Corrosion Resistance of Al-Fe-alloy-coated Steel, Refractory Metals and Ceramics in Lead-Bismuth at 700ºC

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Motivation

High boiling points of lead alloys can provide high temperature reactor with thermal efficiency higher than 40%.

Candidate materials compatible with lead alloys

- ✓Structural materials: **400-550 ºC**
  - High Cr F-M steels (with Si and Al addition)
- ✓Cladding materials: **650-700 ºC**
  - High Cr F-M steels with Si and Al additions
  - Al-Fe-Surface coated steels
  - Refractory metals
  - Ceramics

Results of previous corrosion tests

Flowing fluid: Pb-Bi eutectic (LBE)
Temperature: **550°C**
Velocity: 1 or 2 m/s
Exposure time: 1,000 or 2,000 hrs
Oxygen concentration: 10^{-8}-10^{-6} (wt%)

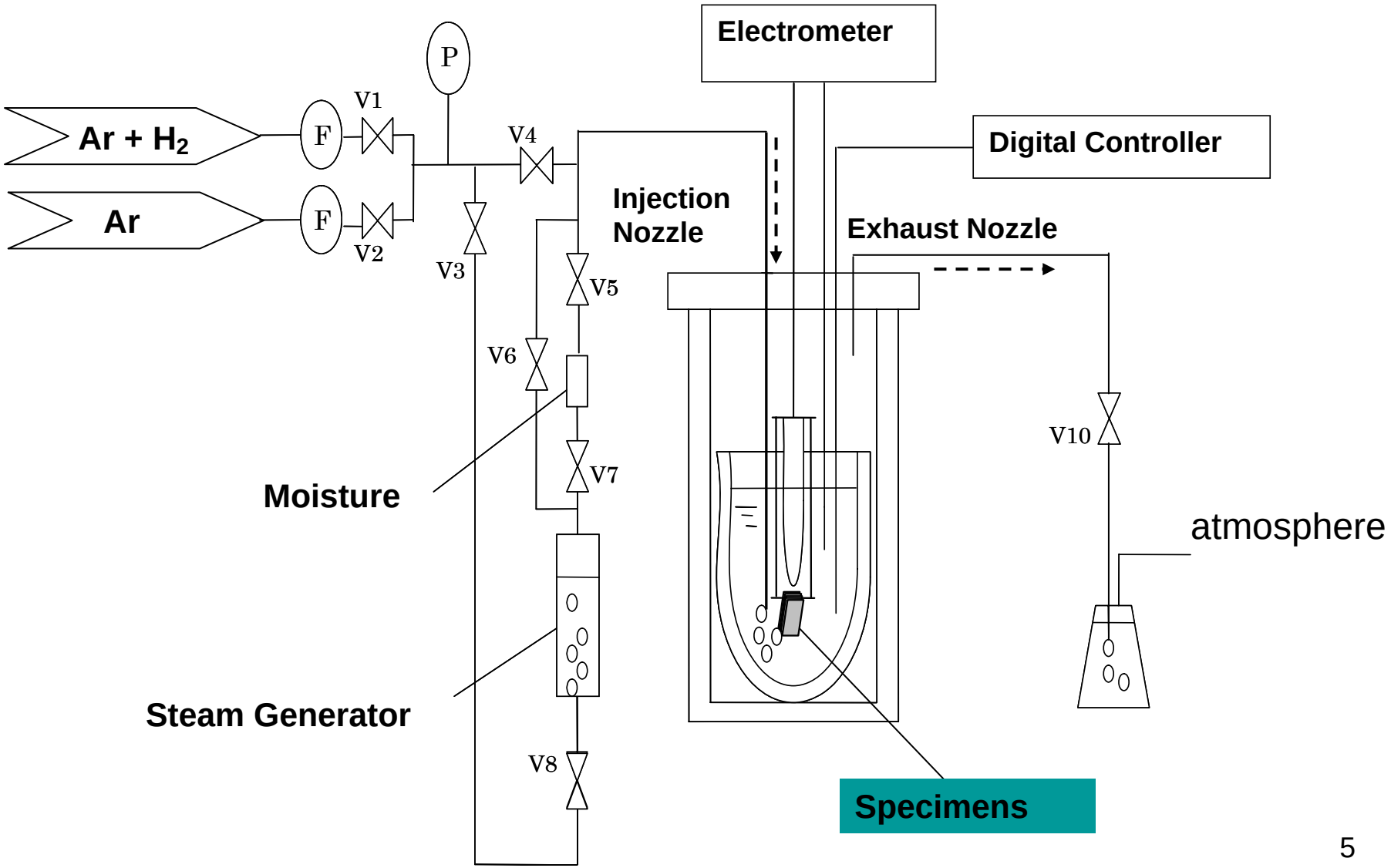
		Materials	Compatibility
Steels	Austenitic steels	SS316, SS316FR	poor
	12Cr steels	HCM12A, etc.	good
	10-18Cr steels with Si and Al addition	SUH3, NTK04L, Recloy10, SUS430	excellent
	Al-alloyed surface (GESA)	ODS	locally good
Refractory metals		W, Mo	excellent
Ceramics		SiC, Si_3N_4	excellent

Purpose

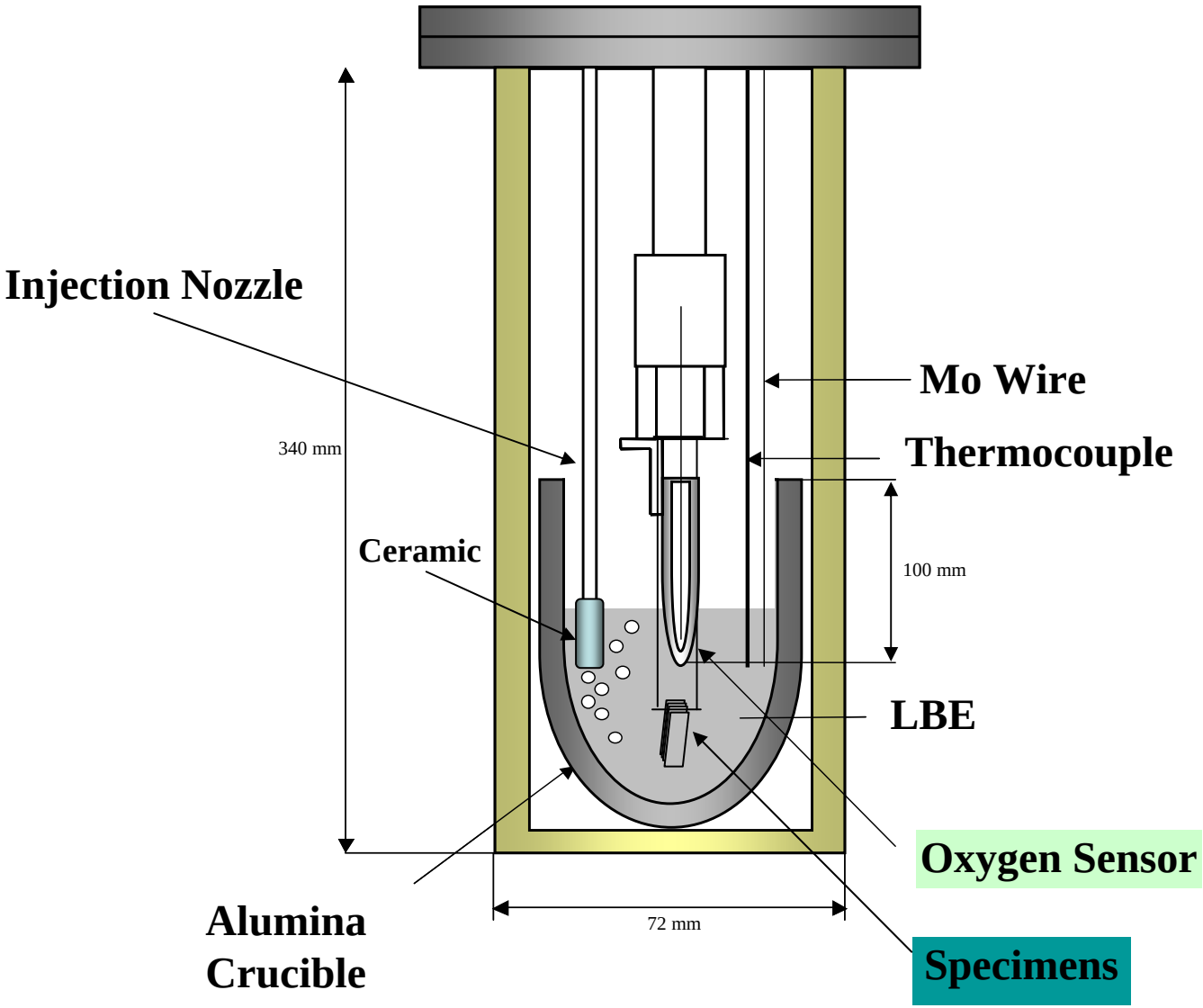
To investigate the compatibility of materials in stirred LBE at 700 ºC

- Steels: High Cr steels, Al-Fe-coated ones
- Ceramics: SiC, Ti_3SiC_2,
  SiC/SiC composites
- Refractory metals: W, Mo, Nb

Test apparatus



Corrosion test section

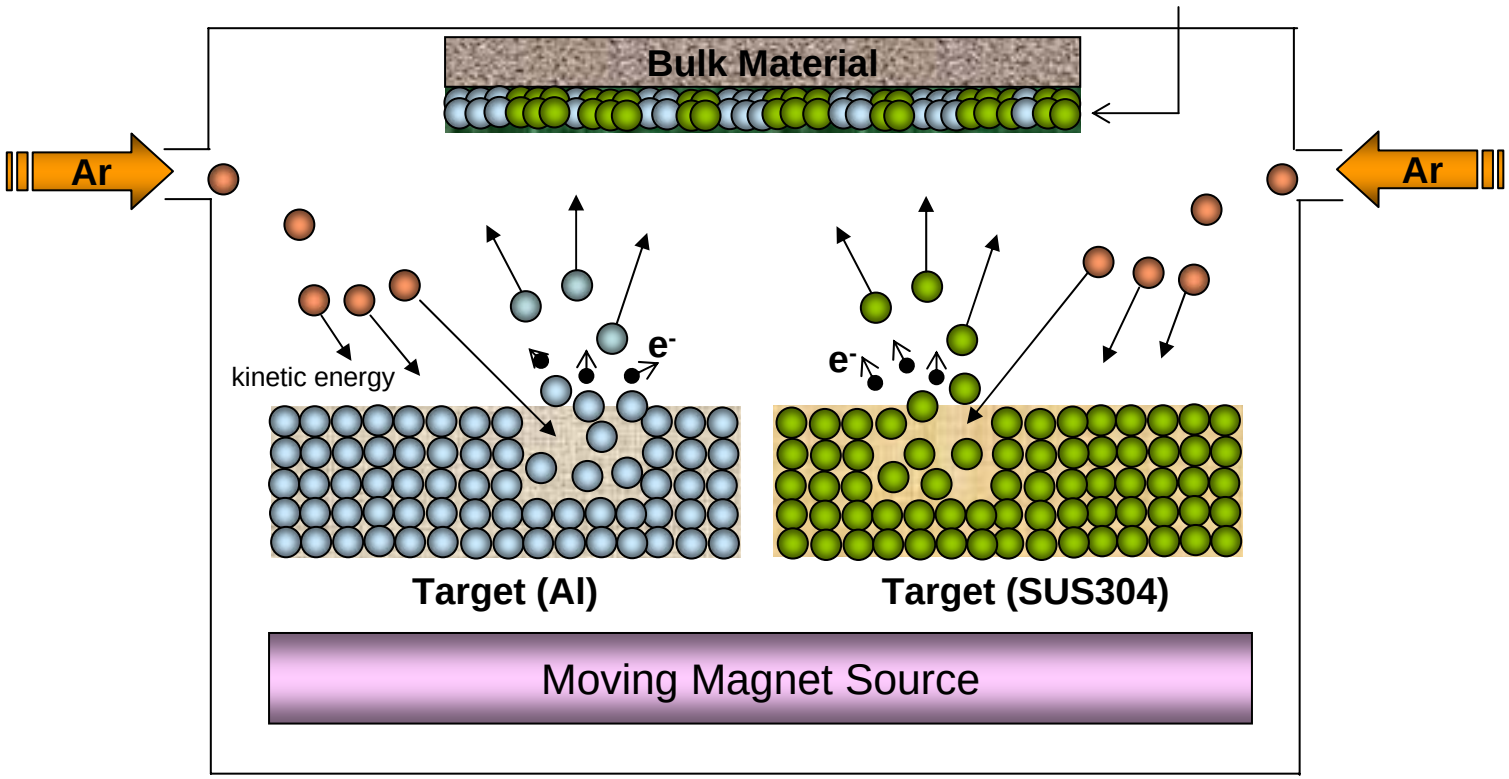


Experimental conditions

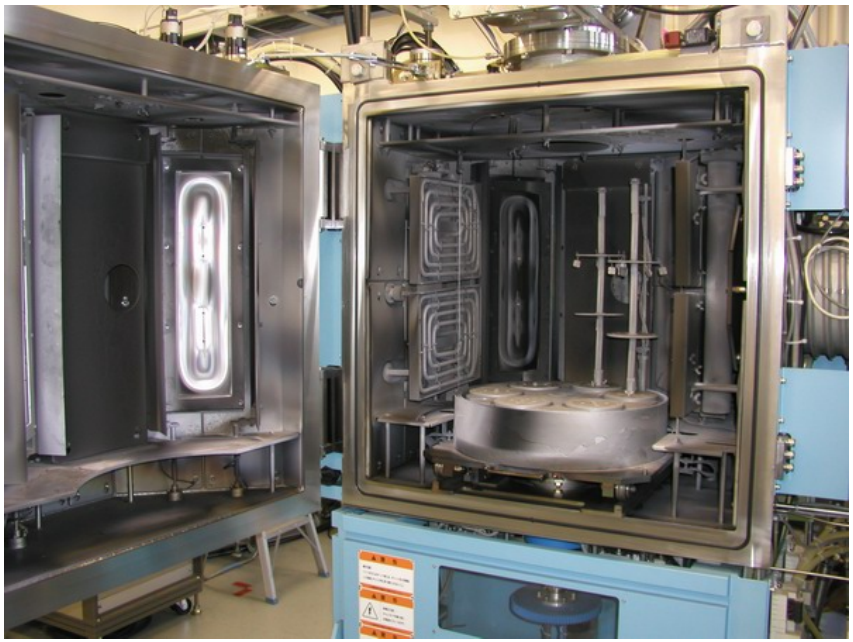
Run	No. 1	No. 2
Materials	STBA26, SiC/SiC composites	NTK04L, SUS316FR Recloy10, SUS430, Al-Fe-coated steel, W, Mo, Nb, SiC, Ti_3SiC_2
Oxygen concentration (wt%)	~$6.8x10^{-7}$	~$5x10^{-6}$
Injection Gas	Ar	Ar+H_2 (3%) and Ar
Type of Sensor	Y_2O_3-ZrO_2	
Temperature of LBE (ºC)	700	
Immersion time (hr)	1,000	

Unbalanced Magnetron Sputtering (UBMS)

Al-Fe coating (thickness: 21.45μm)

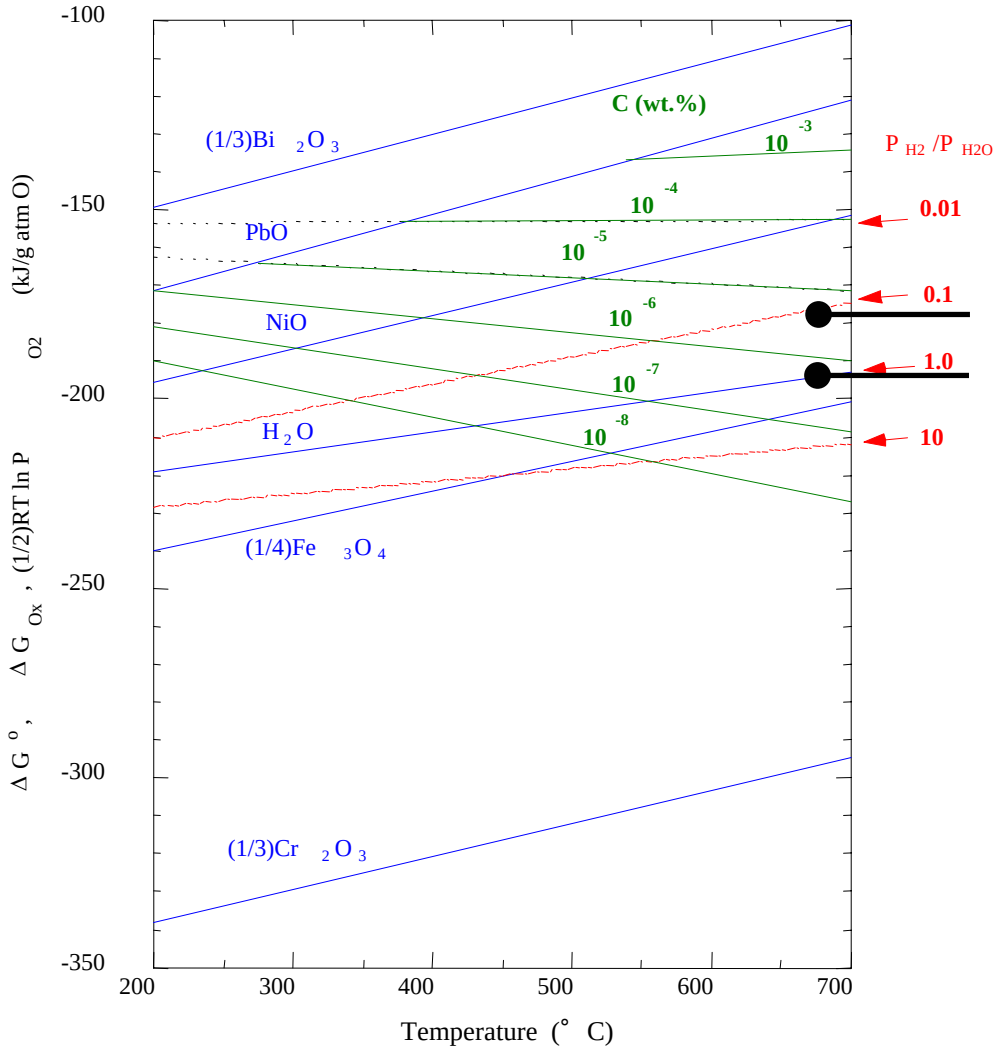


Unbalanced Magnetron Sputtering (UBMS)



Specimens

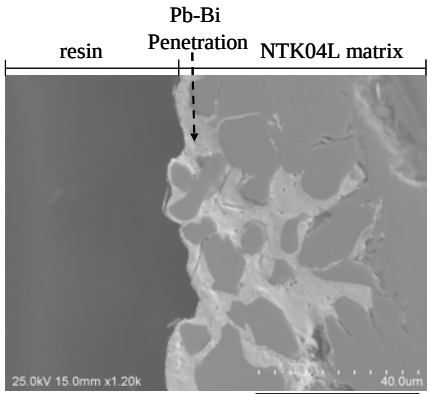
Oxygen concentration

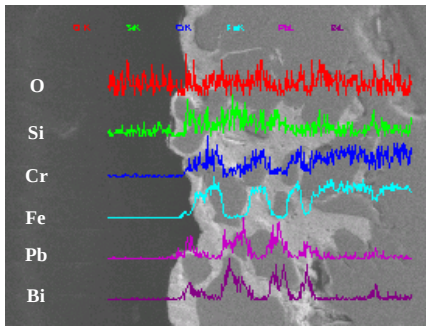


High Cr Steels (NTK04L, STBA26, SUS316FR)

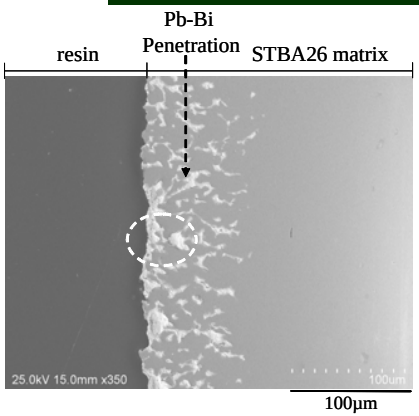
$C_{O2} = 5 \times 10^{-6}$ wt.% (NTK04L, SUS316FR)

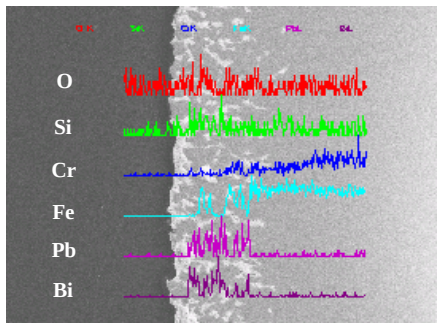
$C_{O2} = 6.8 \times 10^{-7}$ wt.% (STBA26) 700ºC



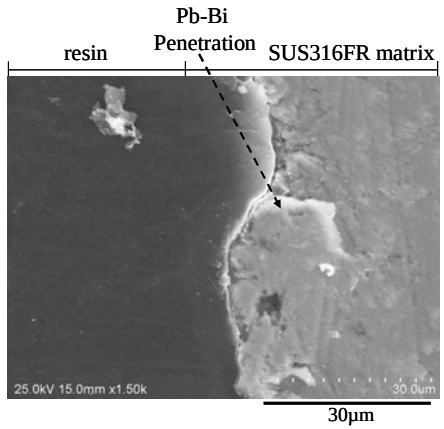


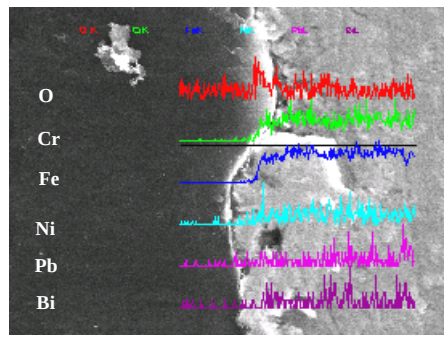
NTK04L 17.8Cr-0.4Si-3.34Al





STBA26 9Cr-0.2Si

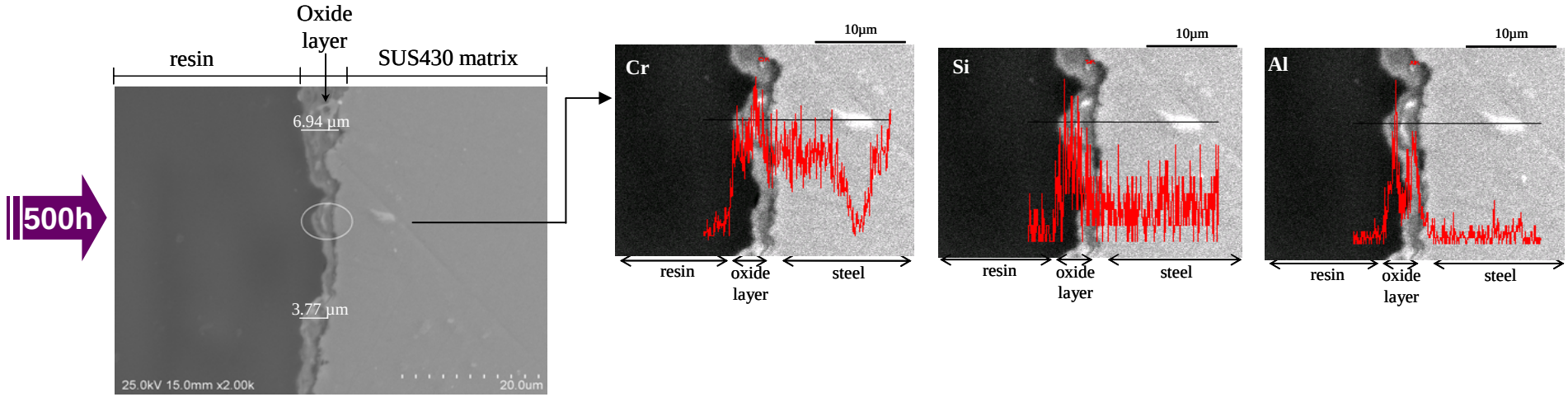


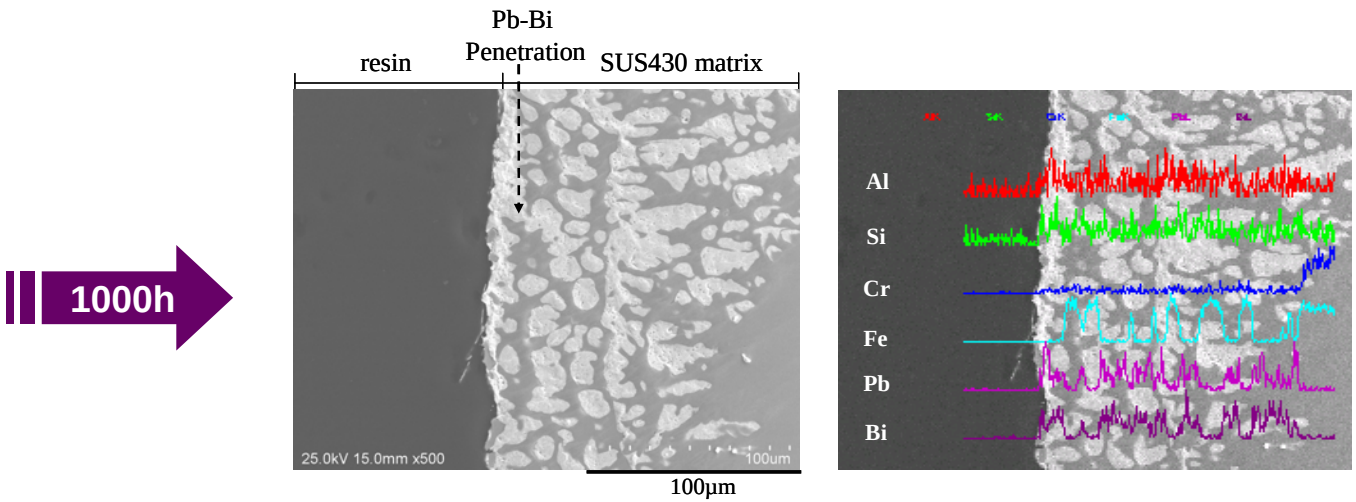


SUS316FR 18Cr-12Ni

High Cr Steels (Recloy10 17.7Cr-1Si-0.9Al)

$C_{O2} = 5 \times 10^{-6}$ wt%, 700ºC

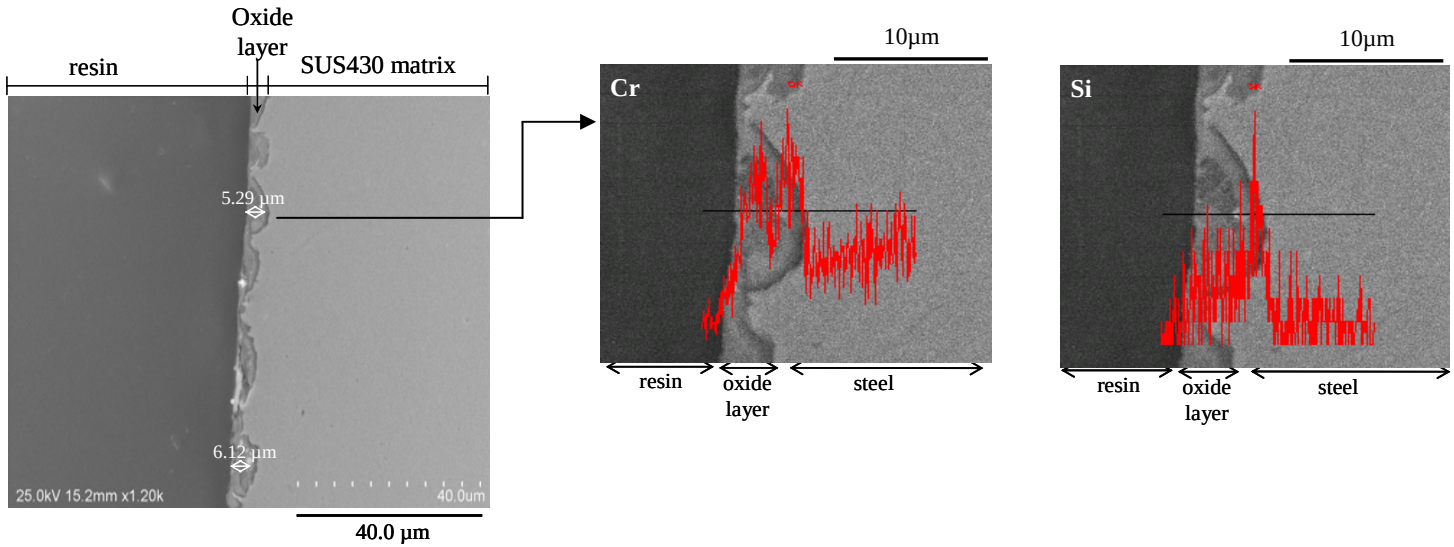




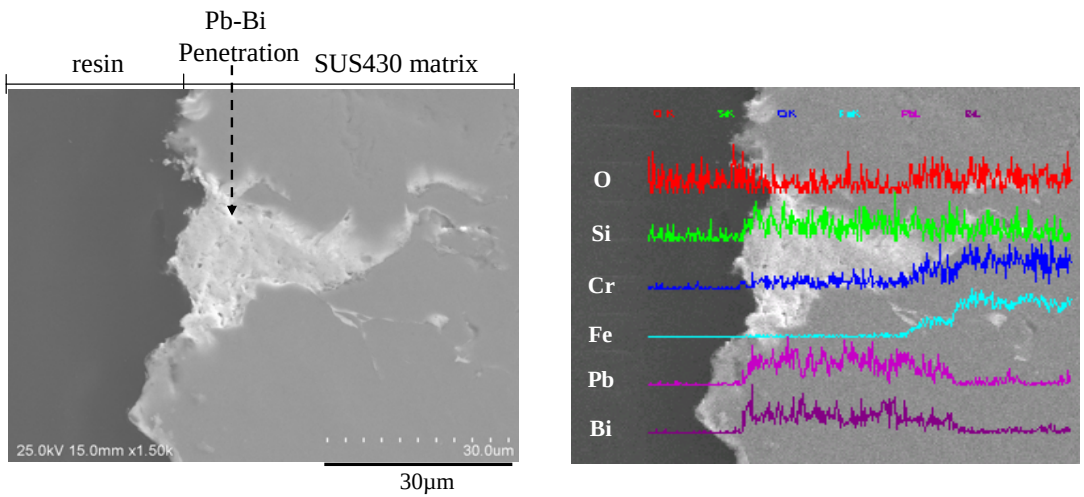
High Cr Steels (SUS430 18Cr-0.75Si)

$C_{O2} = 5 \times 10^{-6}$ wt%, 700ºC

500h

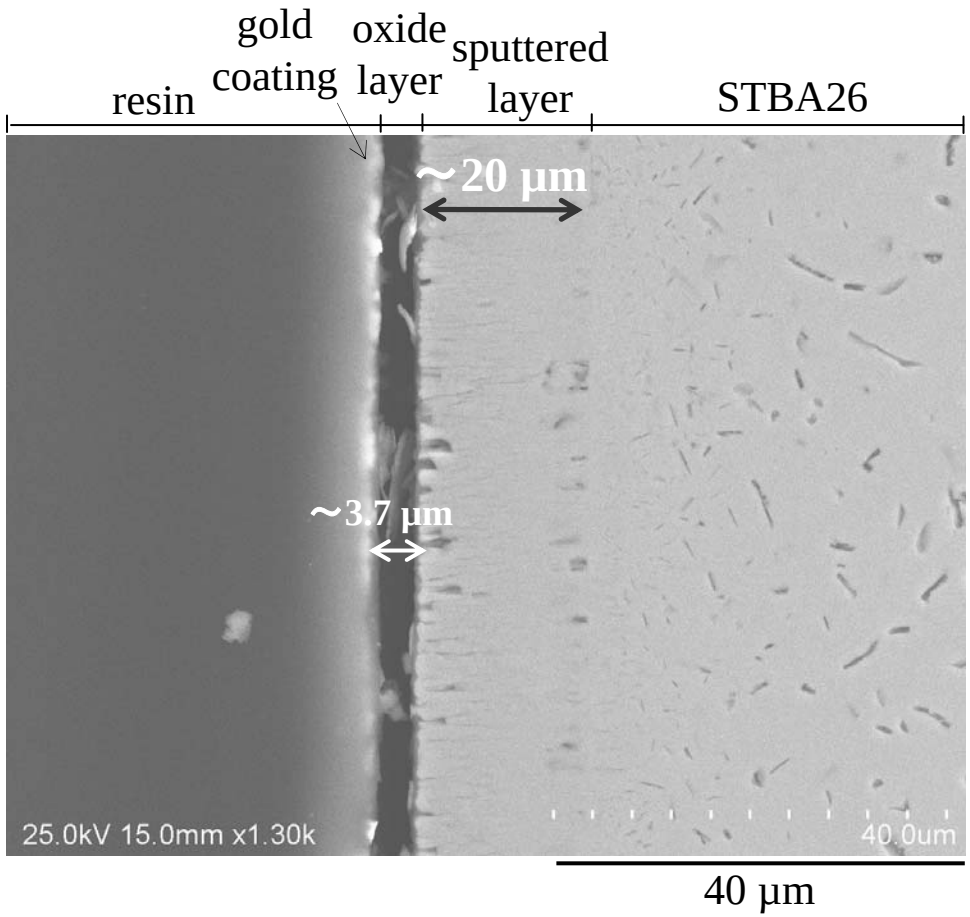


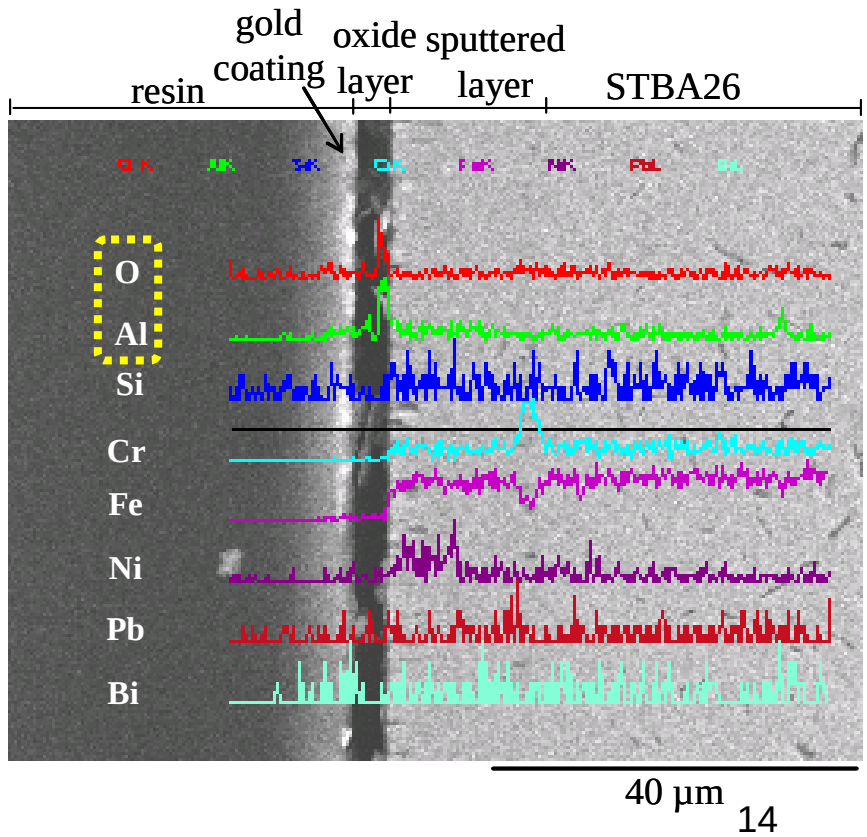
1000h



Al-Fe-coated (STBA26)

C_{O2} = 6.8 x 10^{-7} wt.%, 700ºC

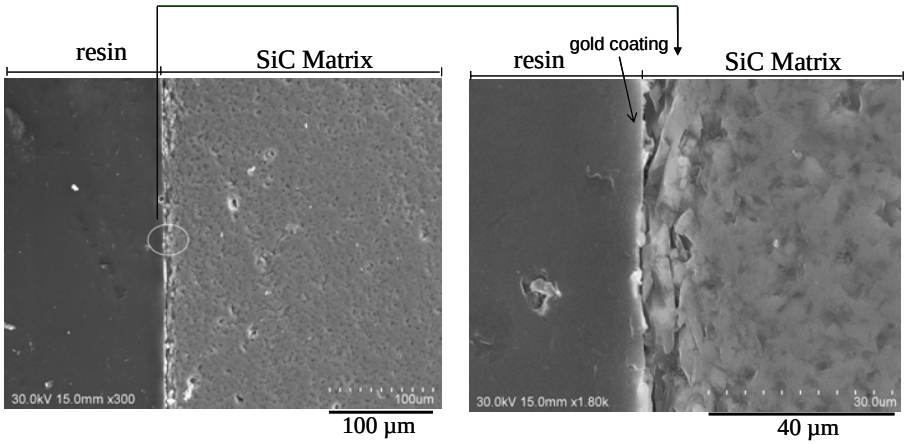




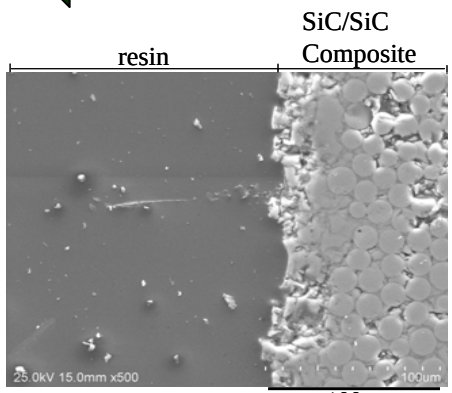
Ceramics

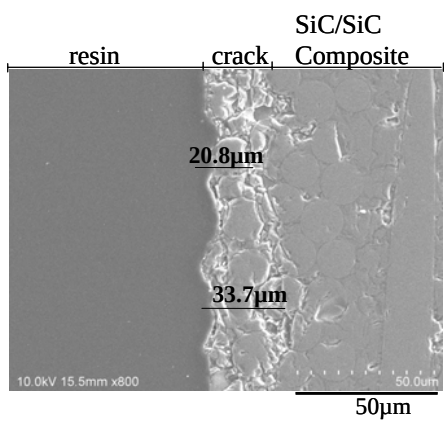
1000 hours, C_{O2} = 5 x 10^{-6} wt.% (SiC, Ti_3SiC_2)

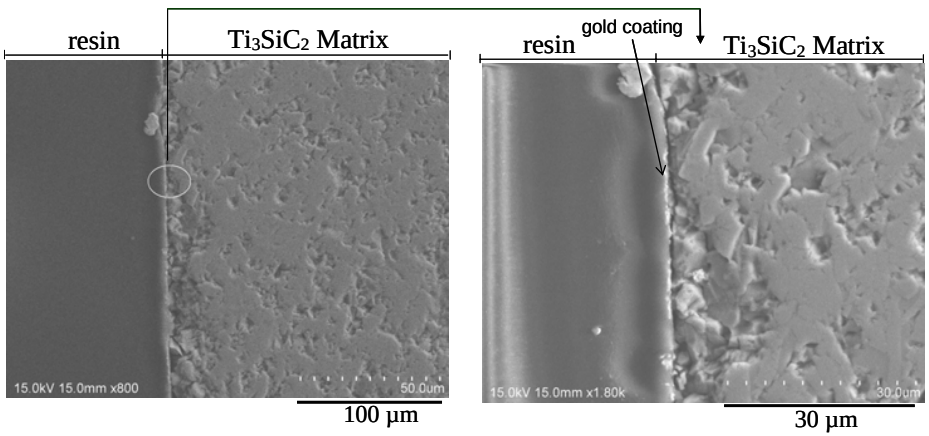
C_{O2} = 6.8 x 10^{-7} wt.% (SiC/SiC composite) , 700°C



SiC



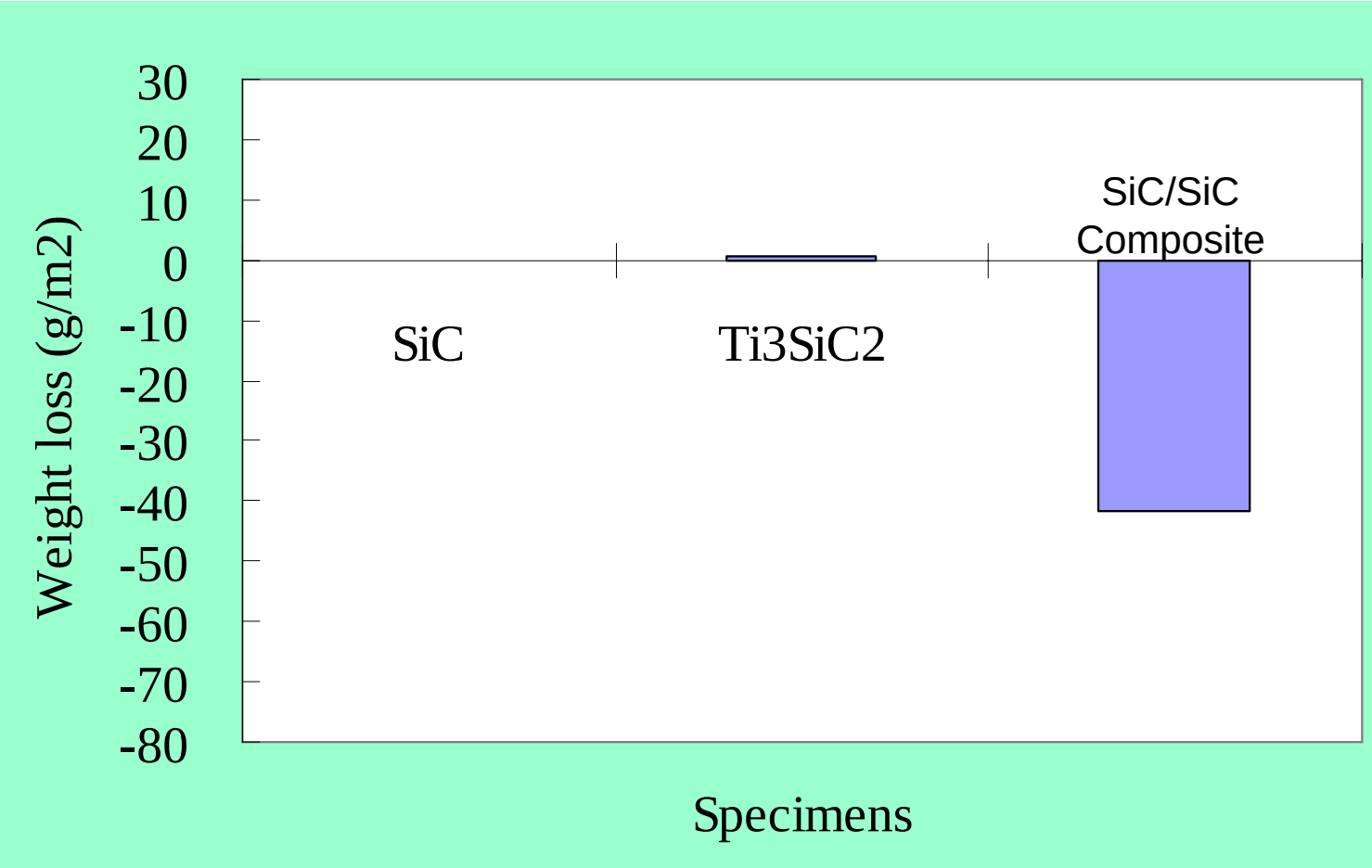




Ti_3SiC_2

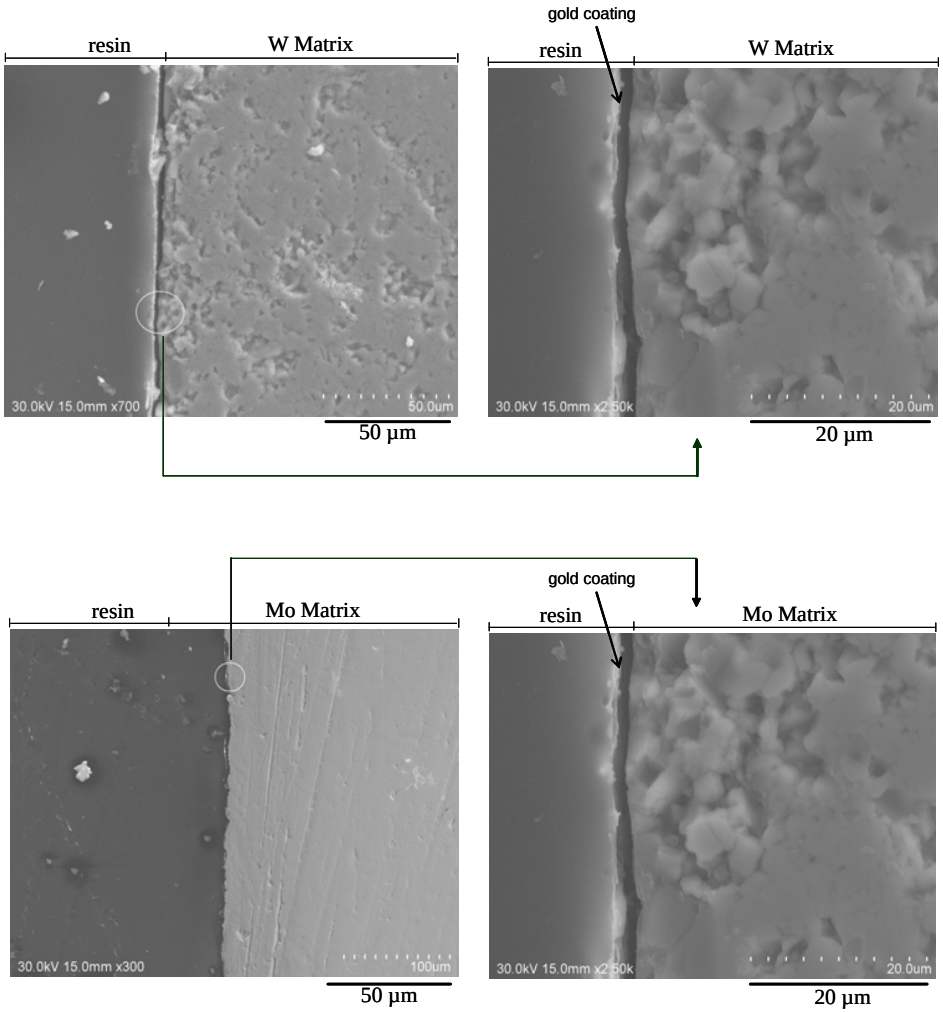
SiC/SiC composite

Weight Change of Ceramics

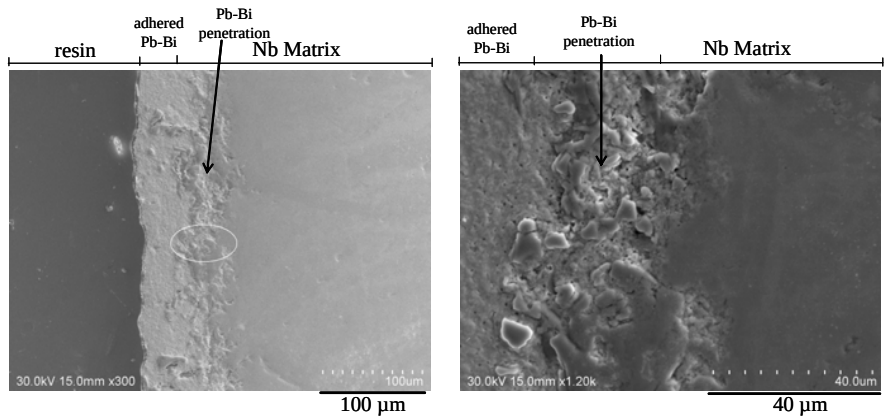


Result- Refractory Metals

$C_{O2} = 5 \times 10^{-6}$ wt.%, 700°C



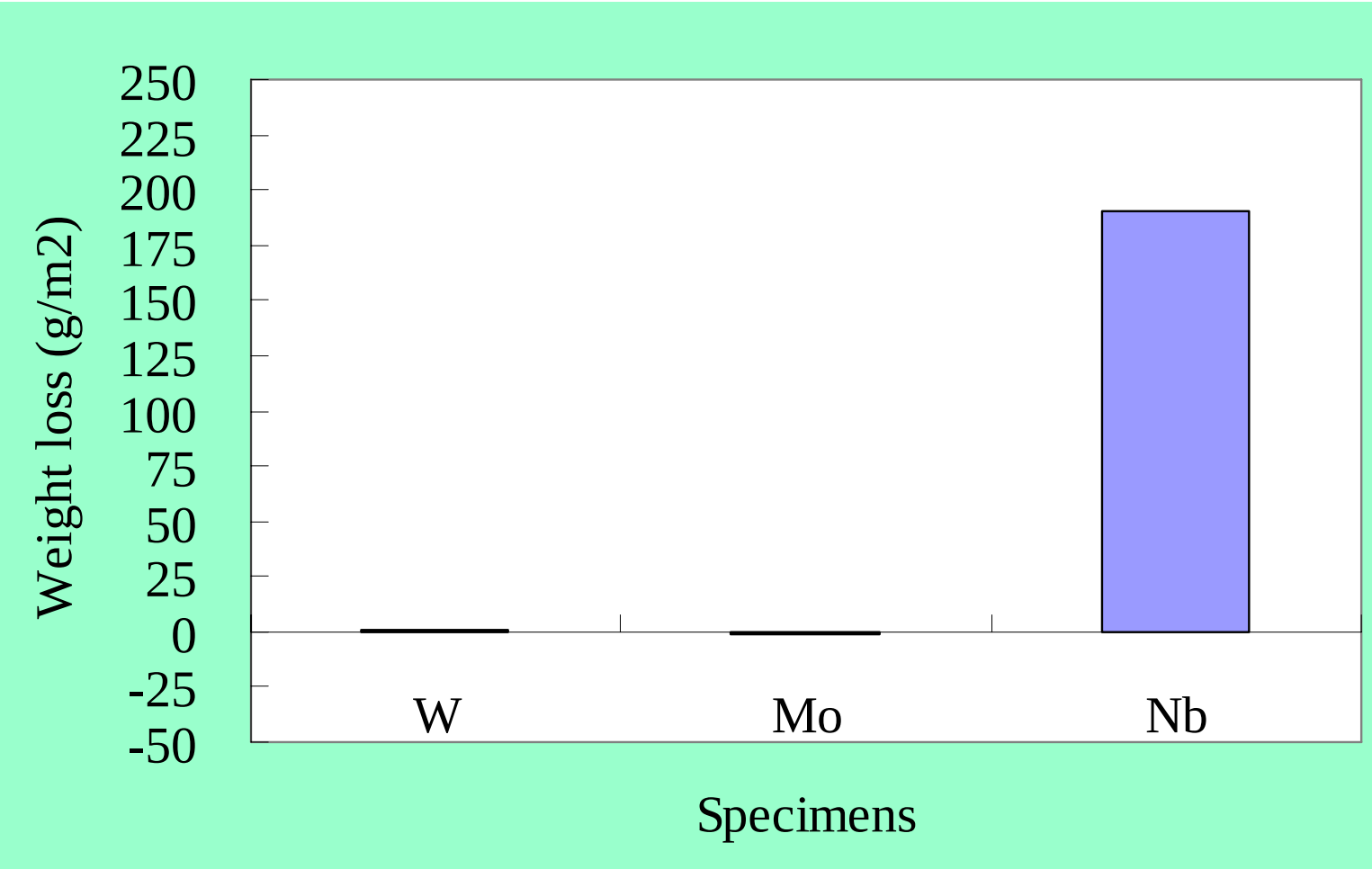
W



Nb

Mo

Weight Change of Refractory Metals



Conclusions

1. **Al-Fe-coated steel**, **W**, **Mo**, **SiC** and **Ti_3SiC_2** exibited good corrosion-resistance in LBE at 700 ºC.
2. **Nb** exibited poor corrosion-resistance in LBE at 700 ºC.
3. **SiC/SiC composite** showed that LBE penetrated into the matrix due to high porosity of the material, and a thin crack layer appearedin LBE at 700 ºC.