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HARBIN INSTITUTE OF TECHNOLOGY

ABLATION RESISTANCE AND MECHANICAL PROPERTIES OF OVERALL STRUCTURE CONTINUOUS GRADIENT CERAMICS-POLYMER BIONIC COMPOSITE

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preface

ABSTRACT

Due to the need of the integration of heat insulation and load-bearing for the surface materials of hypersonic vehicles, higher requirements are put forward on the ablation resistance and mechanical properties of the functional gradient composite materials under large temperature conditions. Inspired by the continuous gradient of animal bone and the bamboo structure materials composition. A novel overall structure continuous gradient ceramics-polymer bionic composite was proposed. A three-dimensional carbon fiber prefabricated reinforced ceramic polymer gradient composite was designed, and the density change in the thickness direction decreased from top to bottom. A unidirectional heat transfer system of electromagnetic induction heating was designed to prepare ceramic/polymer continuous graded composites.

Keywords

Variable density composite

Continuous gradient

Ceramics

Ablation resistance

List

CONTEXT

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INTRODUCTION

3-High temperature load
large temperature gradient

2-Short time pneumatic
heating to high temperature

4-High temperature high low temperature
alternating cycle thermal shock/ablation

1-High mobility
(high Mach number)

5-High temperature gas erosion
erosion failure. Complex
environment (oxidation, etc.)

Inspired by the gradient material

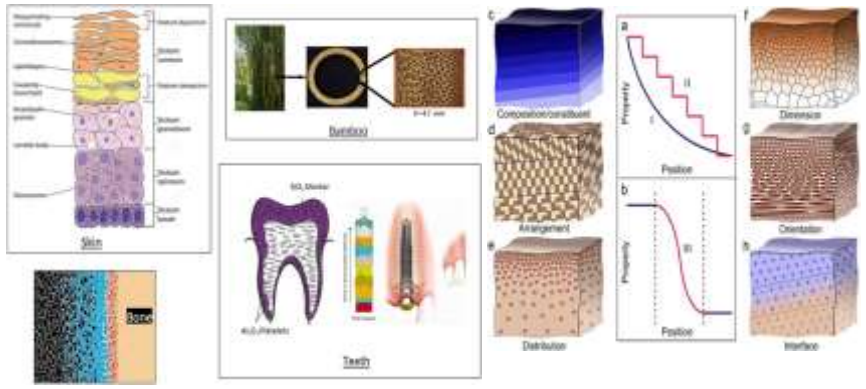
Challenges faced by thermal protection materials:

- Conventional thermal protection materials often face the problems of thermal stress concentration and thermal short circuit
- The design contradiction between the thermal insulation unit and the mechanical bearing unit exists in conventional thermal protection materials
- Thermal stress can not be released slowly, thermal shock resistance is poor, easy to appear stratified damage.

The gradient materials is a novel composite material whose composition and structure present continuous gradient variation. It is a type of heterogeneous composite whose composition and structural properties vary continuously or quasi-continuously in the direction of material thickness or length. Composites whose properties generally vary with internal position.

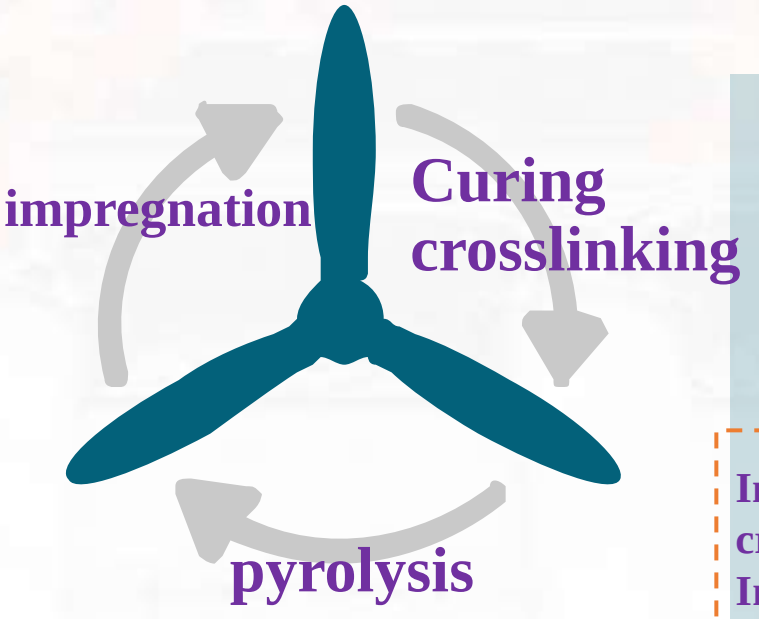
The concept of gradient can overcome design defects in thermal protective materials

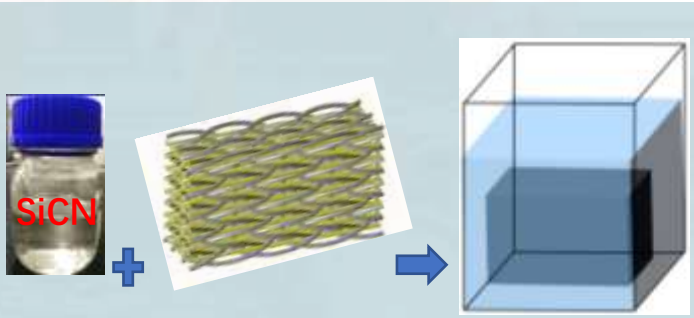
eg.



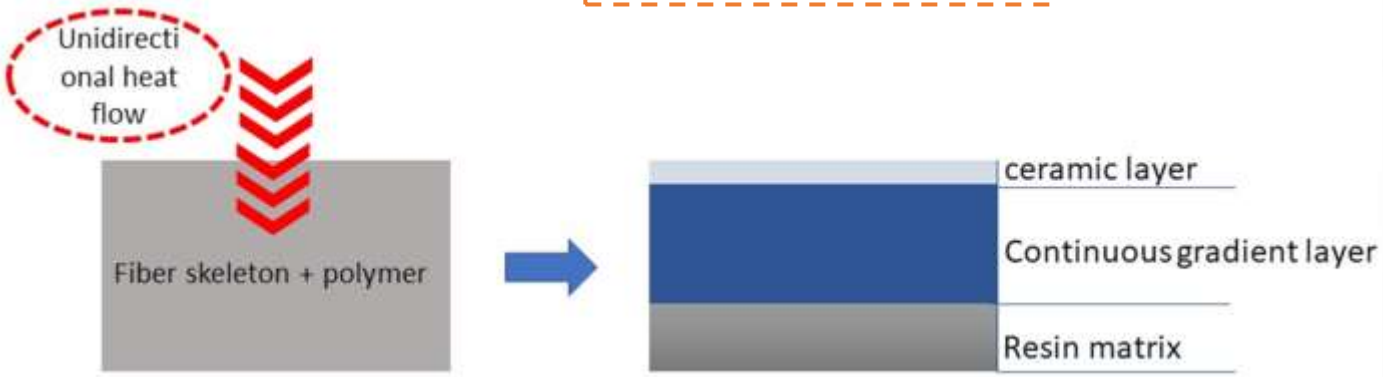
Main content

- Based on Polymer Derived Ceramics, PDCs, and Polymer Ipregnation Pyrolysis, PIP. the ceramic polymer continuous gradient composite was designed by using the precursor of polyborosilazane ceramic and the prefabricated three-dimensional braided body.
- The three-dimensional braided body was impregnated in the liquid precursor resin for 10h by vacuum impregnation.
- Low temperature curing crosslinking was completed by drying oven, and the heat was kept at 180℃ for 120min under argon.
- The pyrolysis process is completed by using the unidirectional heat transfer pyrolysis test device built by ourselves, forming the ceramic - polymer continuous gradient material.



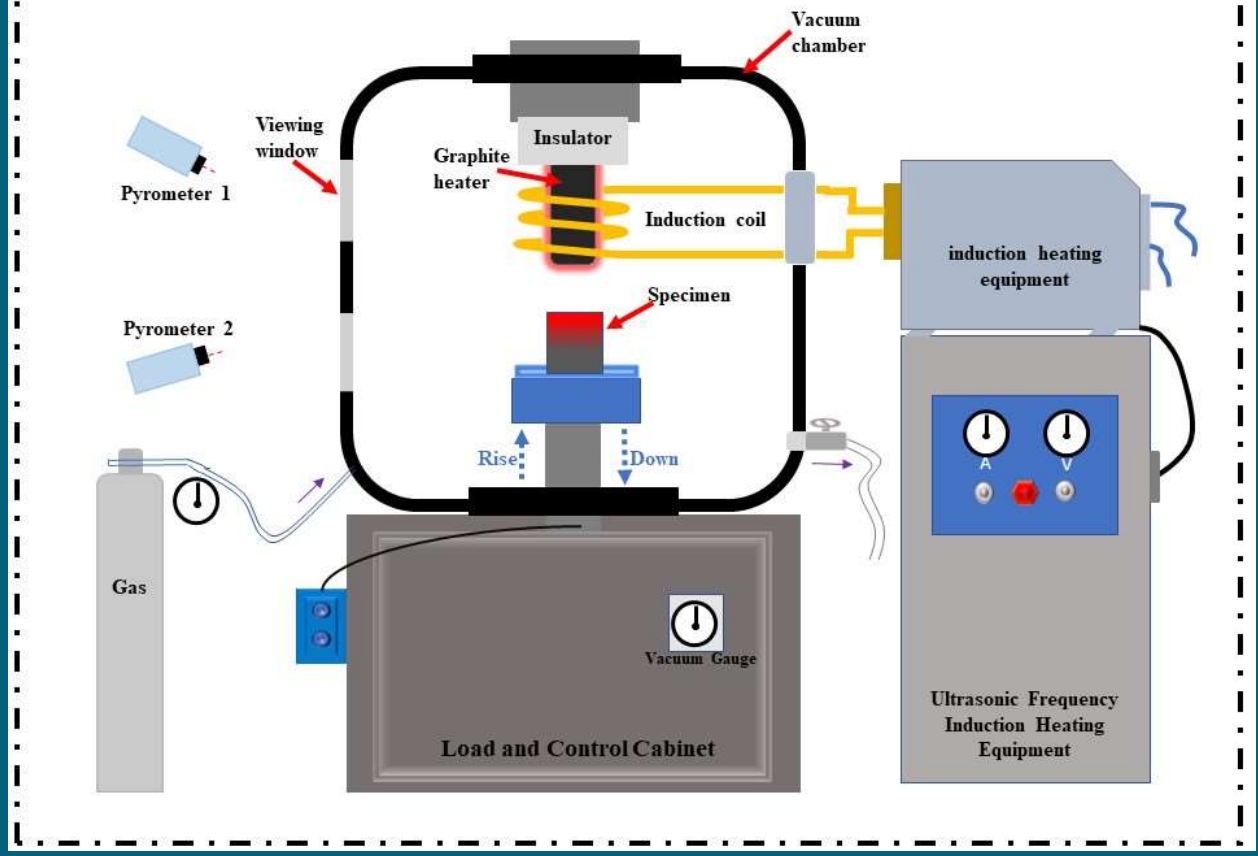


Impregnation-cure crosslinking conditions:
Impregnation: Vacuum, 10h
Curing: Ar, 180℃



Main content

- Heating rate controllable induction heating equipment (The test equipment built by oneself)
- Rapid surface pyrolysis in one direction (Fast heating speed)
- The heating atmosphere is controllable(Ar, N_2, O_2, etc.)



(The test equipment built by myself)

Main content

Basic performance

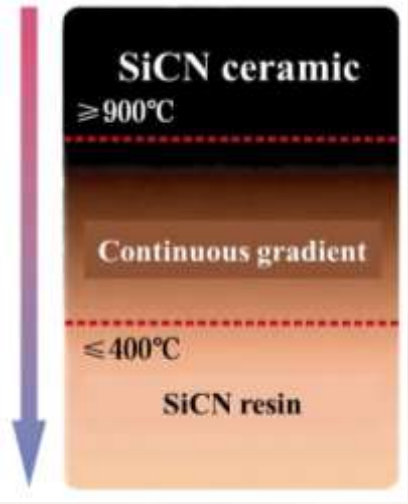
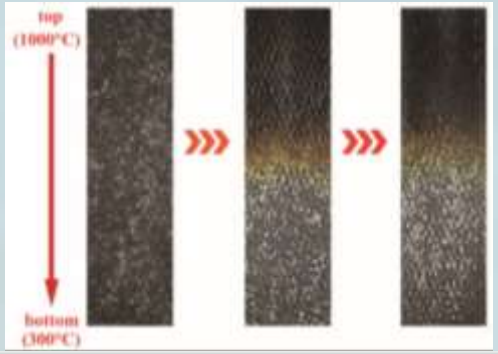
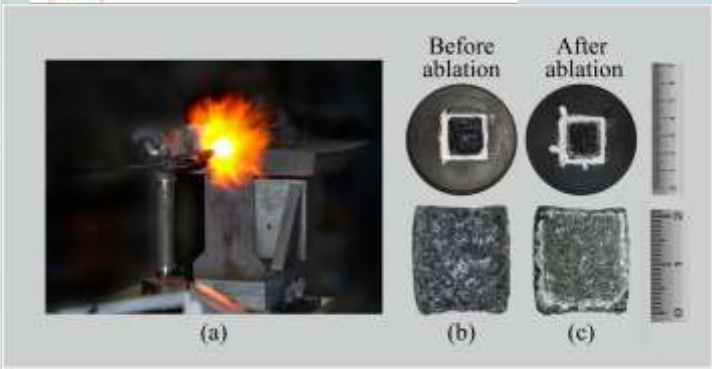


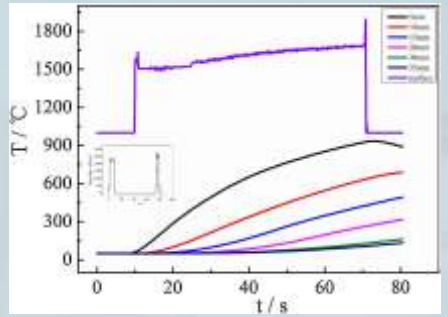
Diagram of ceramic - polymer continuous gradient structure

- Gradient material volume density variation range (1.76–1.43 g/cm^3)
- The chemical composition of gradient material shows continuous gradient change in thickness direction
- The ceramic layer has good anti-heat insulation performance, and the bottom resin layer has good load-bearing performance

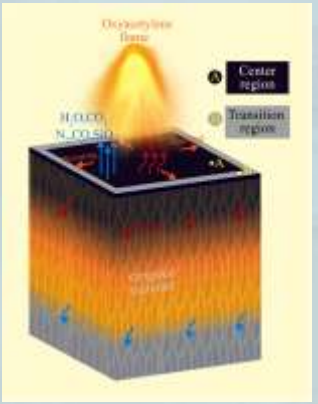


Oxy-acetylene ablative conditions:
Heat flow - 2.38 MW/m^2
Flame distance -10mm





- ✓ The surface ablation temperature is above 1500℃, and the back temperature is less than 150℃
- ✓ There is no obvious ablative pit on the ablative surface



conclusions

1

- ✓ A successful preparation of continuous gradient ceramic–polymer gradient composite.

2

- ✓ The SEM analysis results showed that the surface of the material had a clear partition morphology and that it was covered by molten SiO2.
- ✓ The ablation resistance of the gradient material was remarkable

3

- ✓ The polysilazane coating and amorphous SiCN ceramics provided good surface protection.
- ✓ The 3D carbon fiber braid was used as a reinforcement to transmit surface loads and provide good mechanical support.

➢ **It provides a new solution to the problem of thermal mismatch and thermal short-circuit caused by the performance difference between materials.**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Thanks!

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