Thermal Durability of Bonded Interface between SiC and Tungsten for Nuclear Application

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Abstract
Applications of ceramic materials to LWRs, GFR, Fusion reactors and even irradiation testing of those, bonding/jointing technologies with metal/alloy are generally required. Among many joining methods, solid-state bonding, brazing/soldering and laser/electron beam welding are currently under R & D as potential candidates. This study focuses SiC/SiC composite material as a potential candidate for nuclear systems, where bonding with varieties of metals should be identified and established. This presentation covers bonding interface characterization and stability of W-SiC bonded panel. Bonding technology for W and SiC will be applied for fuel pin/reactor internals of LWR and GFR and divertors/arms of fusion reactors. As a fundamental and scoping research W and SiC panels were bonded by solid-state method. The characterization of W-SiC interface has been done micro-structural and micro-mechanical methods and those results are presented. Also thermal durability tests results are presented.

Bonded panel of W and SiC for nuclear application Previous study of bonding between metal and SiC

Objective
To provide basic thermal durability of W-SiC bonded panels under R & D at elevated temperatures.

The durability evaluation by two simulation condition; short term at higher temperature and long term at lower temperature.

The mechanical evaluation by shear strength and nano-hardness before and after the thermal durability test.

Experimental

- Outline of fabrication method for the bonded panel
  
  SiC plate, Hexoloy SiC (u-SiC)
  
  W plate, 99.9% purity, sintered and rolled

- Outline of TDT (thermal durability test)
  
  Specimen size : 2x2x3mm
  
  High temperature for short-time (HS)
  
  Temperature : 1400°C-1600°C
  
  Holding time : 1-20h
  
  Atmosphere : Vacuum
  
  Low temperature for Long-time (LL)
  
  Temperature : 800°C-1000°C
  
  Holding time : 100-200h
  
  Atmosphere : Vacuum

- Evaluation/Analysis
  
  Microstructure
  
  FE-SEM
  
  EPMA

- Nano indentation hardness
  
  (For TDT-HS)

- Resistivity measurement
  
  (For TDT-LL)

Results

- Microstructure and Mechanical property evolution of W-SiC bonded panel by TDT-HS

  Before TDT
  
  Columnar structure extend from the interface to W. After TDT-HS
  
  Reaction phase near the interface is disappeared and that is changing to large or fine grains. The columnar structure was unstable at 1500°C exposure in a vacuum. However a thin uniform multi-grain layer was generated.

- Microstructure and Mechanical property evolution of W-SiC bonded panel by TDT-LL

  Before TDT
  
  Columnar diffusion layer, consists of SiC rich phase and C rich phase, extends in W. Diffusion distance of SiC phase and C phase are controlled by reaction with W.

  After TDT-HS
  
  Contrast of O and Si disappeared or faded indicating evaporation of C and Si at the surface.

  The columnar structure was disappeared and thin layer of W-C phase was detected.

Summary

- The fabrication of W-SiC solid-state bonded panel was successfully accomplished without inserts nor special surface treatment.

- The excellent thermal durability of W-SiC bonded panel was anticipated by the thermal durability test through the stability of the reaction phase.

- As the next step of the W-SiC bonded panel R & D, two experimental plans are under planning; the short term high heat flux test by plasma exposure and the long term thermal durability test as was done here.

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