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# The Effects of Neutron Irradiation on Thermal Properties of $SiC_f/SiC$ CMC: An overview

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**Abstract:** $SiC_f/SiC$ CMC are under investigation to work in a high temperature, highly radioactive and corrosive environment with superior thermal oxidation resistance in both fission and fusion type nuclear power plants. This paper gives a review on the effects of neutron irradiation on major thermal properties like thermal diffusivity, defect thermal resistance of $SiC_f/SiC$ composites fabricated with HNLS, Tyranno fibers fabricated by CVI process. Thermal diffusivity/conductivity of $SiC_f/SiC$ composites primarily depend on irradiation temperature. Following neutron irradiation at high temperature, HNLS fiber reinforced CMC shows instant fluctuation in thermal diffusivity. As irradiation temperature increases from 400°c to 500°c, Hi-Nicalon fibers show a steep decrease in defect thermal resistance while that of very limited decrement in defect thermal resistance of Tyranno fiber composites. The SIA of both Si and C types generated due to high temperature irradiation plays major role in deciding effect on thermal properties of $SiC_f/SiC$.
**Keywords:** Ceramic-matrix composites (CMC); Chemical vapour infiltration (CVI);Hi-Nicalon Type -S Fiber (HNLS); Self interstitial atoms (SIA).Tyranno SA3(SA3).

## Introduction and Irradiation Thermal Properties [1-8]:

$SiC_f/SiC$ composites are under investigation to use in nuclear environment. In both fusion and fission type reactor, high in energy high speed electron impact on material, it alters microstructures, inducesdefects like frankel defects,antisite defects in both Si and C sub lattices.This affects to CTE,conductivity which redistributes residual stressescausingdebonding between fiber and matrix which affects mechanical properties.In fiber reinforced CMC interphase also plays important role. YutaiKatoh [8] fabricated samples with CVISiC-matrix, woven SiC-fiber ofHNLS and SA3 SiC with pyrocarbon/SiC multilayeredinterphase. Then Specimens irradiated up to 5.3 dpa.Post irradiation conductivity and diffusivity values are summarized in Table 1.Same are plotted inthe figure 1 and 2.It will clear from the figures that up to the point of thermal recovery of irradiation produced defects; the composite specimens are showing linear interdependence betweenreciprocal thermal diffusivity and temperature.HNLS composites show less ambienttemperature thermal diffusivity than SA3.Effect of neutrn irradiation is intense for HNLS composite. Also at higher temperature i.e. above 800°c, there is instant fluctuation in thermal diffusivity. The defect thermal resistance i.e. the difference in reciprocal thermal conductivity before and after irradiation,(1/K unirr and 1/K irrad), respectively of both composites is as shown below (8).The defect thermal resistance ofTyranno composite sample decreases limited as the irradiation temperature increases. While in case of Nicalon type composite, it decreases very steeply.$SiC_f/SiC$ composites with higher density have better conductivity and it shows larger reduction of thermal diffusivity .In case of lower density materials, gas is trapped in pores which act asheat barrier and irradiation has not any significant effect on diffusivity of pores as compared that withfibers and matrix.For the near-stoichiometric SiC composite materials. Y. Katoh [2] confirmed that Irradiationhas minute effect on coefficient of thermal expansivity.

**Table 1.** Post irradiation conductivity and diffusivity

| Condition | Thermal diffusivity (HNLS) $m^2/s$ | Thermal conductivity (HNLS) W/m-K | Thermal diffusivity (Tyranno) $m^2/s$ | Thermal conductivity (Tyranno) W/m-K |
|---|---|---|---|---|
| 440 °C 0.8 dpa | $0.9\times10^{-6}$ | 1.3 | $2.3\times10^{-6}$ | 3.8 |
| 450 °C 2.0 dpa | $1.0\times10^{-6}$ | 1.5 | $2.0\times10^{-6}$ | 3.3 |
| 500 °C 3.0 dpa | $1.4\times10^{-6}$ | 2.4 | $2.4\times10^{-6}$ | 3.9 |
| 860 °C 5.3 dpa | $1.6\times10^{-6}$ | 2.6 | $4.3\times10^{-6}$ | 7.3 |
| 850° C 3.5 dpa | $1.5\times10^{-6}$ | 2.4 | $3.3\times10^{-6}$ | 5.6 |

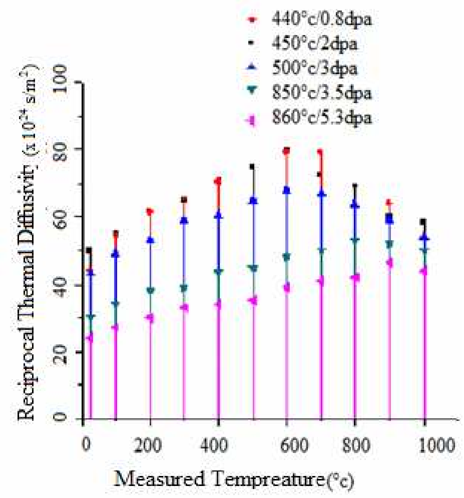
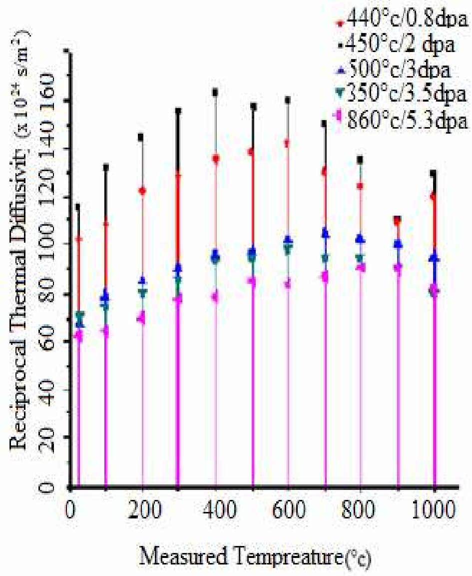



**Fig: 1** Reciprocal Thermal Diffusivity of Tyranno composite



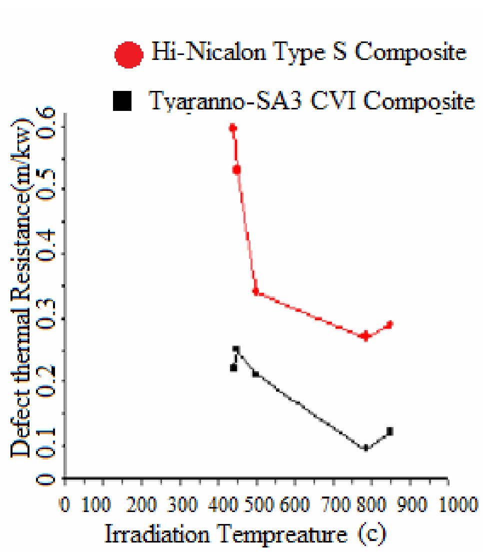




**Fig:2** Reciprocal Thermal Diffusivity of Hi-Nicalon Type-S Composite

**Fig:3** Defect Thermal Resistance of composites

CTE decrease over the entire temperature range after irradiation at 830°c for the composites with both fiber types, possibly indicating the effect of lattice swelling on thermal expansion. The change in thermal conductivity during irradiation saturates at relatively low fluence levels.

## **Conclusions**:

Density of composites, fiber types it's bonding with matrix,interface in between them plays major role in deciding the thermal properties of samples at different irradiation condition.Nicalonfibres shows the better radiation thermal resistivity as compared to other fibers.In case of both Hi-Nicalon and Tyranno composite, reciprocal thermal diffusivity shows increment upto irradiation temperature of 450°c to 550°c and then it start to decrease at high irradiation temperature.The thermal diffusivity of specimens found to decrease with irradiation temperature.Defect thermal resistance of HNLS composite decreases sharply at 400°c to 500°c irradiation temperature while that of Tyranno composites picks up. At irradiation temperature of beyond 500°c,defect thermal resistance of both composite decreases but in case of Tyranno composite decrement is steep. Self interstitial atoms generated due to high irradiation dose and high working temperature is the major defect producing cause which affects more in case of thermal properties which in turn causes the problems like generation of residual stresses volumetric swelling, crack propagation and other changes in mechanical properties. So it can be concluded that various defects causing degradation in thermal conductivity has different aspect of contribution for Nicalon and for Tyranno composite and this is due to difference in impurities.This observation indicates that the materials with the greater as-fabricated thermal resistivity develop the greater radiation defect thermal resistivity for a given irradiation condition.

## **References:**


1. C.P. Deck, H.E. Khalifa, B. Sammuli, T. Hilsabeck, C.A. Back, "Fabrication of SiC/SiC composites for fuel cladding in advanced reactor designs" Progress in Nuclear Energy, 2012, 57, 38-45.
2. YutaiKatoh , Kazumi Ozawa , Chunghao Shih, Takashi Nozawa, Robert J. Shinavski Akira Hasegawa, Lance L. Snead, "Continuous SiC fiber, CVI SiC matrix composites for nuclear applications: Properties and irradiation effects" Journal of Nuclear Materials, 2013.
3. Lars Hallstadius, Steven Johnson, Ed Lahoda,"Cladding for high performance fuel" Progress in Nuclear Energy, 2012,57, 71-76.
4. C.R.F. Azevedo, "Selection of fuel cladding material for nuclear fission reactors," Engineering Failure Analysis. 2011,18, 1943–1962,
5. R. Naslain. Design, "Preparation and properties of non-oxide CMCs for application in engines and nuclear reactors: an overview," Composites Science and Technology. 2004, 64, 155–170.
6. A. Hasegawa , A. Kohyama , R.H. Jones, L.L. Snead d, B. Riccardi, P. Fenici, "Critical issues and current status of SiC/SiC composites for Fusion," Journal of Nuclear Materials. 2000, 283-287, 128-137.
7. George Newsome, Lance L. Snead , Tatsuya Hinoki, YutaiKatoh, Dominic Peters, "Evaluation of neutron irradiated silicon carbide and silicon carbide composites," Journal of Nuclear Materials. 2007.371, 76–89.
8. YutaiKatoh, Lance L. Snead, Takashi Nozawa, Sosuke Kondo, Jeremy T. Busby, "Thermophysical and mechanical properties of near-stoichiometric fiber CVISiC/SiC composites after neutron irradiation at elevated temperatures" Journal of Nuclear Materials, 2010,403,48–61.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