RADIATION RESPONSE OF SIC-BASED FIBERS - G. E. Youngblood and R. H. Jones (Pacific Northwest National Laboratory)*, Akira Kohyama (Institute of Advanced Energy, Kyoto Japan) and L. L. Snead (Oak Ridge National Laboratory)

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EXTENDED ABSTRACT

The radiation response of a base-line silicon carbide composite (SiC/SiC) made with Nicalon™ CG fiber reinforcement was presented for a broad range of dose and irradiation temperatures. Strength loss in this composite and a similar composite made with Tyranno™ fiber was related to shrinkage and a predicted mass loss in the Nicalon CG or Tyranno fibers. In Table 1, measured relative density and length changes ($\Delta p/p_o$ and $\Delta L/L_o$, respectively) for coated and uncoated fibers irradiated at high doses and temperatures (43 dpa-SiC at 1000°C and 80 dpa-SiC at 800°C) are given. Also given are the relative mass loss changes $\Delta m/m_o$, calculated from $\Delta p/p_o$ and $\Delta L/L_o$ by the expression $\Delta m/m_o \approx 3\, \Delta L/L_o + \Delta p/p_o$.

Table 1. Comparison of measured relative density and length changes and calculated mass changes for coated and uncoated SiC fibers irradiated to 43 dpa-SiC at 1000°C and to 80 dpa-SiC at 800°C.

Fiber Type	**$\Delta p/p_o$ 43 dpa (%)**	**$\Delta p/p_o$ 80 dpa (%)**	**$\Delta L/L_o$ 43 dpa (%)**	**$\Delta L/L_o$ 80 dpa (%)**	**$\Delta m/m_o$ 43 dpa (%)**	**$\Delta m/m_o$ 80 dpa (%)**
Tyranno	+11.7	12.6	-5.6	-4.8	-5	-2
Tyranno+PyC[1]	**+12.0**	**+12.5**	**-16.6**	**-32.4**	**-38**	**-84**
Nicalon CG	+9.9	+9.7	-3.4	-3.9	-0.3	-2
Nic CG + BN[1]	+12.4	+9.8	-3.0	-3.4	-3	-0.4
Nic CG+PyC[1]	**+9.9**	**+11.3**	**-7.1**	**-8.9**	**-11**	**-15**
Hi Nicalon	+6.3	+10.2	-4(2)*	-4.1	-6	-2
Dow X	-0.2	+1.6	-1.5	+1(2)*	-5	+5

[1] The boron nitride (BN) and PyC coatings were 150 nm thick.
* Unusually large length uncertainties given in parenthesis.

From this table, it is easy to see that the fiber mass loss, related to a carbothermal reduction of the excess oxygen in the Tyranno and Nicalon CG fibers, is enhanced by the pyrocarbon (PyC) coating. For these irradiation conditions, crystallization and crystal growth also were observed to have taken place at the Nicalon CG and Hi Nicalon fiber surfaces by SEM (see Fig. 1) and in the bulk by XRD.

In Figure 2, the measured densities are given for four categories of SiC-based fibers irradiated over four decades of fluence. The four fiber categories are: (1) "amorphous fibers with excess carbon and oxygen content," represented by Tyranno; (2) "more crystalline fibers than Tyranno,

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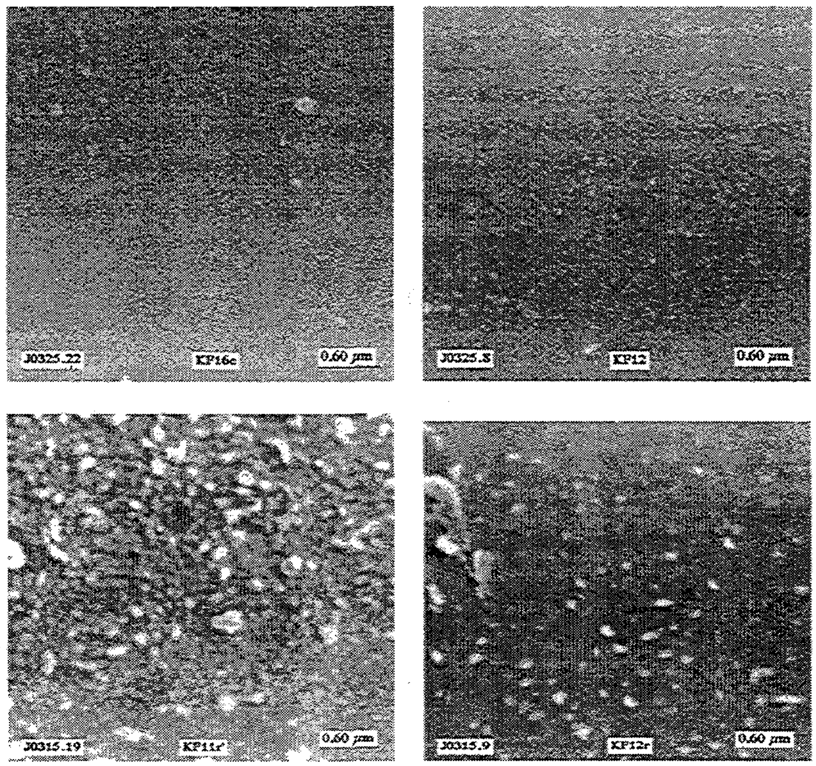

Figure 1. SEM views of unirradiated (upper) and irradiated (lower) fiber surfaces (Nicalon CG, left and Hi Nicalon, right) showing crystallization and crystal growth due to the irradiation conditions.

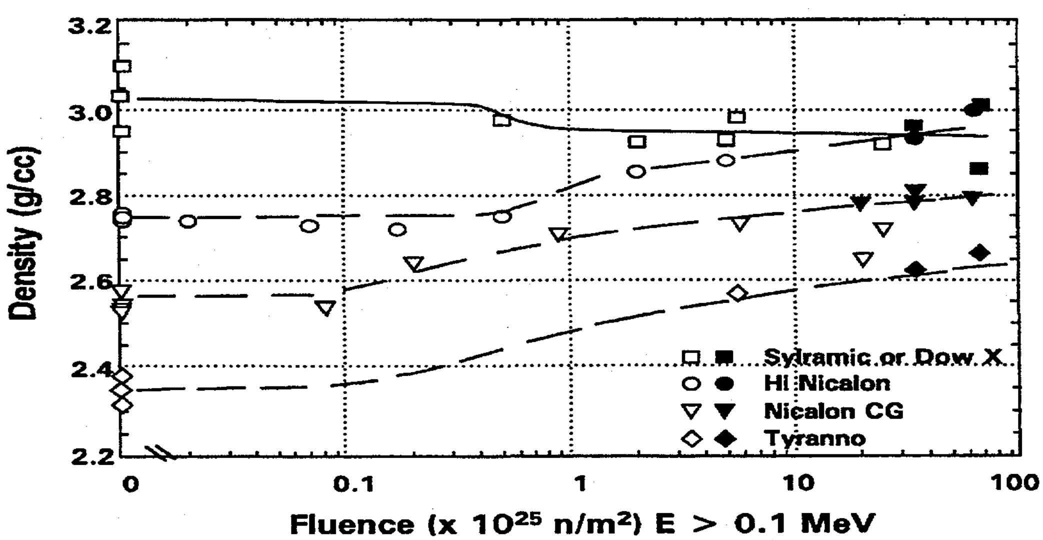

Figure 2. Density as a function of fluence for four categories of irradiated (uncoated) SiC-based fibers. As a rough rule, a fluence of 1 x 10^{25} n/m^2 (E > 0.1 MeV) is equivalent to 1 dpa-SiC dose.

but with excess carbon and oxygen content," represented by Nicalon CG; (3) "relatively all crystalline fiber with low oxygen, but with excess carbon," represented by Hi Nicalon; and (4) "crystalline fibers with essentially stoichiometric SiC compositions," represented by Dow X (an early version of now available Dow Sylramic™ fiber).

The guidance lines in Fig. 2 indicate similar increases in density with fluence up to 69 x 10^{25} n/m^2 (≈80 dpa-SiC) for the three non-stoichiometric SiC fiber categories. In contrast, the Dow X stoichiometric SiC fiber indicates slightly decreasing densities with fluence.

Although the Hi Nicalon fiber exhibited similar dimensional instability when compared to Nicalon CG or Tyranno fibers (Table 1 and Fig. 2) and crystal growth (Fig. 1), it should not be subjected to degradation by internal carbothermal reduction since it does not contain excess oxygen. Nevertheless, long-term degradation of irradiated Hi Nicalon fiber due to crystallization and crystal growth indicates that composite made with this fiber will not exhibit acceptable radiation tolerance. In contrast, a crystalline fiber with stoichiometric SiC composition (Dow X) exhibited only slight swelling, which is similar to that observed for irradiated monolithic SiC. Thus, in a composite, this type of fiber should not exhibit shrinkage and debonding from the matrix. However, the effects of irradiation on strength for these fibers still needs to be examined.