 1000⁰C, only some preforms show strength degradation. Therefore, correlation between microstructure and strength is least understood in these preforms.

SUMMARY OF RESULTS

Microstructural characterization, and room temperature physical and tensile property measurements were performed on BN/SiC coated Hi-Nicalon and Sylramic SiC preforms heat treated in argon at temperatures to 1800⁰C for 1 and 100 hr. Key findings are as follows:

- (1) The Hi-Nicalon preforms are stable up to 1200⁰C. Beyond this temperature, the preforms showed weight loss, shrinkage, and strength degradation. The property degradation increased with increasing temperature and time. Probable causes of strength degradation are grain growth in the SiC fibers and crystallization of the BN coating.
- (2) The maximum heat treatment temperature without strength loss for Sylramic preforms can reach to 1600⁰C. However, between 1000⁰ and 1600⁰C some preforms showed strength

degradation and others did not. Preforms also showed dimensional changes and weight loss above 1400 °C.

- (3) In both preforms, microstructural changes were detected in the fiber and the BN interface for heat treatment above 1000 °C. With increasing temperature or time of exposure, the degree of crystallinity in the BN interface, and the grain size of SiC in the fibers also increased. The CVI SiC coating on top of the BN coating is stable after 1h heat treatment at 1800 °C. For longer time exposures at the same temperature, the morphology of the SiC coating converted from columnar to equiaxed grains.

REFERENCES

1. Johnson, A.M., Bartlett, B.J. and Troha, W.A., "Material Challenges and Progress Toward Meeting the High Speed Civil Transport Propulsion Design Requirements," *Proceedings of the 13th International Symposium on Air Breathing Engines*, Chattanooga, Tennessee, U.S.A., September 7-12, 1997, Vol. II, ISABE 97-7179, Billing. S., Ed, pp. 1321-1328.
2. Seguchi, T., Sugimoto, M. and Okamura, K., "Heat-Resistant SiC Fiber Synthesis and the Reaction Mechanism from Radiation Cured Polycarbosilane Fiber," *Proceedings of International Conference on High Temperature Ceramic Matrix Composites*, 1993, pp.51-57, ECCM-6, Bunsell, A.R, Kelly, A. and Massiah, A. Eds, Woodhead Publishing, Bordeaux.
3. Berger, A.H., Hochet, N. and Bunsell, A. R., "Microstructure and Thermo-Mechanical Stability of a Low Oxygen Nicalon Fiber," *J. Microscopy*, Vol. 177, 1995, pp. 230-241.
4. Takeda, M., Imai, Y., Ichikawa, H., Ishikawa, T., Kasai, N., Seguchi, T. and Okamura, K., "Properties of the Low Oxygen Content SiC Fiber on High Temperature Heat Treatment," *Ceram. Eng. Sci. Pro.*, No.12, 1991, pp. 1007-1018.
5. Lipowitz, J., Rabe, J.A, Zangvil, A. and Xu, Y., "Structure and Properties of Sylramic™ Silicon Carbide Fiber-A Polycrystalline, Stoichiometric-SiC Composition," *Ceram. Eng. Sci. Pro.*, No. 18, 1997, pp. 147-157.
6. Halada, J., AlliedSignal Composites, Private communications.
7. Yun, H.M. and DiCarlo, J.A., "High Temperature Contraction Behavior of Polymer-Derived SiC Fibers," *Ceram. Eng. Sci. Pro.*, No. 18, 1997, pp. 135-141.
8. Takeda, M., Imai, Y., Ichikawa, H., Ishikawa, T., Kasai, N., Seguchi, T. and Okamura, K., "Thermal Stability of the Low Oxygen Silicon Carbide Fibers Derived from Polycarbosilane," *Ceram. Eng. Sci. Pro.*, No.13, 1992, pp. 209-217.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (<i>Leave blank</i>)	2. REPORT DATE June 1999	3. REPORT TYPE AND DATES COVERED Technical Memorandum	
4. TITLE AND SUBTITLE Effects of High Temperature Argon Heat Treatment on Tensile Strength and Microstructure of BN/SiC Coated SiC Fiber Preforms		5. FUNDING NUMBERS WU-523-21-13-00 1L162211A47A	
6. AUTHOR(S) Ramakrishna T. Bhatt and Yuan L. Chen			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) NASA Glenn Research Center Cleveland, Ohio 44135-3191 and U.S. Army Research Laboratory Cleveland, Ohio 44135-3191		8. PERFORMING ORGANIZATION REPORT NUMBER E-11622	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001 and U.S. Army Research Laboratory Adelphi, Maryland 20783-1145		10. SPONSORING/MONITORING AGENCY REPORT NUMBER NASA TM-1999-209067 ARL-TR-1999	
11. SUPPLEMENTARY NOTES Prepared for the ICCM-12 sponsored by the L' Association pour les Materiauz Composites, Paris, France, July 5-9, 1999. Ramakrishna T. Bhatt, U.S. Army Research Laboratory, NASA Glenn Research Center and Yuan L. Chen, Dynacs Engineering Corporation, Inc., 2001 Aerospace Parkway, Brook Park, Ohio 44142 (work funded under NASA Contract NAS3-98008). Responsible person, Ramakrishna T. Bhatt, organization code 0300, (216) 433-5513.			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified - Unlimited Subject Category: 27 This publication is available from the NASA Center for AeroSpace Information, (301) 621-0390.		12b. DISTRIBUTION CODE	
13. ABSTRACT (<i>Maximum 200 words</i>) Preforms of BN/SiC coated Hi-Nicalon and Sylramic SiC fibers were heat treated under 0.1 MPa argon pressure between 1000° to 1800 °C for 1 and 100h. The effects of high temperature exposure on physical dimensions, weight, room temperature tensile strength, and microstructure of preforms have been studied. Both preforms showed shrinkage and weight loss, and microstructural changes beyond 1000 °C. After 100 hr exposure, the Hi- Nicalon preforms showed strength degradation beyond 1200 °C. The mechanisms of the strength degradation appear to be grain growth of the SiC fibers and crystallization of the BN coating. After 100 hr, the Sylramic preforms heat treated to 1000 °C retained their as-produced strength while some of those heat-treated between 1000° and 1800 °C showed strength degradation and others did not. At 1800 °C, the ultimate tensile strength decreased with increasing time of exposure. Reasons for strength degradation of Sylramic preforms are being investigated.			
14. SUBJECT TERMS SiC fibers; Preform; Microstructure; Tensile strength; BN/SiC interface		15. NUMBER OF PAGES 16	
		16. PRICE CODE A03	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT