The Fabrication of C/C Composites with Plasma Chemical Vapor Infiltration

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Introduction

Carbon/Carbon (C/C) composites are currently fabricated by using many cycles of resin or pitch impregnation followed by carbonization and high-temperature graphitization [1]. Chemical vapor deposition (CVD) is well adopted for the manufacture of C/C composites. The shortcomings of those methods include long processing time, high temperature, and large energy consumption. This paper presents a plasma chemical vapor infiltration process (PCVI) [2], where the reactor operates at low temperature and low pressure. This process can reduce processing time and achieve uniformly dense composites.

Experimental

1. Preform fabrication

PAN carbon cloth was immersed with novolac-added ground graphite (7% of carbon cloth), winded up outside the cover of cathode, cured, and carbonated (Ar, 50-920°C).

2. Infiltration Carbon with PCVI

The preform was covered upon the cathode in the pulse glow discharge depositing furnace, the heat shield was used as an anode. During the infiltration carbon process, the pressure was 400Pa, the voltage was 670V, the electric current was 2A, and the heated power was 150V*240A. The carbon source was propane (99.5% pure), the diluent gas was nitrogen, and the flow was 200mL/min respectively.

3. Characterization

The density of composite was measured in terms of volume and weight. The microstructure was determined by scanning electron microscopy.

Results and Discussion

The experimental result shows that the densities of C/C composites change from 0.85g/cm3 (preform) to 1.64g/cm3 after carbonated 15h. One can see that this process is superior to the ordinary one. In this PCVI, some of the limitations can be overcome by using the thermal gradient at the thickness direction of the sample. See Table 1[3].

This PCVI has less gas consumption and high infiltration efficiency. Dense C/C composites can be fabricated in a relatively short time. Scanning electron microscopy was used to determine if the infiltration was uniform throughout the thickness of the composites. The densification was found to be uniform, it was observed to be quite compact with strong bonding between fibers and matrix. Under high electric power, the energy E of second electron can be calculated by the formula:

$$E = \frac{e \cdot l \cdot U}{d}$$

where e is the second electron charge, l is the distance of freedom, U is the discharge voltage, and d is the thickness of cathode potential drop. Under the conditions of the experiment, U = 670V, the energy E can be calculated to be 600eV which is larger than the energy of C-C, C-H covalent bond. It causes the covalent bond of C-C C-H to break. Under this condition, the propane was pyrolyzed [5] to produce positive ions and small molecules which contained C H. Those high energy ions and molecules removed to cathode rapidly, forced a flow throughout the preform and repeatedly collided with fiber and matrix carbon, and finally deposited at high temperature region to form carbon. In plasma the propane decomposed and ionized more quickly and completely than CVD. So that the heat gradient process is superior to CVD, and has a homogeneous structure and a high depositing rate.

Time (hour)	2	3	3	3	4
Surface temperature (°C)	855	905	925	955	985
Intra temperature (°C)	945	955	1015	1045	1075

Table 1. The infiltration process of carbon

Conclusions

The following conclusions were drawn from the present work:

1. In this PCTI the propane decomposed and ionized more quickly and completely. Dense carbon/carbon composites can be fabricated in a relatively short time.

2. In this PCVI, it is necessary by using the thermal gradient at the thickness direction of the sample.

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