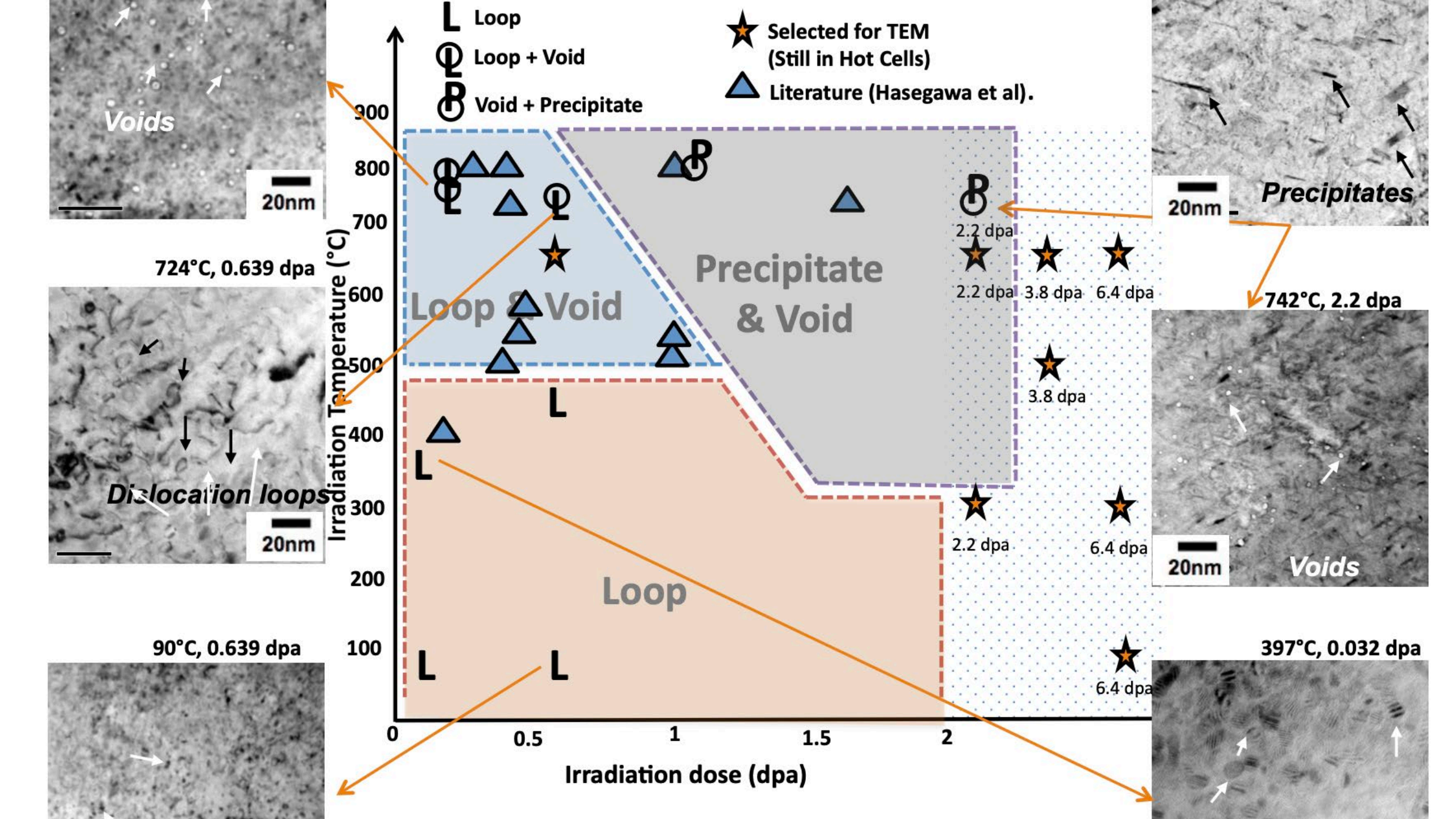
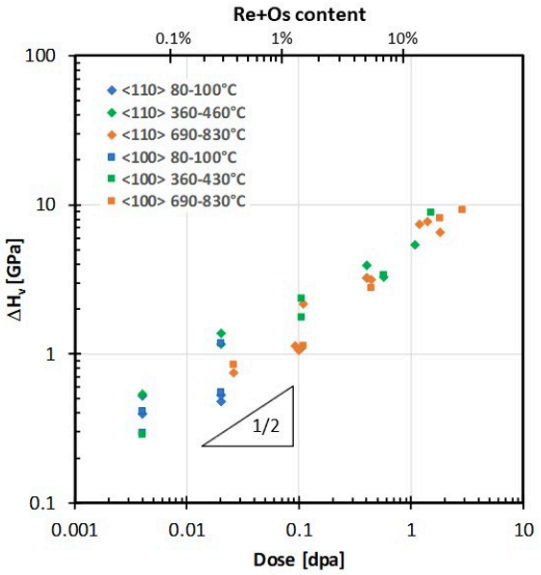
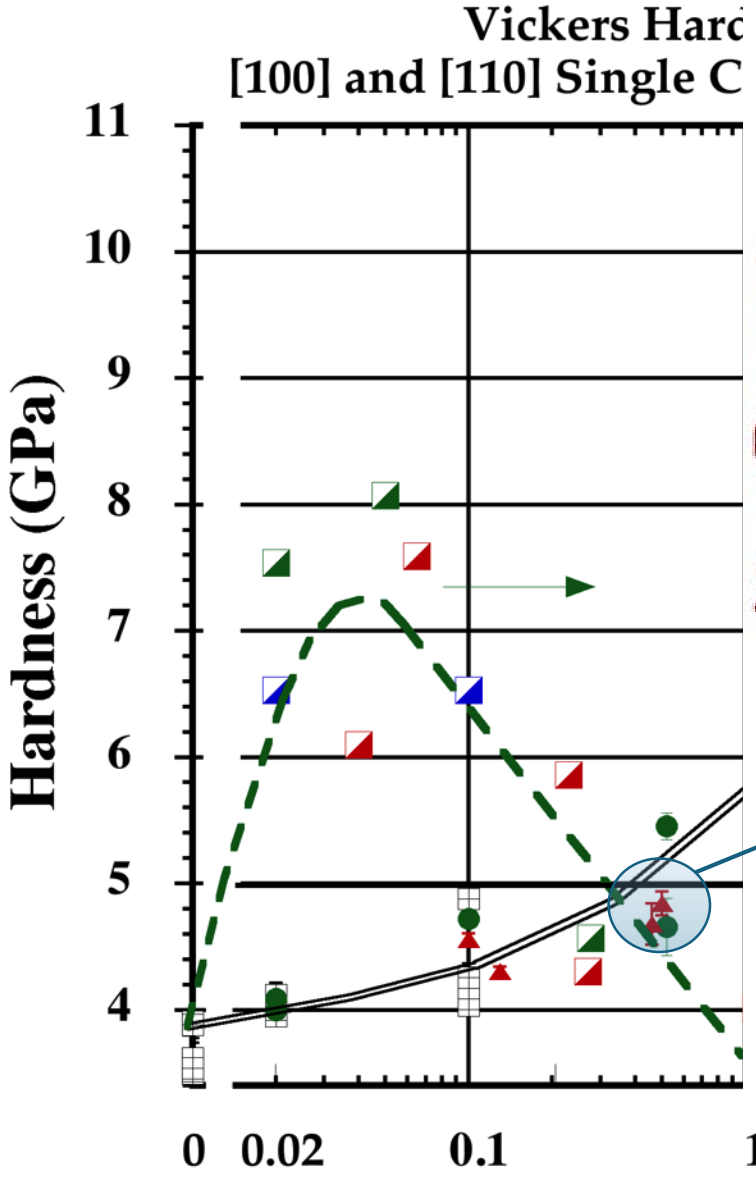
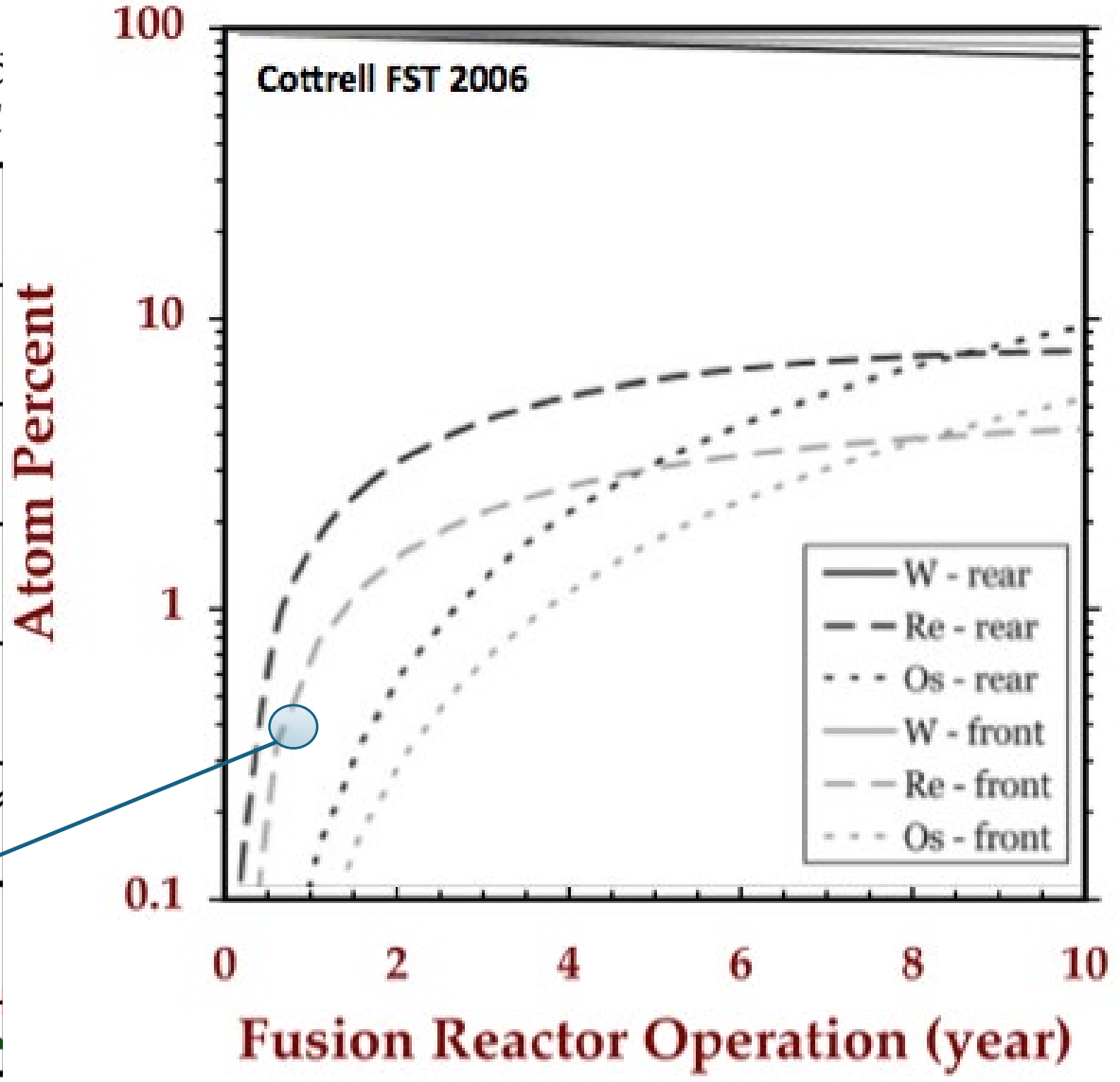

Loop
Loop + Void
Void + Precipitate
Selected for TEM
(Still in Hot Cells)
Literature (Hasegawa et al).
Voids
20nm
724°C, 0.639 dpa
Dislocation loops
20nm
90°C, 0.639 dpa
Irradiation Temperature (°C)
900
800
700
600
500
400
300
200
100
0
0.5
1
1.5
2
Irradiation dose (dpa)
Loop & Void
Precipitate & Void
Loop
2.2 dpa
2.2 dpa
3.8 dpa
6.4 dpa
3.8 dpa
2.2 dpa
6.4 dpa
6.4 dpa
Precipitates
20nm
742°C, 2.2 dpa
Voids
20nm
397°C, 0.032 dpa


Re+Os content
0.1%
1%
10%
100
10
1
0.1
ΔHv [GPa]
<110> 80-100°C
<110> 360-460°C
<110> 690-830°C
<100> 80-100°C
<100> 360-430°C
<100> 690-830°C
1/2
0.001
0.01
0.1
1
10
Dose [dpa]


Vickers Harc
[100] and [110] Single C
Hardness (GPa)
11
10
9
8
7
6
5
4
0
0.02
0.1
1
10
Neutron Fluence (E25 n/m², E>0.1 MeV)


Cottrell FST 2006
Atom Percent
100
10
1
0.1
W - rear
Re - rear
Os - rear
W - front
Re - front
Os - front
0
2
4
6
8
10
Fusion Reactor Operation (year)

SiC / SiC as a Model Refractory Composite ?

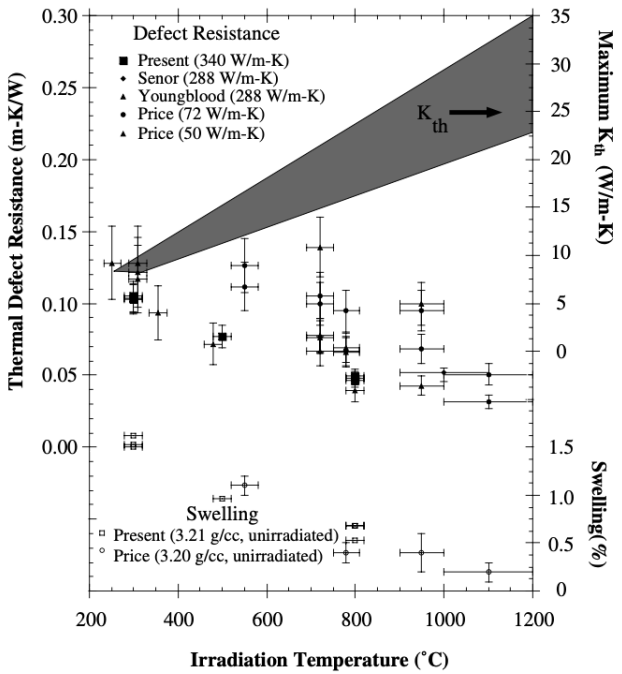


Fig. 3. Thermal defect resistance (filled symbols) and swelling (open symbols) of irradiated CVD SiC. The plot includes data from Refs. [15–17].

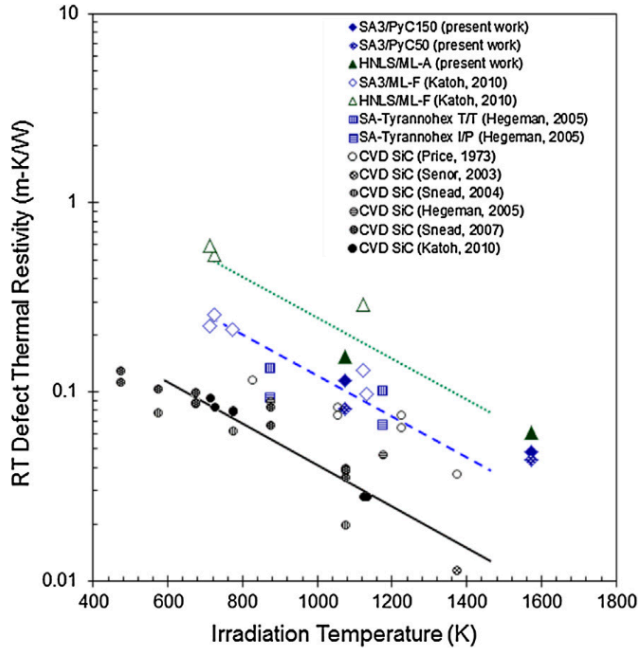
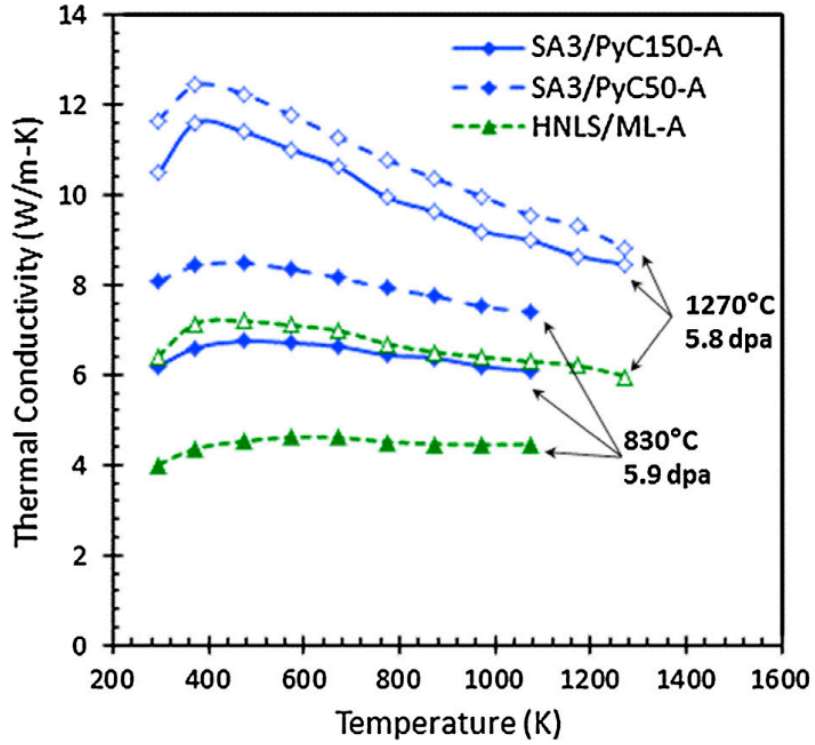
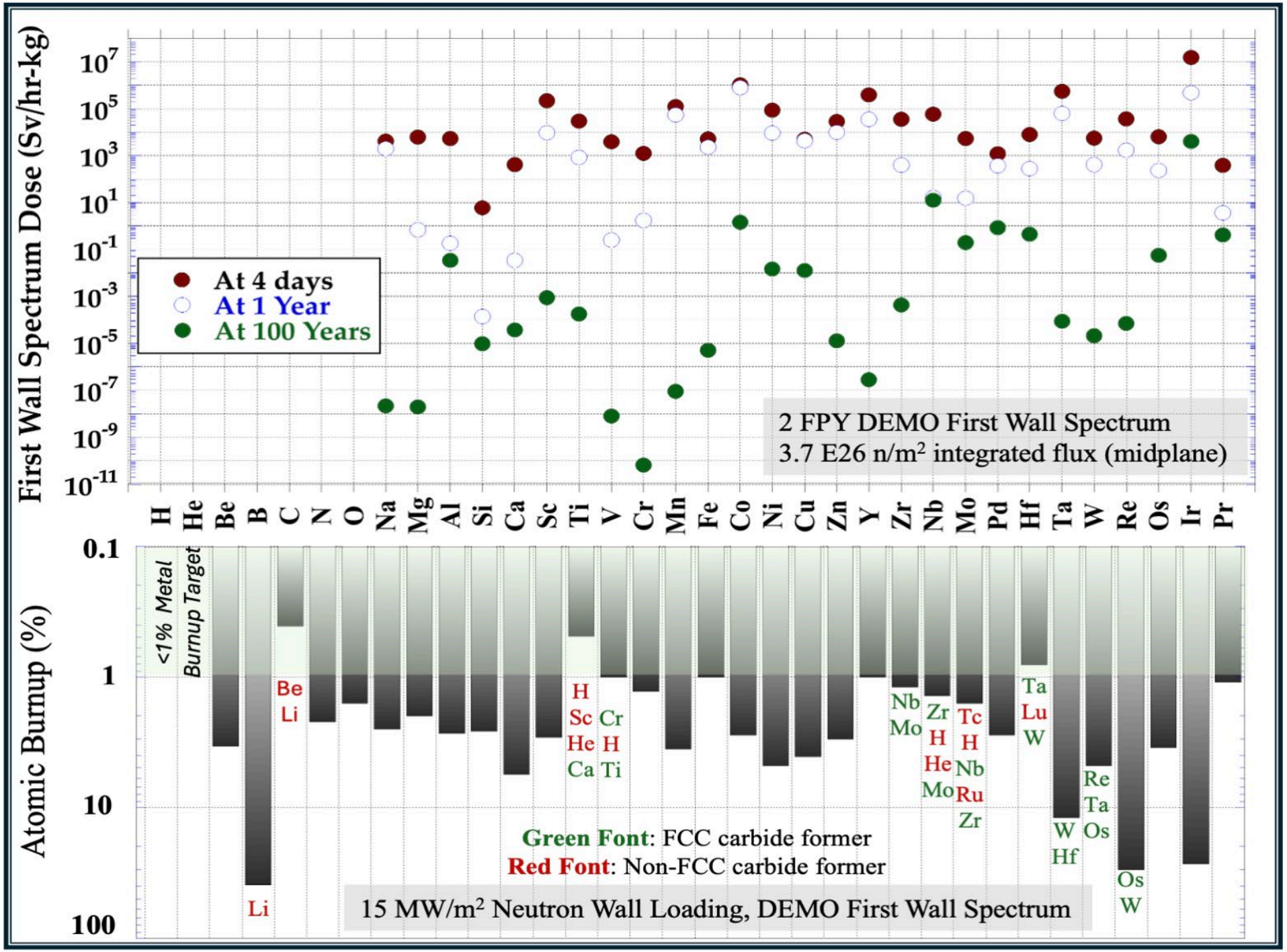


Fig. 13. Radiation-defect thermal resistivity at room temperature for neutron-irradiated 2D SiC/SiC composites plotted against irradiation temperature [17,73,94,102–104].




First Wall Spectrum Dose (Sv/hr-kg)
10^{7}
10^{5}
10^{3}
10^{1}
10^{-1}
10^{-3}
10^{-5}
10^{-7}
10^{-9}
10^{-11}
At 4 days
At 1 Year
At 100 Years
2 FPY DEMO First Wall Spectrum
3.7 E26 n/m² integrated flux (midplane)
H He Be B C N O Na Mg Al Si Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Y Zr Nb Mo Pd Hf Ta W Re Os Ir Pr
Atomic Burnup (%)
0.1
1
10
100
<1% Metal Burnup Target
Be Li
Li
H Sc He Ca
Cr H Ti
Nb Mo
Zr H He Mo
Tc H Nb Ru Zr
Ta Lu W
W Hf
Re Ta Os
Os W
Green Font: FCC carbide former
Red Font: Non-FCC carbide former
15 MW/m² Neutron Wall Loading, DEMO First Wall Spectrum

Suggestion on Next Steps

- Our primary HHF candidate materials (W, SiC) for near-term demonstration devices have fundamental neutron damage limitations that significantly limit, or render them inviable, for power reactor application. However, they are very good model materials for design of next-generation materials and can be DEMO-class HHF materials.

- An approach of materials-development as informed by design is essential for the next generation of HHF materials. Currently the materials community designs material in the absence of informed guidance on critical parameters such as toughness, thermal transport, fatigue properties.

- Following on the previous point, composite engineering is a powerful tool to address HHF component issues and can address many of the threats imposed. Our understanding of how to design with composite in a predictive manner is not mature-this should be a focus.

- Refractory (metal, ceramic, ultra-high temperature ceramics), especially in the composite form are likely successors to W and SiC and should be pursued in parallel with W and SiC/SiC, whose application will be limited to low dose devices.