TRANSMUTATIONS IN SiC IRRADIATED IN ARIES-IV FIRST WALL- H. L. Heinisch
(Pacific Northwest National Laboratory*)

OBJECTIVE

The objective of this task is to determine the burn-out limit of neutron irradiated SiC.

SUMMARY

The change in concentrations of elements due to transmutations resulting from neutron irradiation in the first wall of the ARIES-IV conceptual fusion energy device were determined as a function of neutron dose. SiC burns out at a rate of about 0.5% per effective full power year. The largest impurity concentration is that of He, but several other elements burn in at rates of hundreds of appm/efpy.

PROGRESS AND STATUS

Transmutation calculations were performed for pure SiC irradiated in the neutron spectrum of the first wall of the ARIES-IV conceptual fusion energy device using the REAC-3 code with FENDL-2.0 nuclear cross sections.

The ARIES-IV first wall has a total neutron flux of 3.6×10^{15} n/cm^2-s and a fast flux (E>0.1 MeV) of 1.9×10^{15} n/cm^2-s. Calculations were performed for a continuous irradiation of up to 12 effective full power years (efpy) to a total neutron dose of 1.37×10^{24} n/cm^2. The elemental composition of the material is not significantly affected by the post-irradiation decay of radioactive isotopes, since they are either too short-lived or too long-lived to affect the composition over a reactor lifetime.

<u>SiC Burn out.</u> In this neutron spectrum, Si burns out somewhat more rapidly than C (Fig. 1), so the Si content controls the stoichiometry of neutron irradiated SiC. Si, hence SiC, burns out at a rate of about 0.0047/efpy. A 3% burnout of SiC has been suggested as a desirable design goal for SiC composites. In ARIES-IV a 3% burnout occurs in about 6.5 efpy (total neutron fluence 7.4×10^{23} n/cm^2).

The differing burnout rates of Si and C result in an excess concentration of carbon totaling about 3500 appm after 6.5 efpy . The Si and C burnout rates are constant, and the excess C increases at the rate of 540 appm excess C/efpy.

<u>Impurity Burn in.</u> The most abundant transmutation products, which burn in at constant rates (Fig. 2), are the following:

Element	Burn-in Rate (appm/efpy)	Concentration at 6.5 efpy (at%)
He	6384	4.2
H	2307	1.5
Mg	1630	1.1
Be	632	0.4
Al	469	0.3
P	146	0.1

* Pacific Northwest National Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under contract DE-AC06-76RLO-1830.

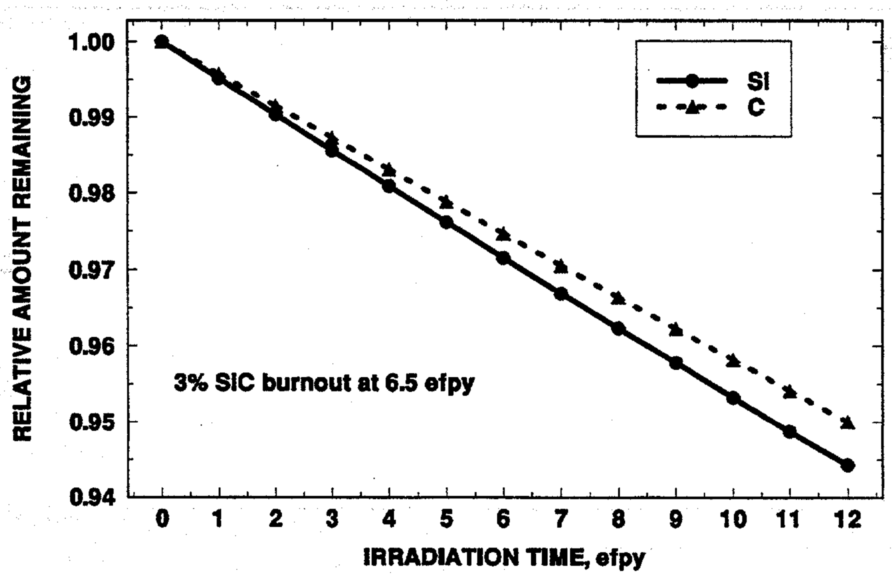

Figure 1. The burnout of Si and C in SiC irradiated in ARIES-IV first wall as a function of dose in effective full power years.

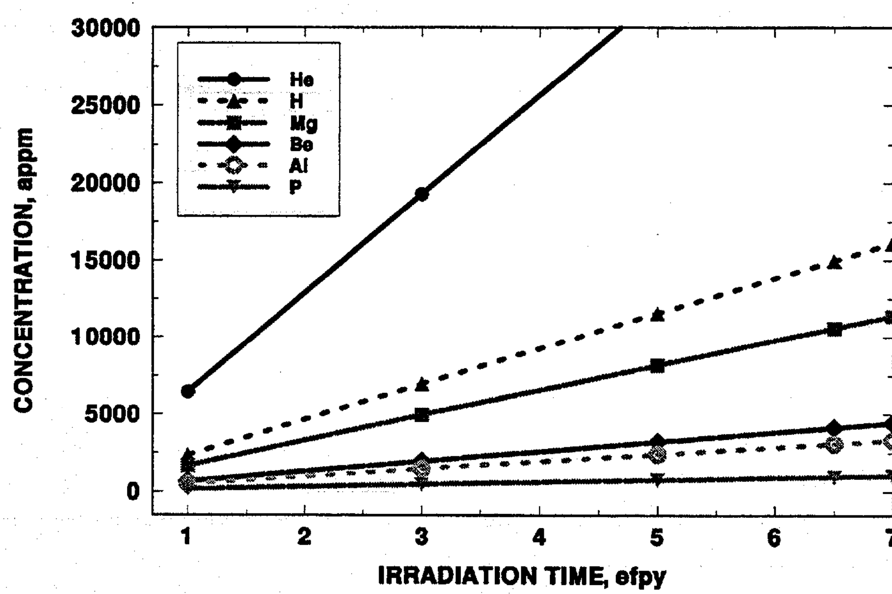

Figure 2. Concentrations of transmutation products in SiC irradiated in ARIES-IV first wall as a function of irradiation time in effective full power years.

After 6.5 efpy, although 3% of the SiC burns out, the concentration of transmutant atoms totals almost 8%. This is because many transmutation reactions create additional H or He atoms, which causes the total number of atoms in the system to increase.

Several other elements burn in through two-step transmutations, so they accumulate nonlinearly as the square of the irradiation time. Their concentrations are relatively small compared to the transmutants discussed above (Fig. 3). The concentrations of elements produced by two-step transmutations after 6.5 efpy are listed below.

Element	Concentration at 6.5 efpy (appm)
Ne	78
S	8
Na	7
Li	4

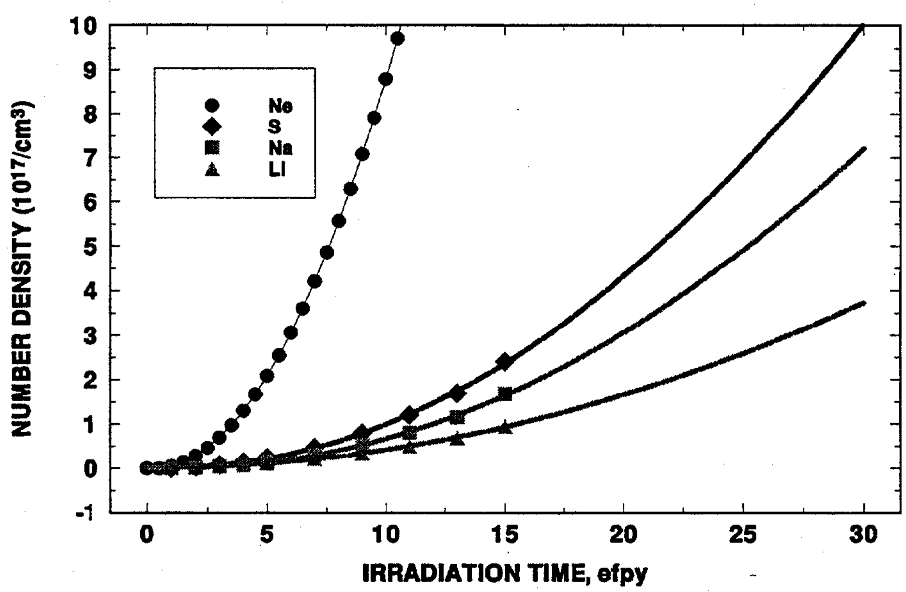

Figure 3. Number density of transmutation products in SiC that result from multiple interactions of a nucleus with neutrons in the ARIES-IV first wall as a function of irradiation time in effective full power years

Of the elements identified as transmutation products in this report, only Al and Na are also considered as possible intrinsic impurities in unirradiated SiC. After only one effective full power **day** the concentration of Al due to transmutation is greater than its typical concentration as an intrinsic impurity. The same is true for Na after 4 efpy Thus, transmutations are responsible for creating an additional set of radiation-induced impurities, having dose-dependent concentrations, that is entirely different from the set of intrinsic impurities.

FUTURE WORK

The effect on the phase stability of SIC due to the burnout of SiC and the build up of excess C under fusion first wall neutron irradiation needs to be examined. Additional calculations have shown that the burnout rate of SiC in neutron spectra typical of fission reactor test facilities (HFIR PTP and EBR-II Row 2) is about one tenth the burn out rate in fusion reactors at the same fast fluence (E>0.1 MeV). The effects of impurities produced in SiC by nuclear transformations also need to be assessed.

ACKNOWLEDGEMENTS

The author is indebted to Laila El-Guebaly, Fusion Technology Institute, University of Wisconsin – Madison, for providing a copy of the ARIES-IV first wall neutron spectrum.