Self-Healing EBC Scales on SiC

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Protective SiO_2 scales react in hot gas environment, form volatile $Si(OH)_4$, give paralinear (recession) kinetics. $k_l \propto$ gas transport model, Opila, et al:

$$SiC + 2O_2 = SiO_2 + CO_2$$

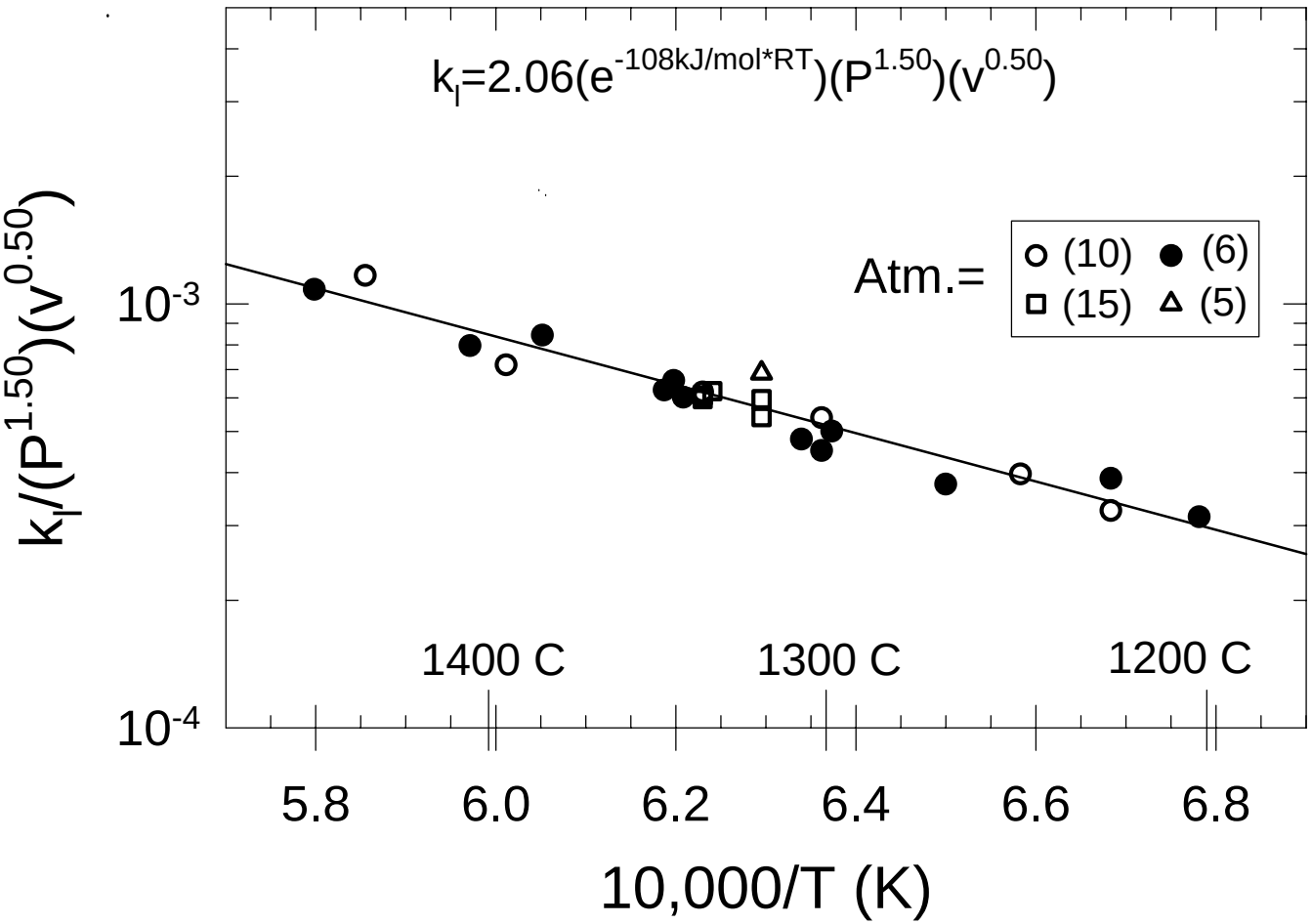
$$SiO_2 + 2H_2O = Si(OH)_4$$

$$k_l\ (HPBR) = 2.0 \exp(-108kJ / RT) \frac{P^2{}_{H_2O}}{P^{1/2}{}_{Total}} v^{1/2}\ (mg / cm^2 hr)$$

Linear Weight Loss of SiC in HPBR

6 atm, 20 m/s

Normalized Recession Rate
5-15 atm, 10-30 m/s



Present Solution: Plasma sprayed EBC oxides

4. BSAS topcoat (barium strontium alumino-silicate)

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3. Mullite + BSAS intermediate layer (furnace sprayed)

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2. Si bondcoat

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1. Molten salt etched, washed, and dried CMC surface

Alternate approach: EBC scales formed on additives

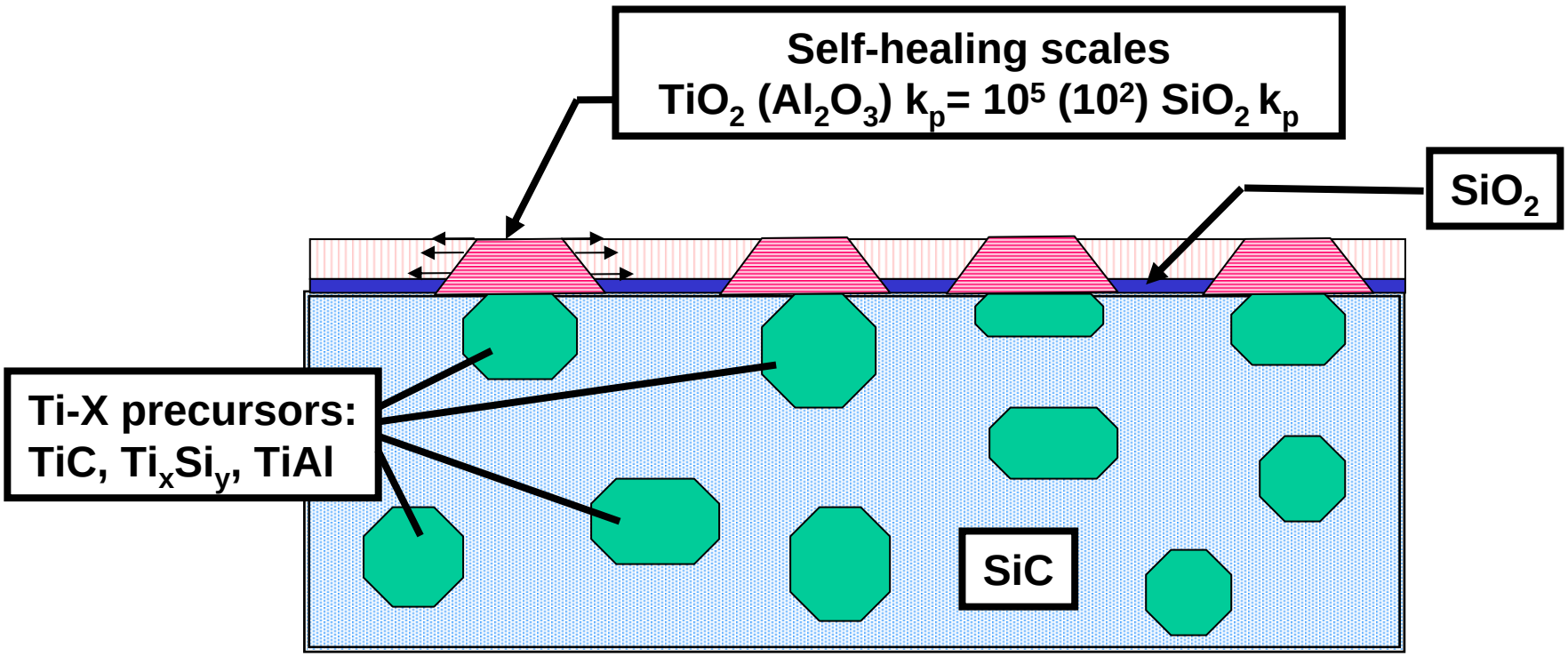
TiC (Ti_xSi_y,TiAl, TiCrAl) $\rightarrow$ TiO_2, Al_2O_3

Hot pressed SiC-%TiX composites

Furnace (air, 50% H_2O), HPBR

Characterization, optimization, kinetic models

Idealized EBC Scale Schematic



critical $k_p \approx 2\mu m^2/hr$ for healing
(100hr @ 10v/o, 10 μm radius)

Pertinent Oxidation Background
(non-oxide, multiphase ceramics)

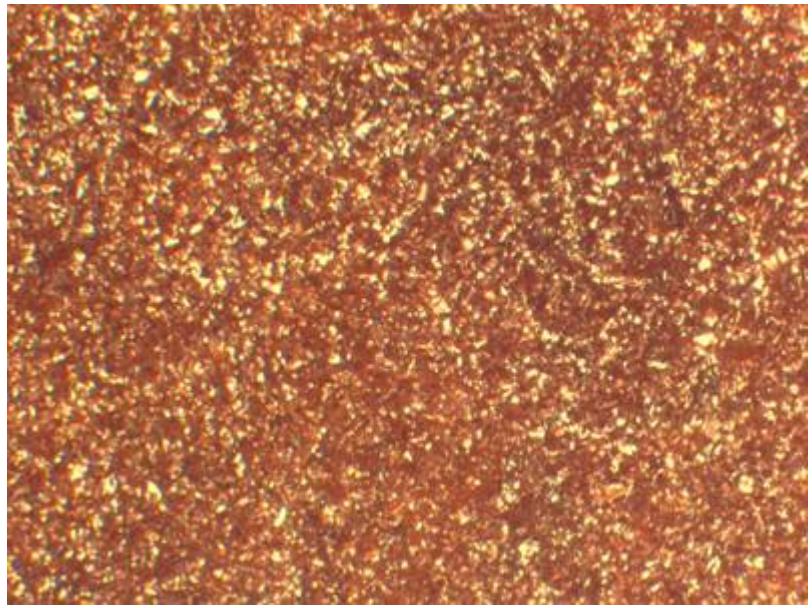
- Si_3N_4–TiN, TiC,… **Gogotsi**, Lavrenko, Yaroshenko…
  Bellosi, Vincenzini, Tampieri…
  Buljan, Zilberstein…
- ZrC, HfC (-TiC), **Shimada**,....
  - At 25 wt.% TiN, continuous TiO_2 surface scale forms.
  - TiO_2 nodules are only over individual particle at lower loadings.
  - $HfTiO_4$ inner scales develop under TiO_2 surface scale.
  - Carbon found in scale at carbide interface (titanium oxycarbide?).

Short Subjects

- 50-50 SiC-TiC furnace data vs T
- 50-50 SiC-TiC, 1330°C HPBR oxidation, scale microstructure
- 50-50, 90-10, 1000°C HPBR weight change
- 50-50 SiC-TiC, 1000°C HPBR microstructure
- $TiSi_2$ furnace oxidation

Self-Healed TiO_2 Scale Formed on SiC-50TiC

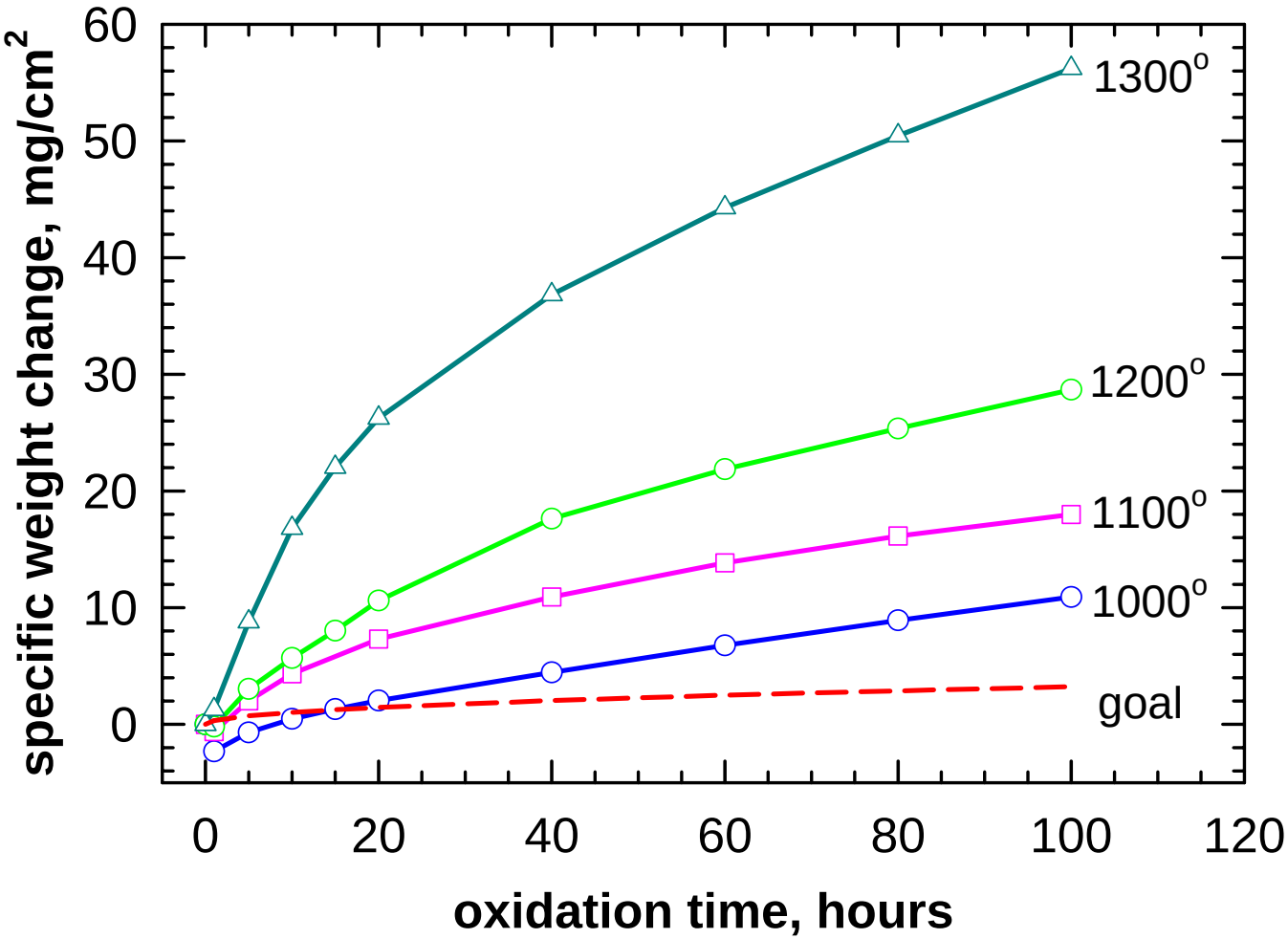
As-polished SiC-TiC



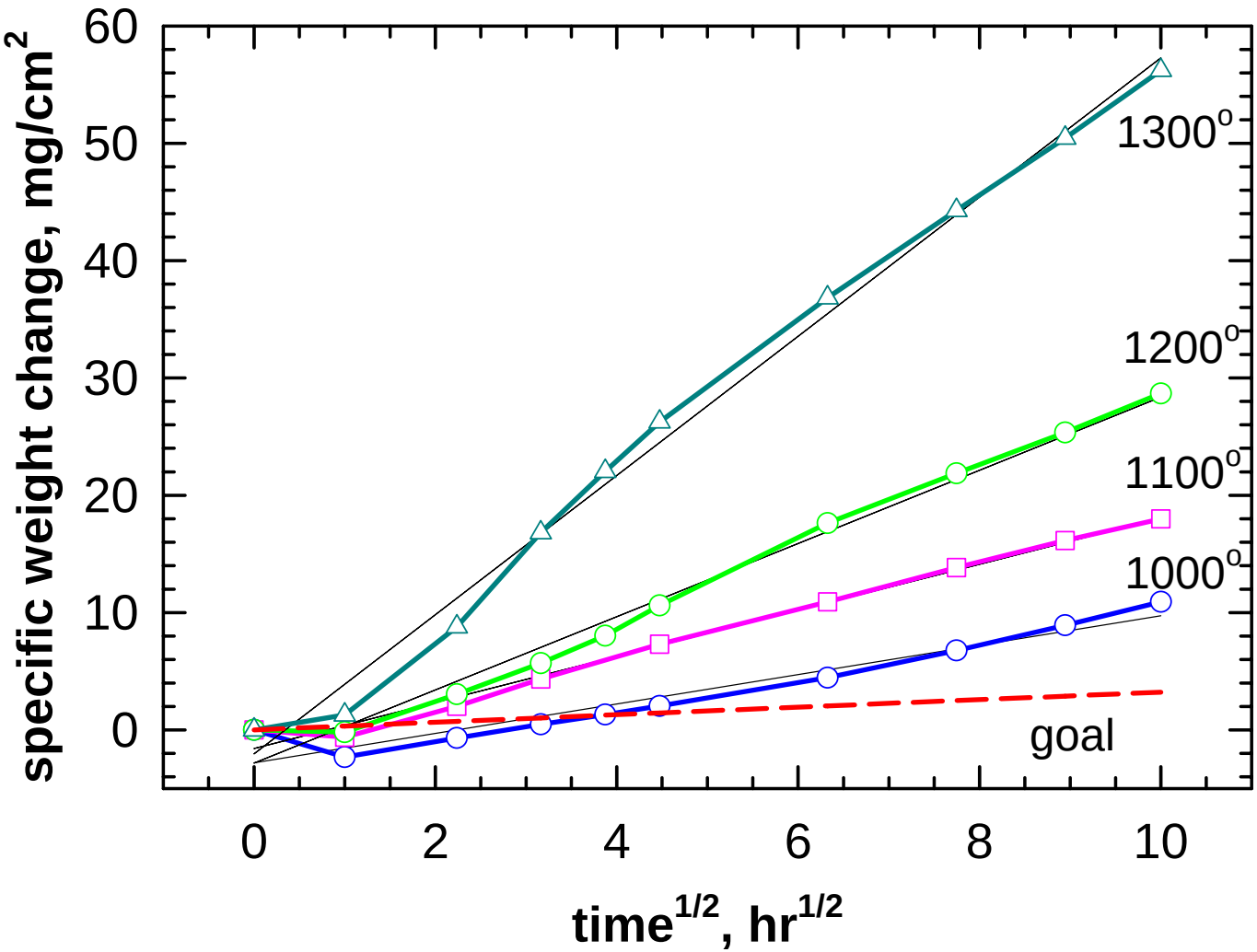
After 500 hr oxidation at 1000°C

25x

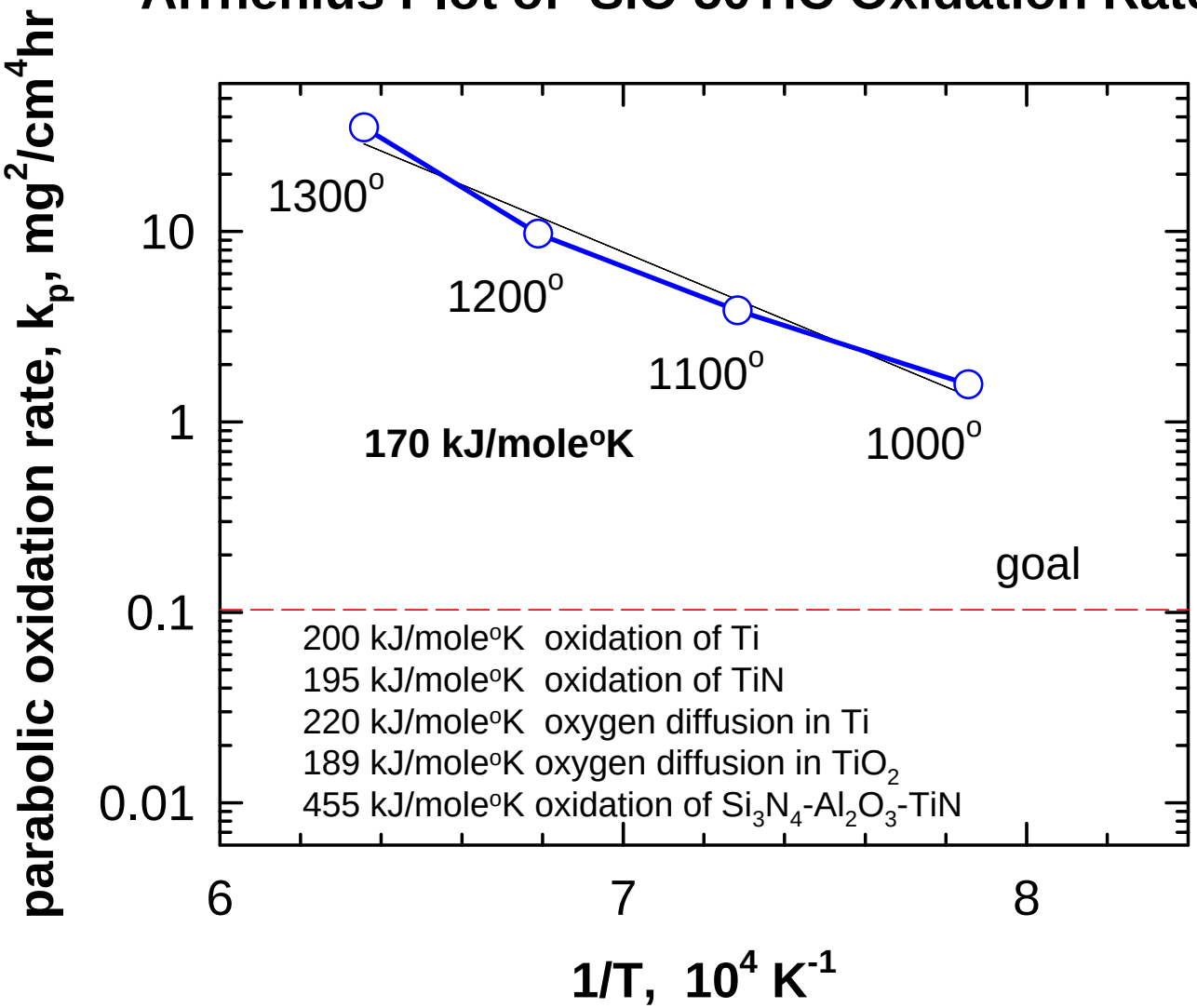
Furnace Oxidation of SiC-50TiC Composites at 1000-1300°C



Furnace Oxidation of SiC-50TiC Composites at 1000-1300°C

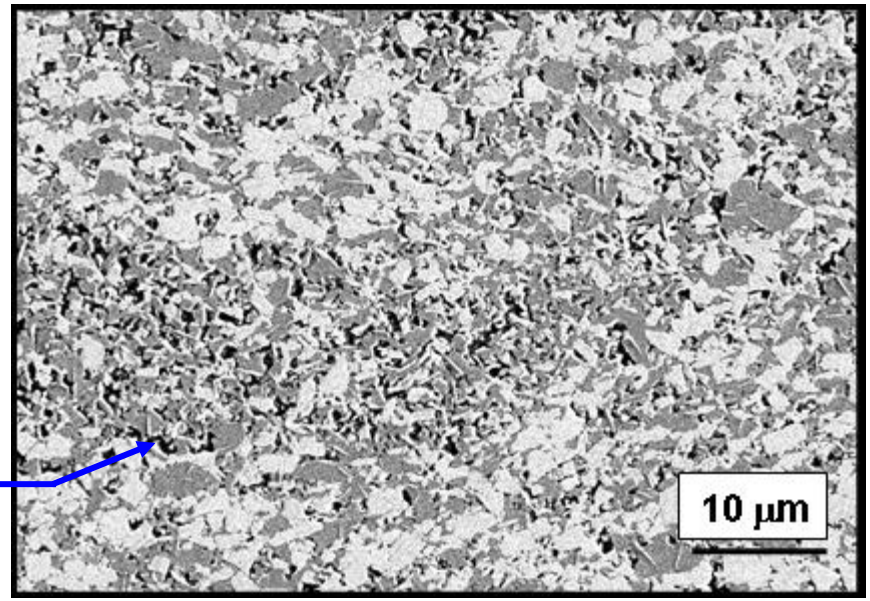


Arrhenius Plot of SiC-50TiC Oxidation Rates

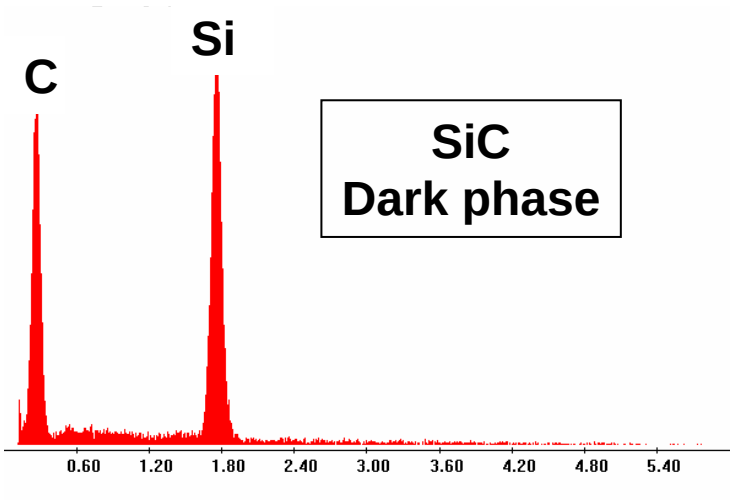


Unaffected core

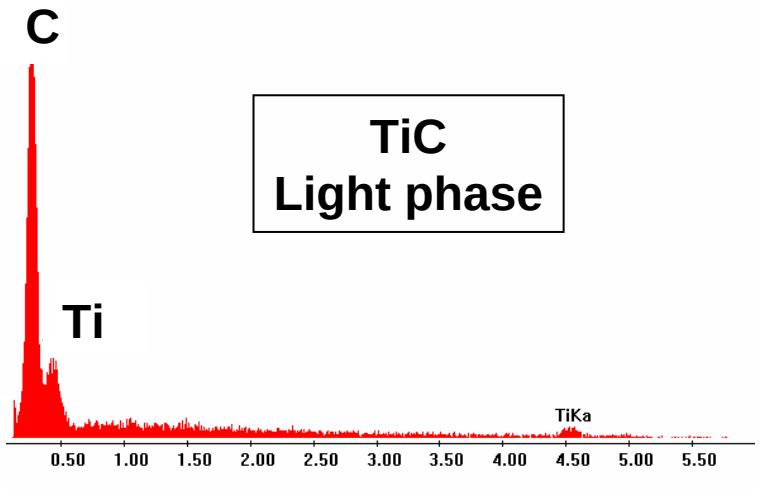
SiC-50TiC, HPBR,1330°C, 7.5 hr



(dispersed porosity)

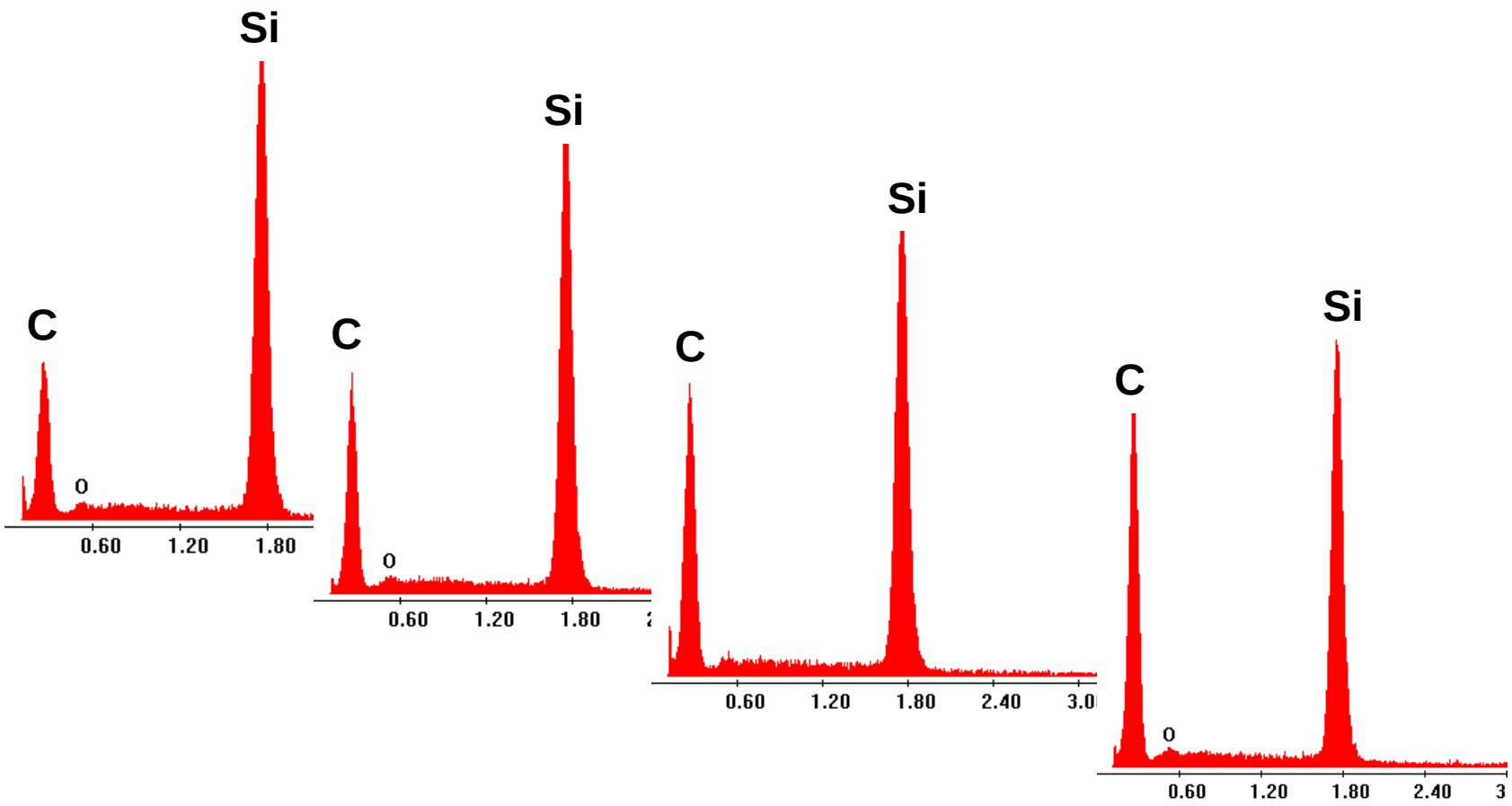


SiC
Dark phase

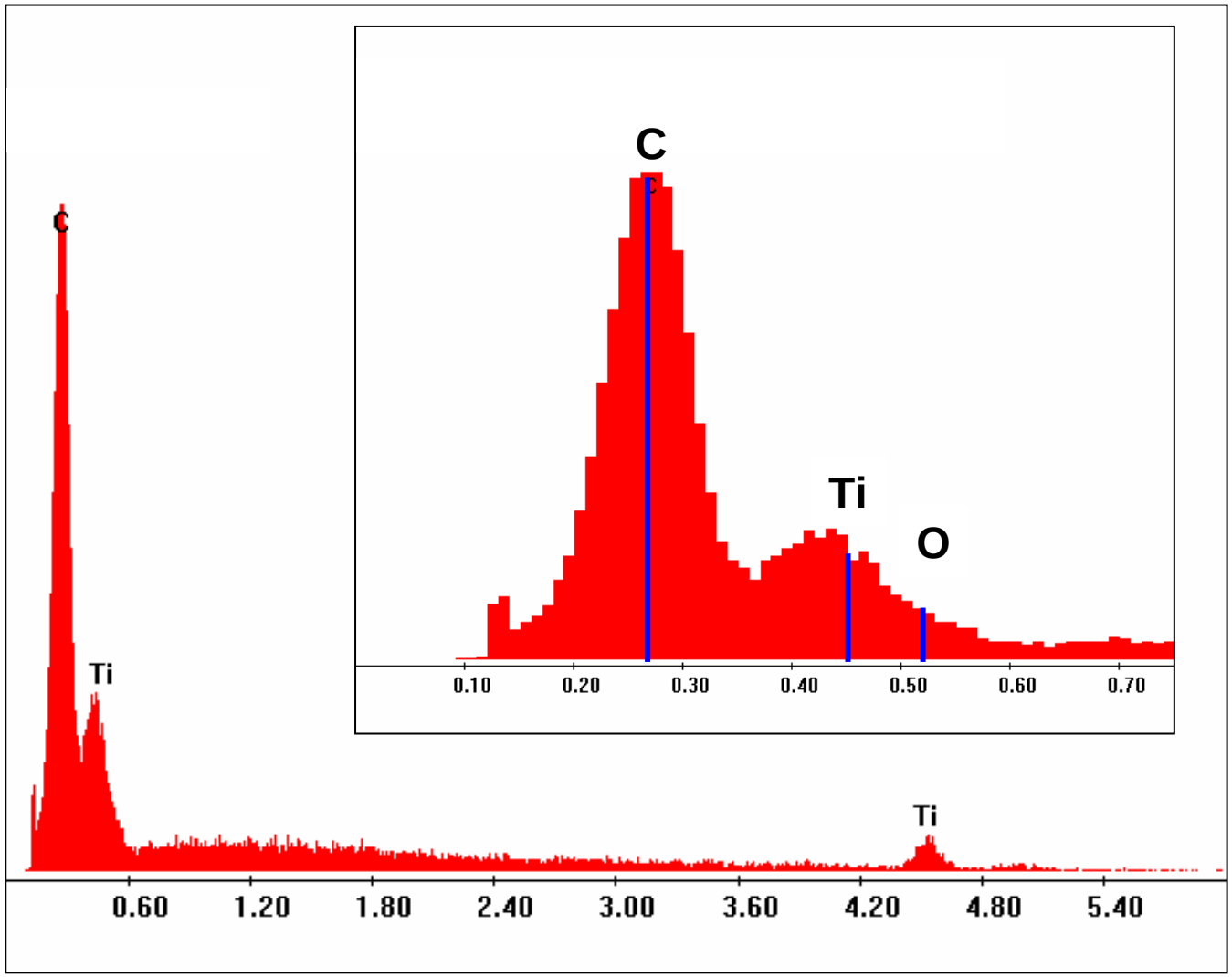


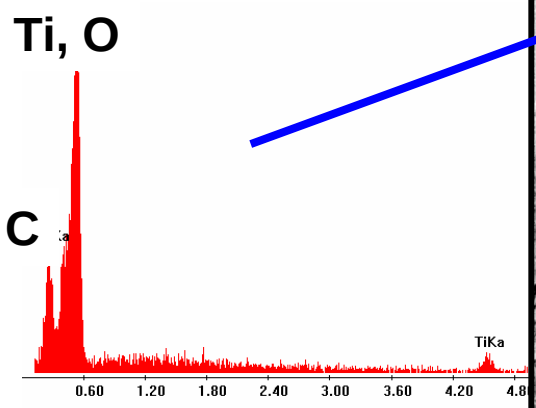
TiC
Light phase

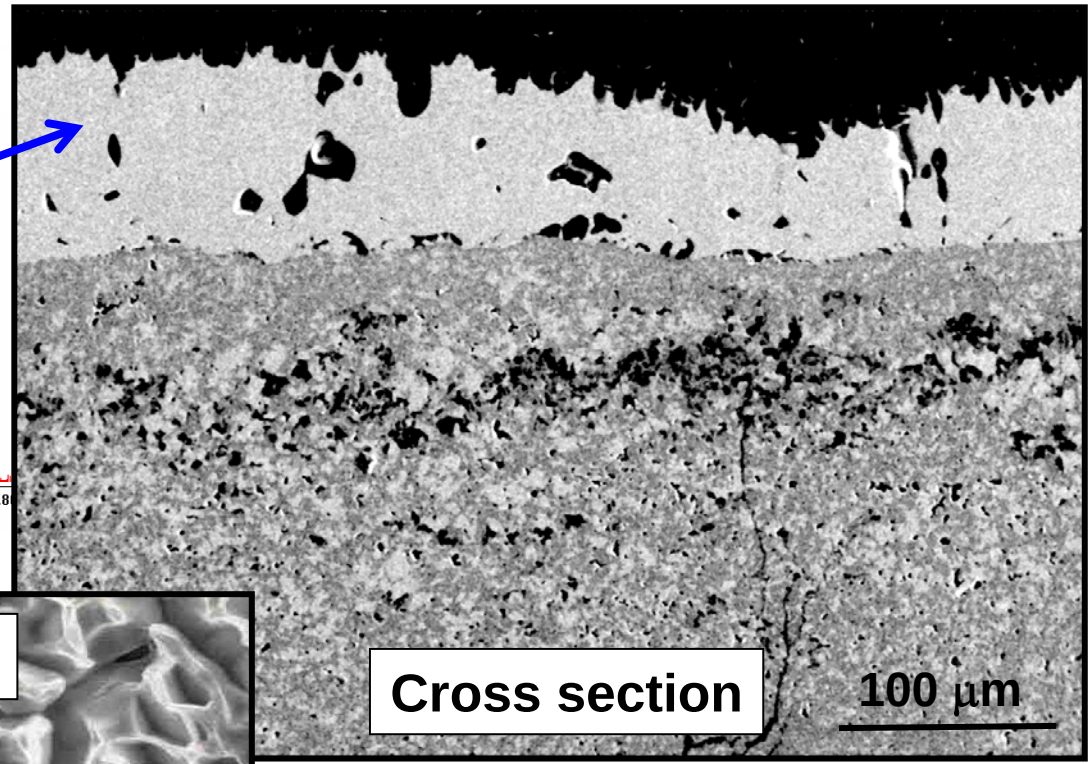
6kV SiC spectra

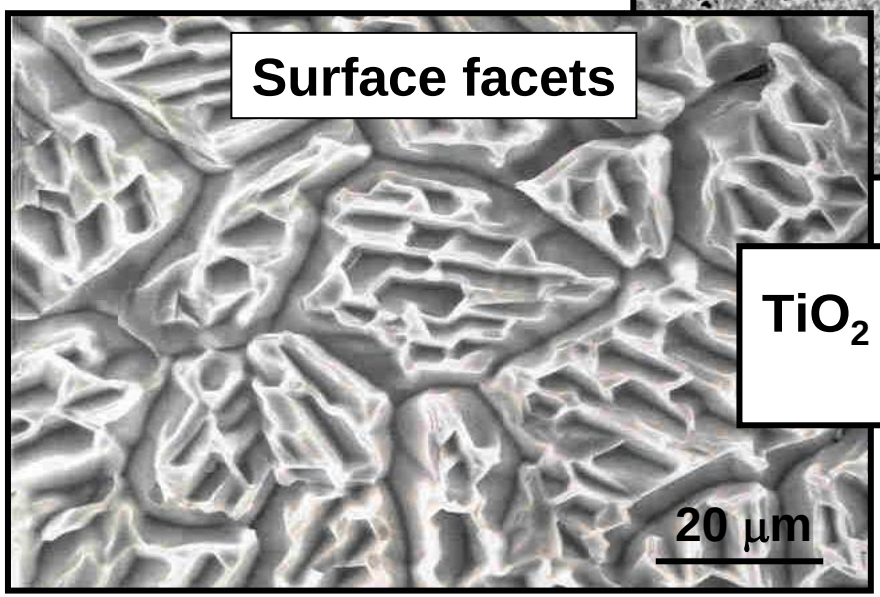


6kV TiC spectrum

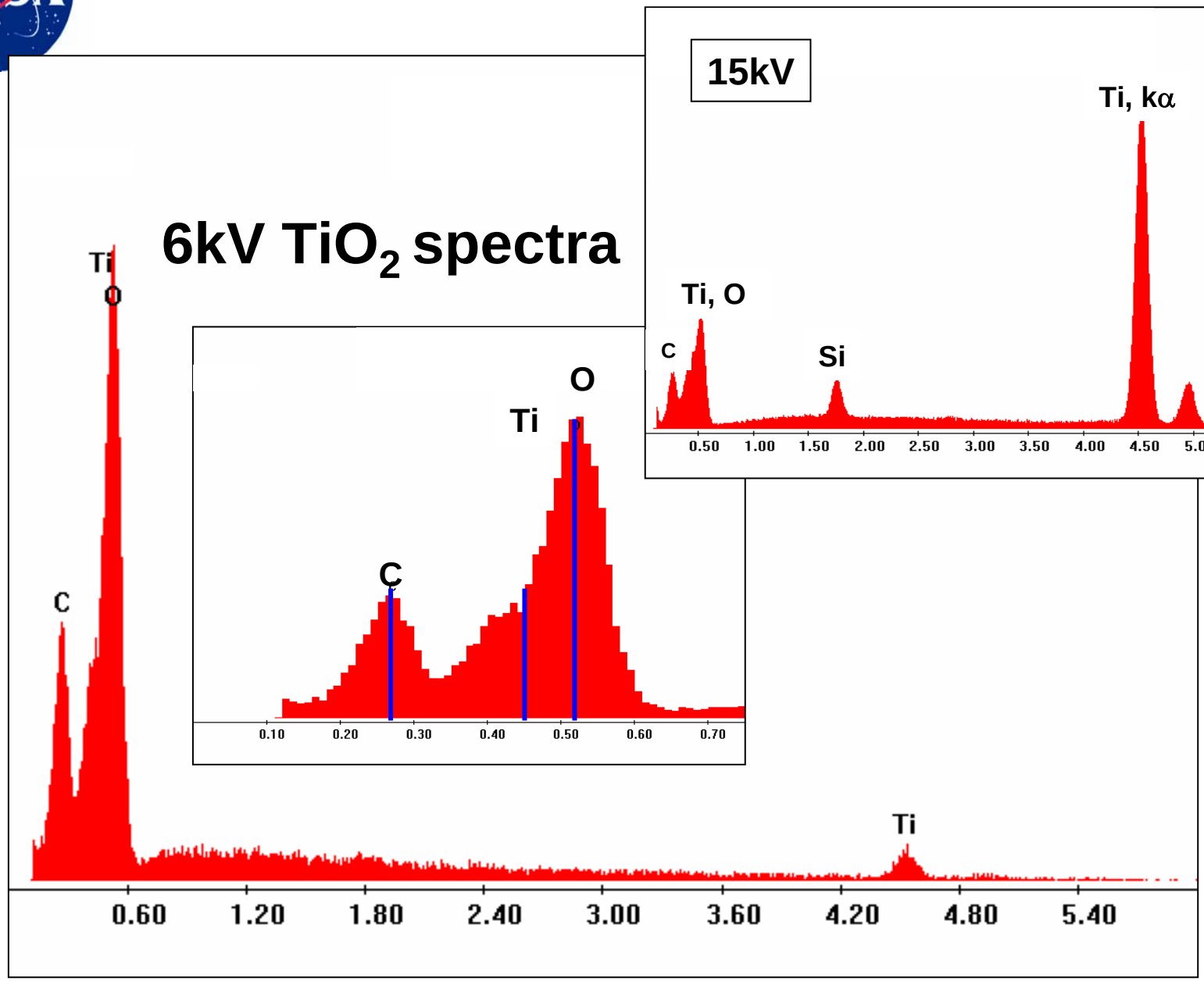


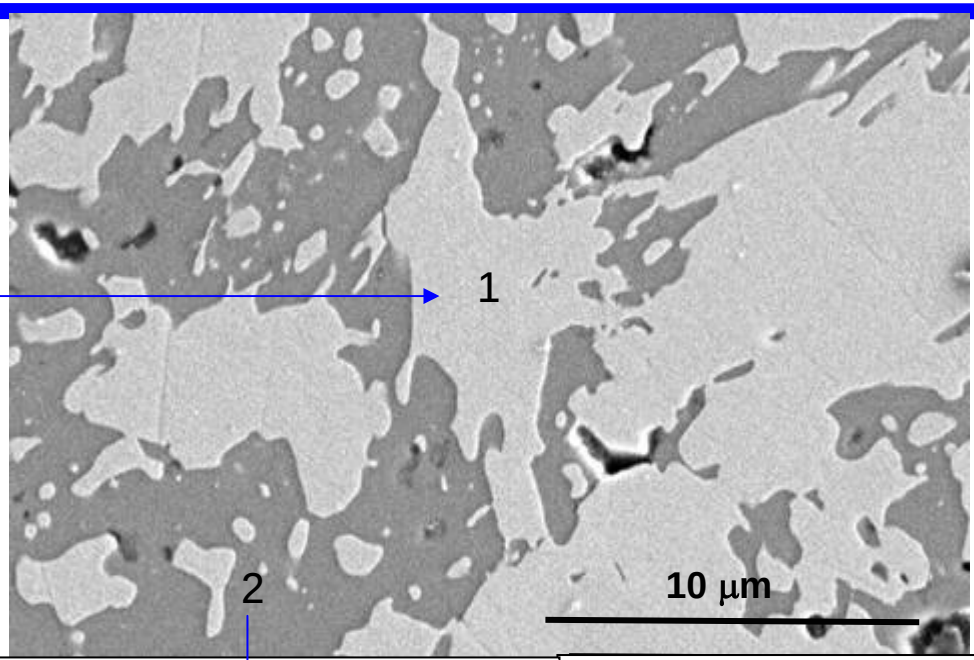




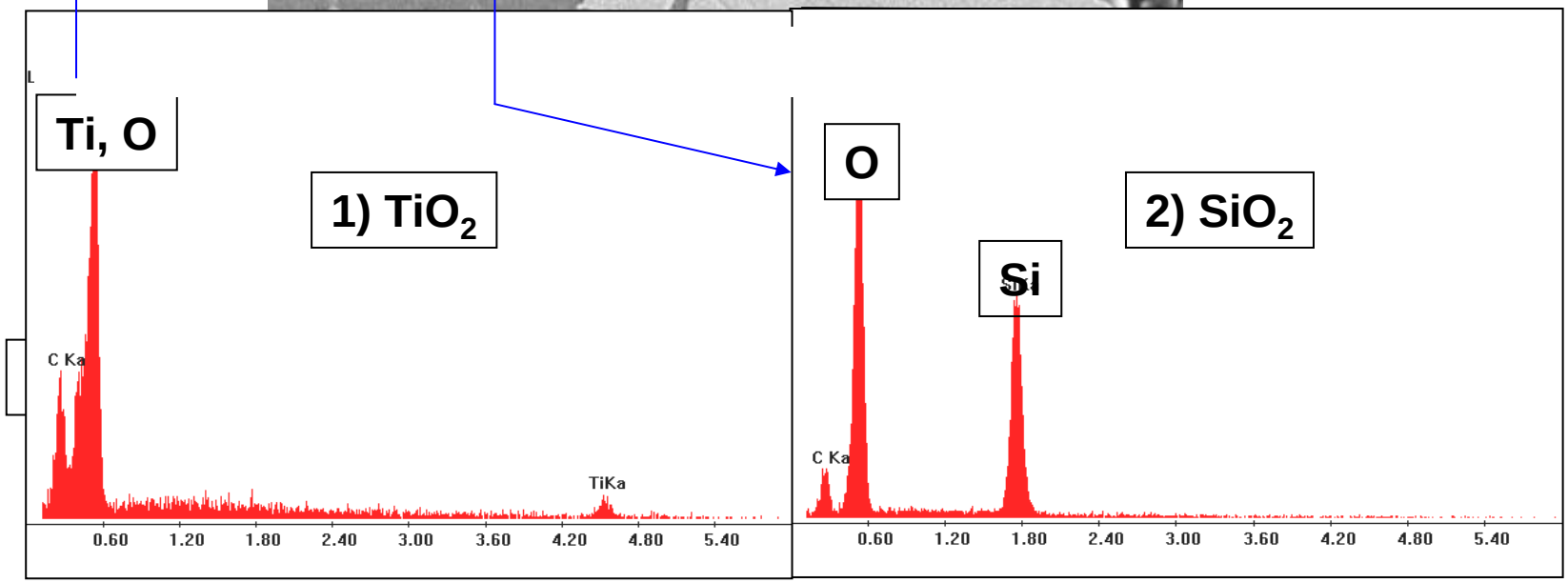


TiO_2 External Scale Formed in HPBR SiC-50TiC, 1330°C, 7.5 hr

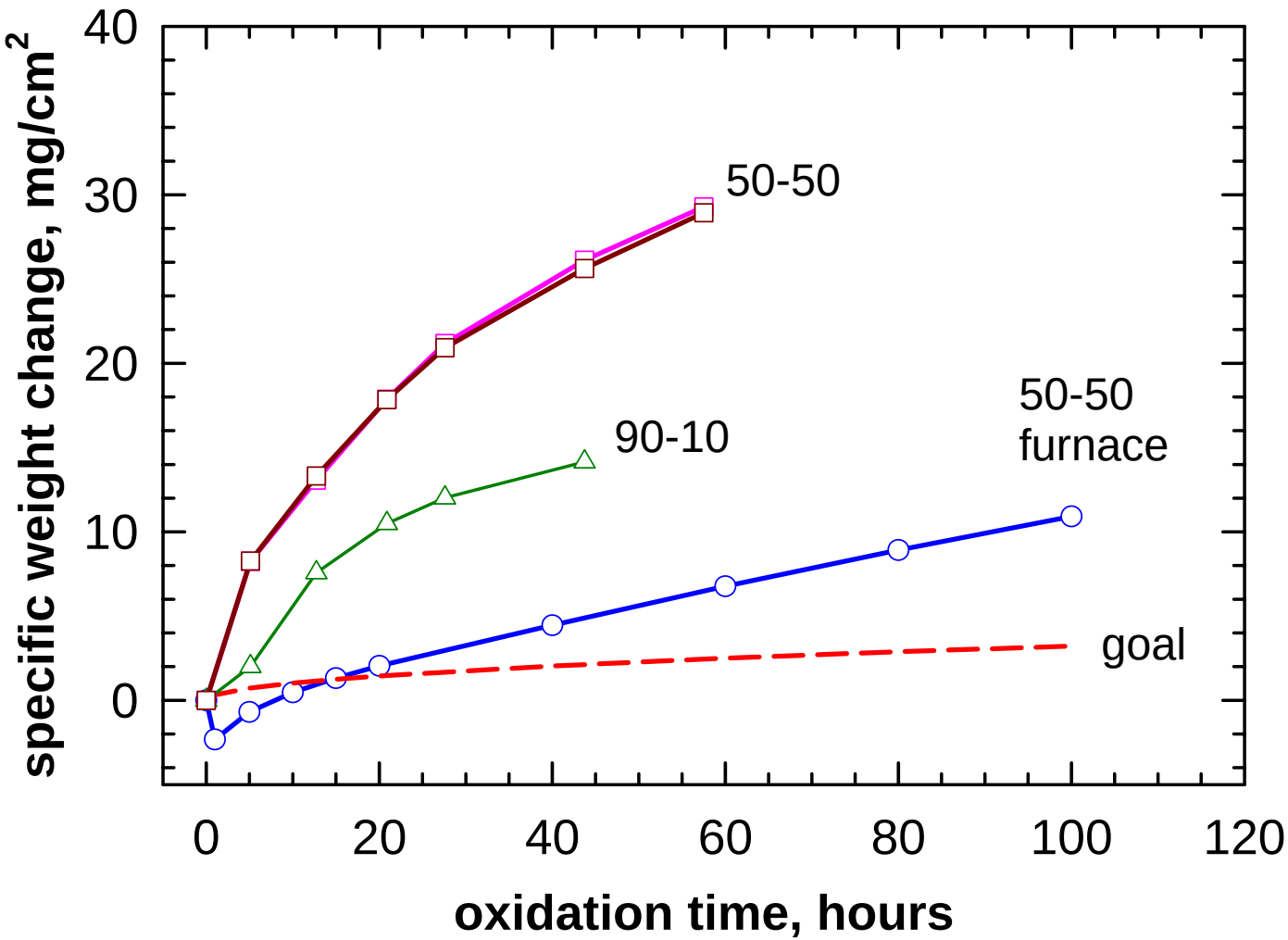

6kV TiO_2 spectra
15kV
Ti, kα
Ti, O
C
Si
0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50
O
Ti
C
0.10 0.20 0.30 0.40 0.50 0.60 0.70
Ti
O
C
Ti
0.60 1.20 1.80 2.40 3.00 3.60 4.20 4.80 5.40



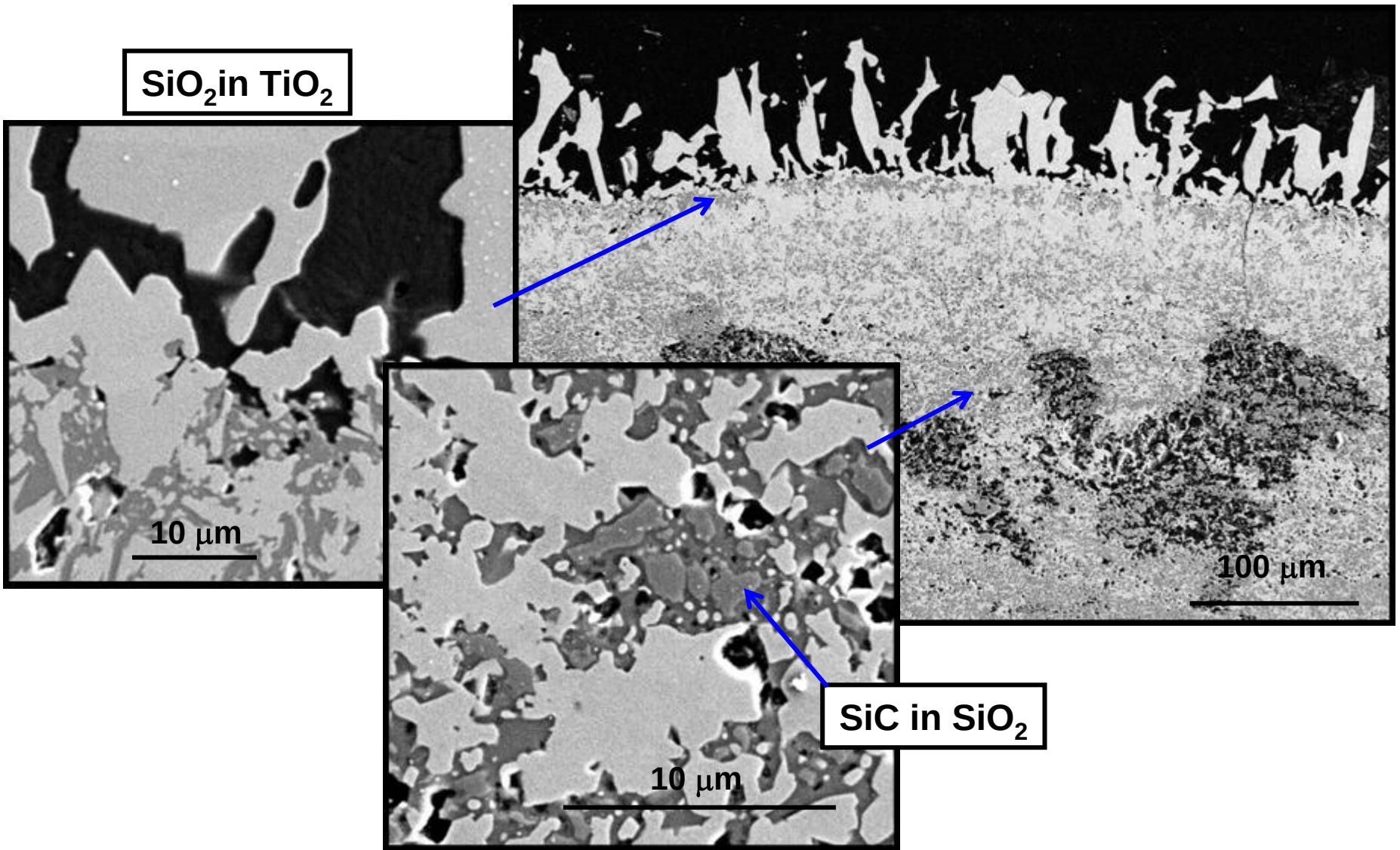
immediate subscale



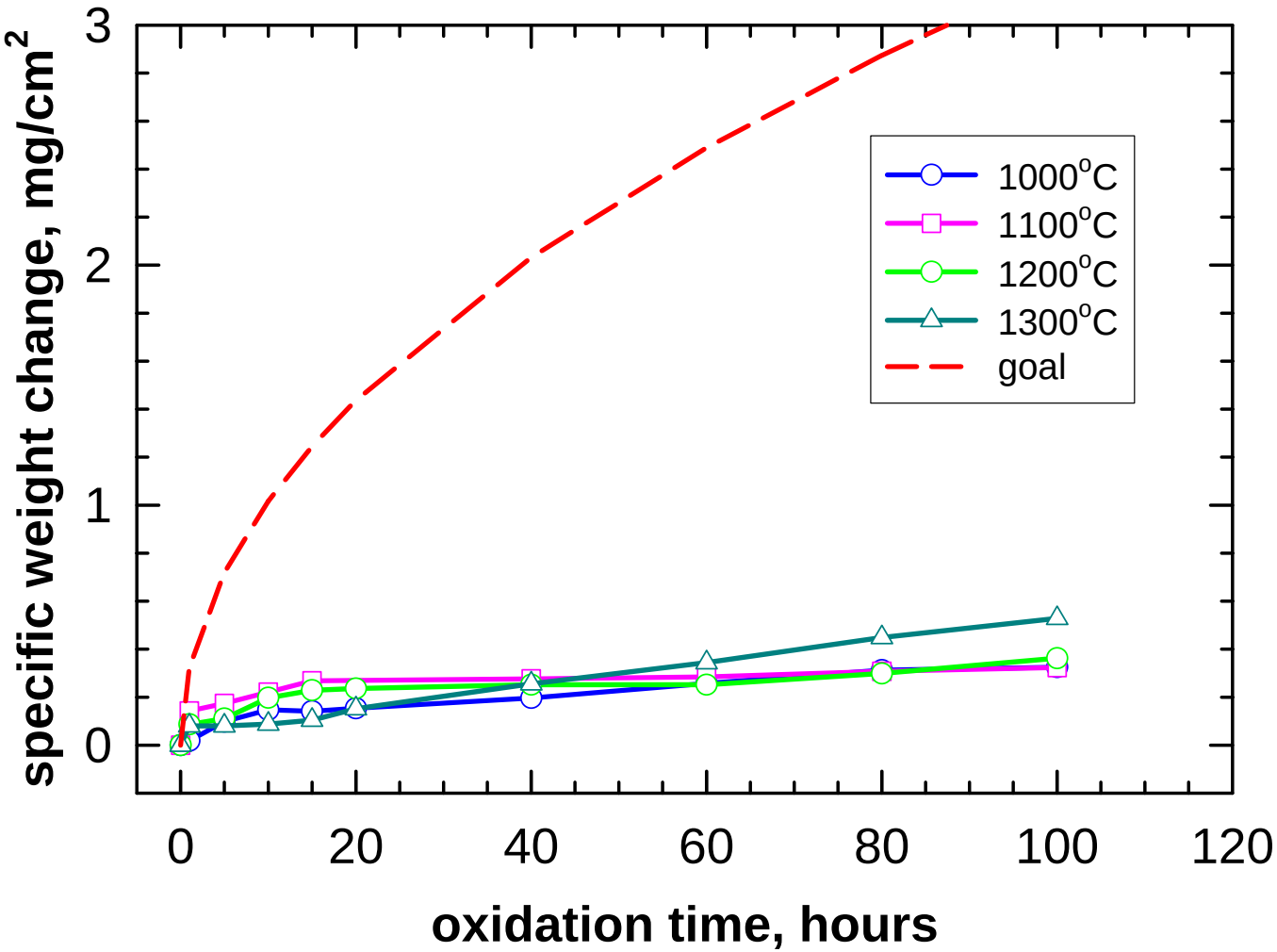
HPBR Oxidation of SiC-TiC Composites at 1000°C



SiC-50TiC, HPBR, 1000°C, 60 hr



Furnace Oxidation of $TiSi_2$ Composites at 1000-1300°C



Preliminary Status Report

- Hot pressed SiC-TiC; oxidized at 1000-1300^{o}C.
- At 25 and 50%, distinct, oversealing TiO_2 scales formed.
- Oxidation rates greatly exceeded target; porosity.
- HPBR tests indicate even higher growth rates.
- Faceted, continuous TiO_2 surface, mixed TiO_2+SiO_2 subscale (not effective), then ‘intact’ SiC+TiO_2
- (No guarantee of moisture resistance)