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Erosion-corrosion Assessment of Steels in HPHT Sweet Corrosive Environment

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Introduction

- Corrosion: Material degradation due to chemical or electrochemical action
- Erosion: Material removal by repeated deformation and cutting actions caused by solid particle impingement
- Erosion-corrosion: Simultaneous action of erosion and corrosion. Erosion removes protective film from the surface and exposes fresh surface for corrosion
- Synergistic effect: Total material loss is significantly higher than the sum of the individual contributions acting separately

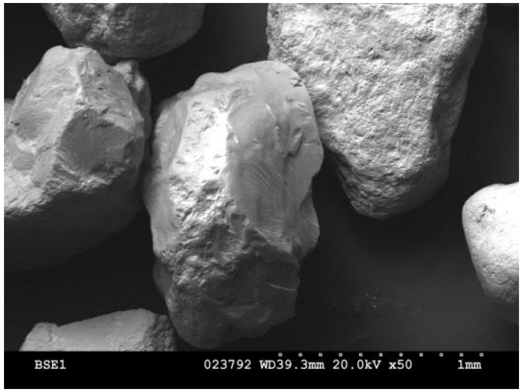
$$T > E_0 + C_0$$

Objective

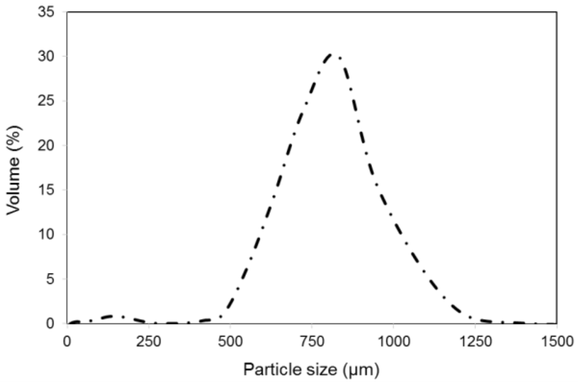
- Introduce high temperature-high pressure erosion-corrosion capability developed by NRC
- Evaluate erosion-corrosion performance of AISI 1018, En30B, API X70 and dupless stainless steel in sweet corrosive environment
- Identify possible wear mechanisms

Experimental

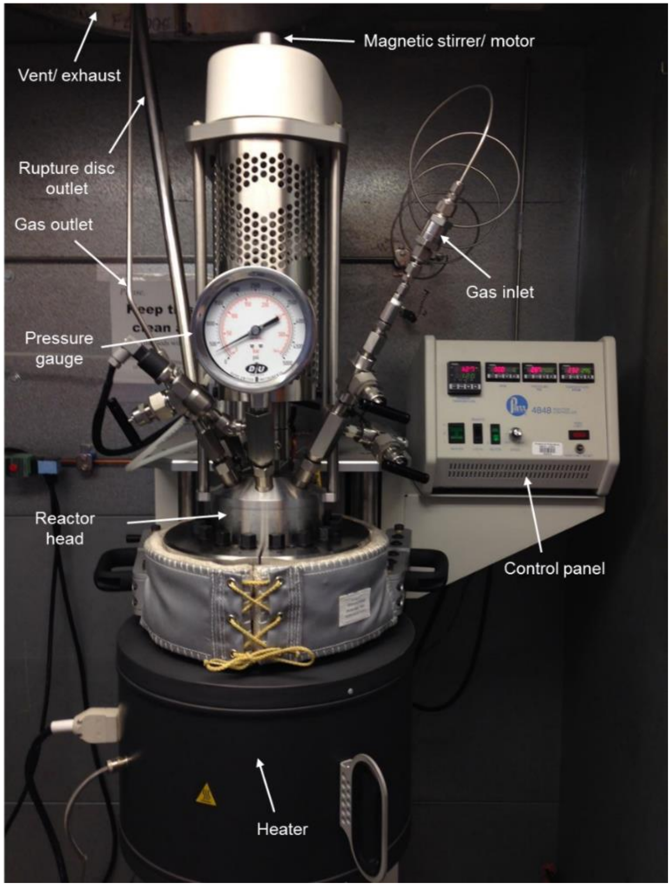
Parameters	Conditions
Materials	AISI 1018, En30B, API X70 and Duplex Stainless Steel
Slurry	10wt% Filter 16-30 + 3.5wt% NaCl (DI Water)
Temperature	45˚C and 200˚C
Pressure	600 psi
Environment	Purged with CO_2
Duration	24 hr



SEM micrograph of Filter 16-30

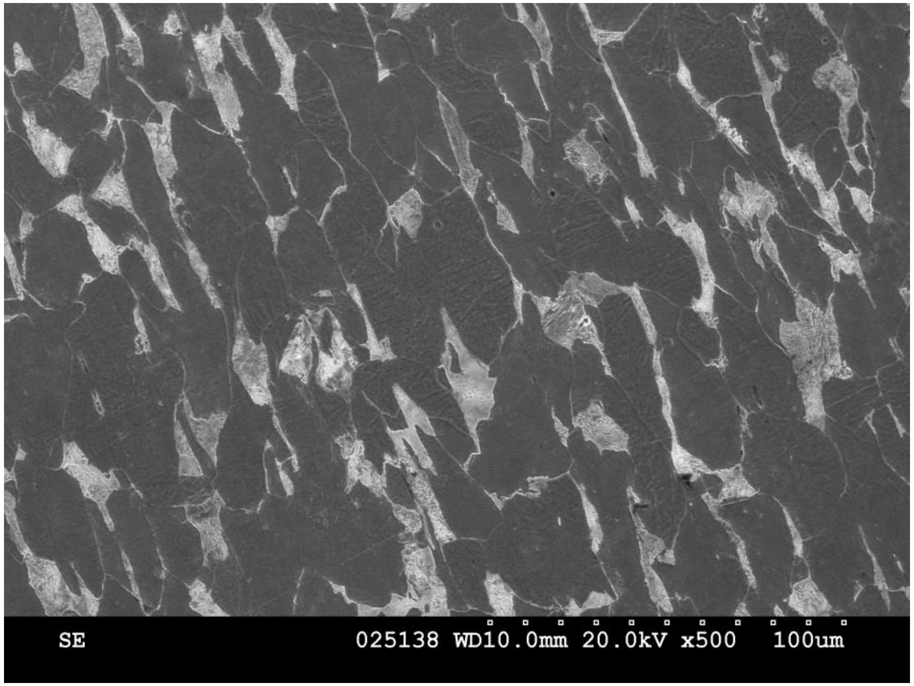


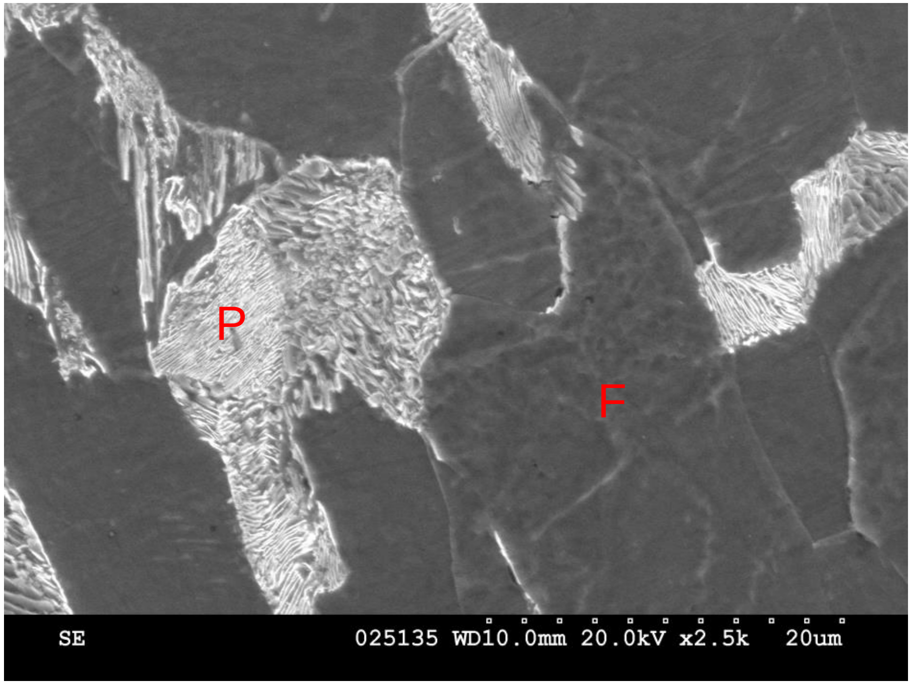
Average particle size 724-823 μm



Erosion-corrosion test apparatus during operation

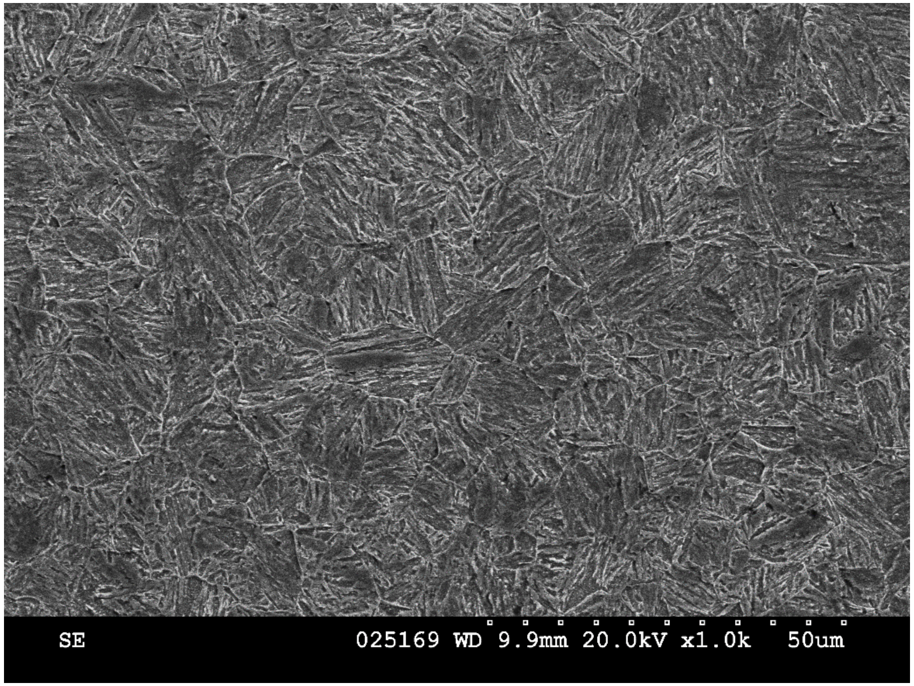
Microstructure (AISI 1018)

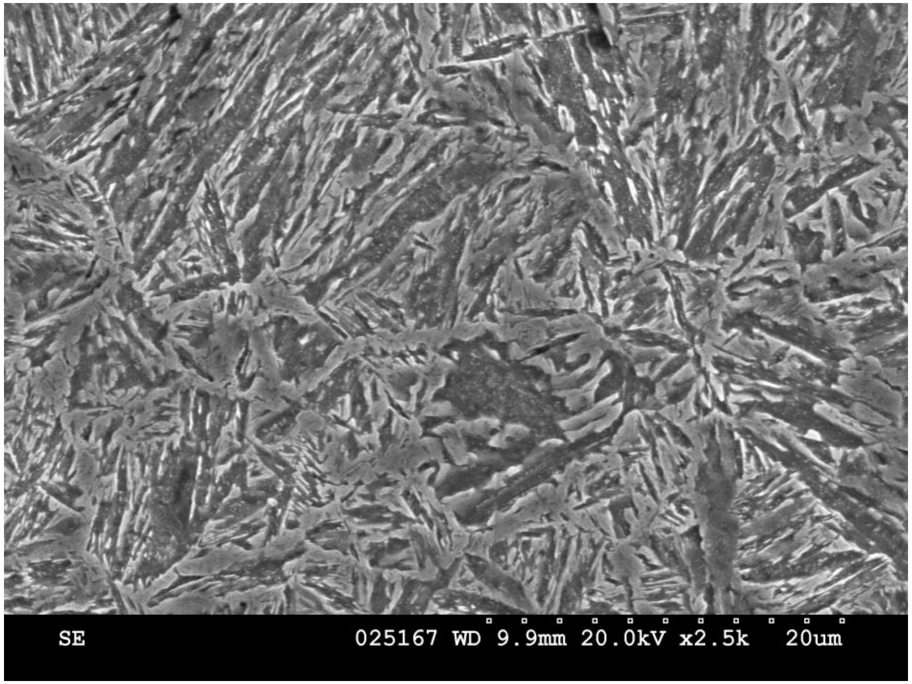




- Microstructure consists of Ferrite (F) and Pearlite (P)
- Grain size ~ 25-40 µm

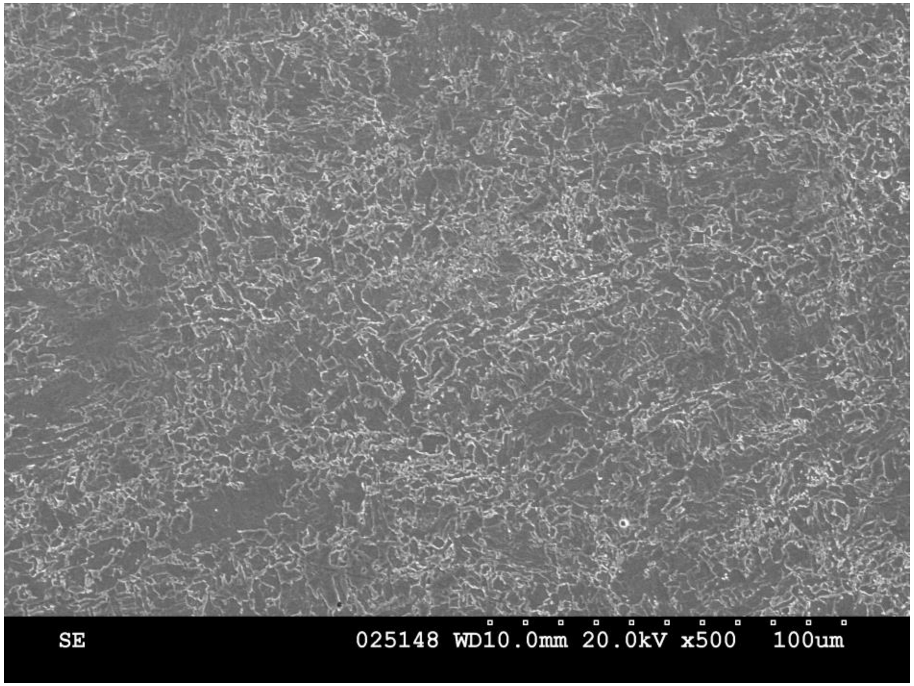
Microstructure (En30B)

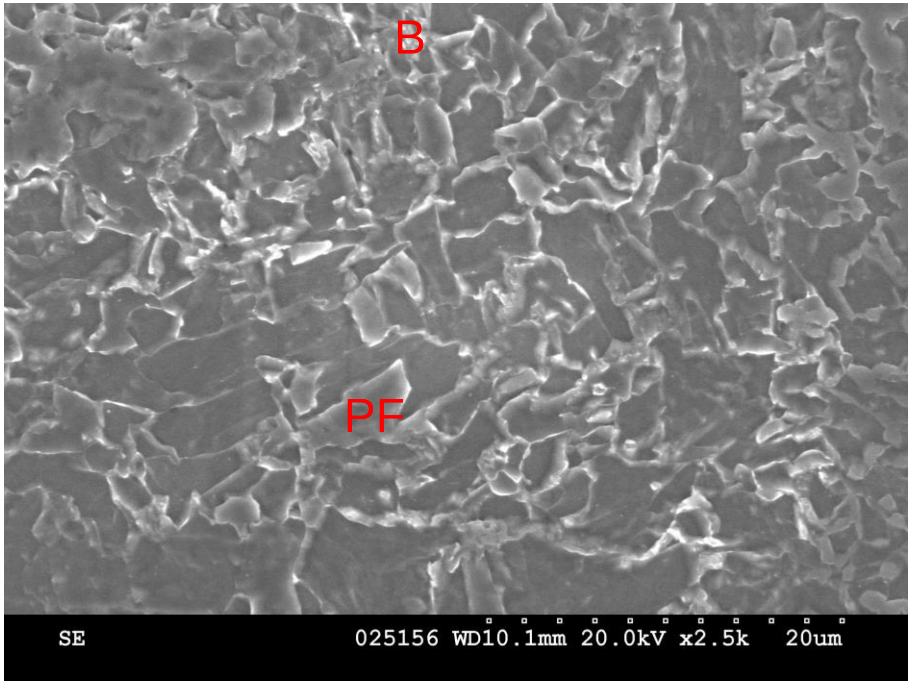




- Martensitic microstructure
- Grain size ~ 10-15 µm

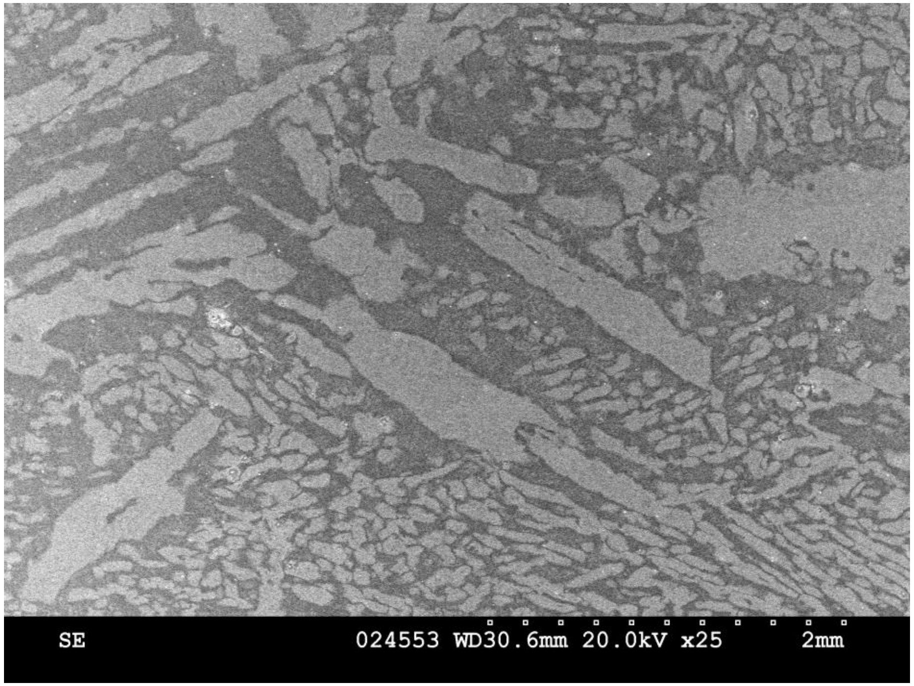
Microstructure (API X70)

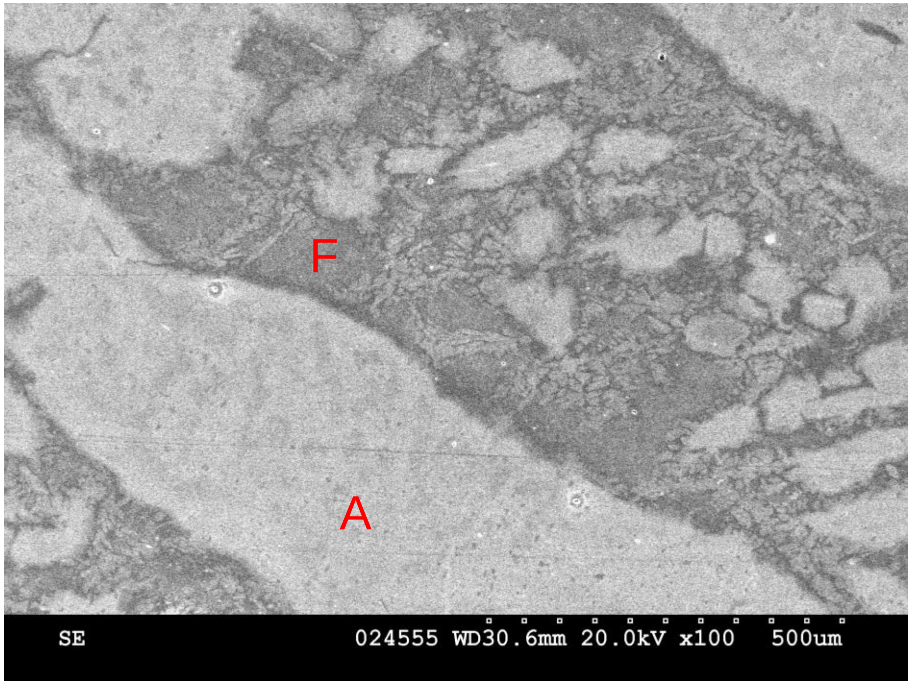




- Microstructure consists of Polygonal Ferrite (PF) and Bainite (B)
- Grain size ~ 2-5 µm

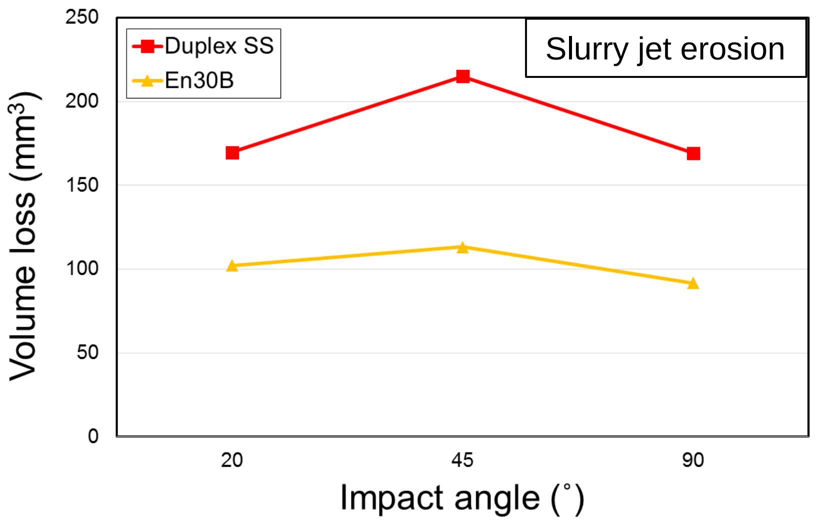
Microstructure (Duplex SS)

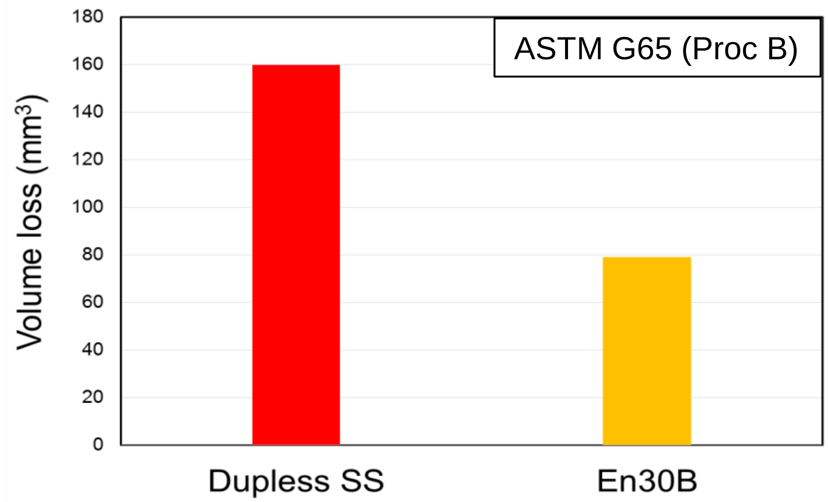


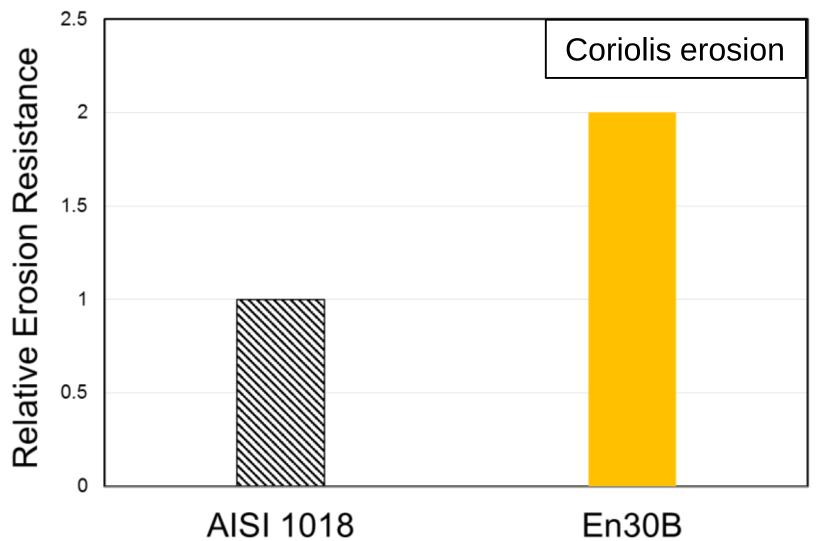


- Microstructure consists Ferrite (F) matrix with islands of Austenite (A)
- Grain size ~ 1-2 mm

Results and discussion

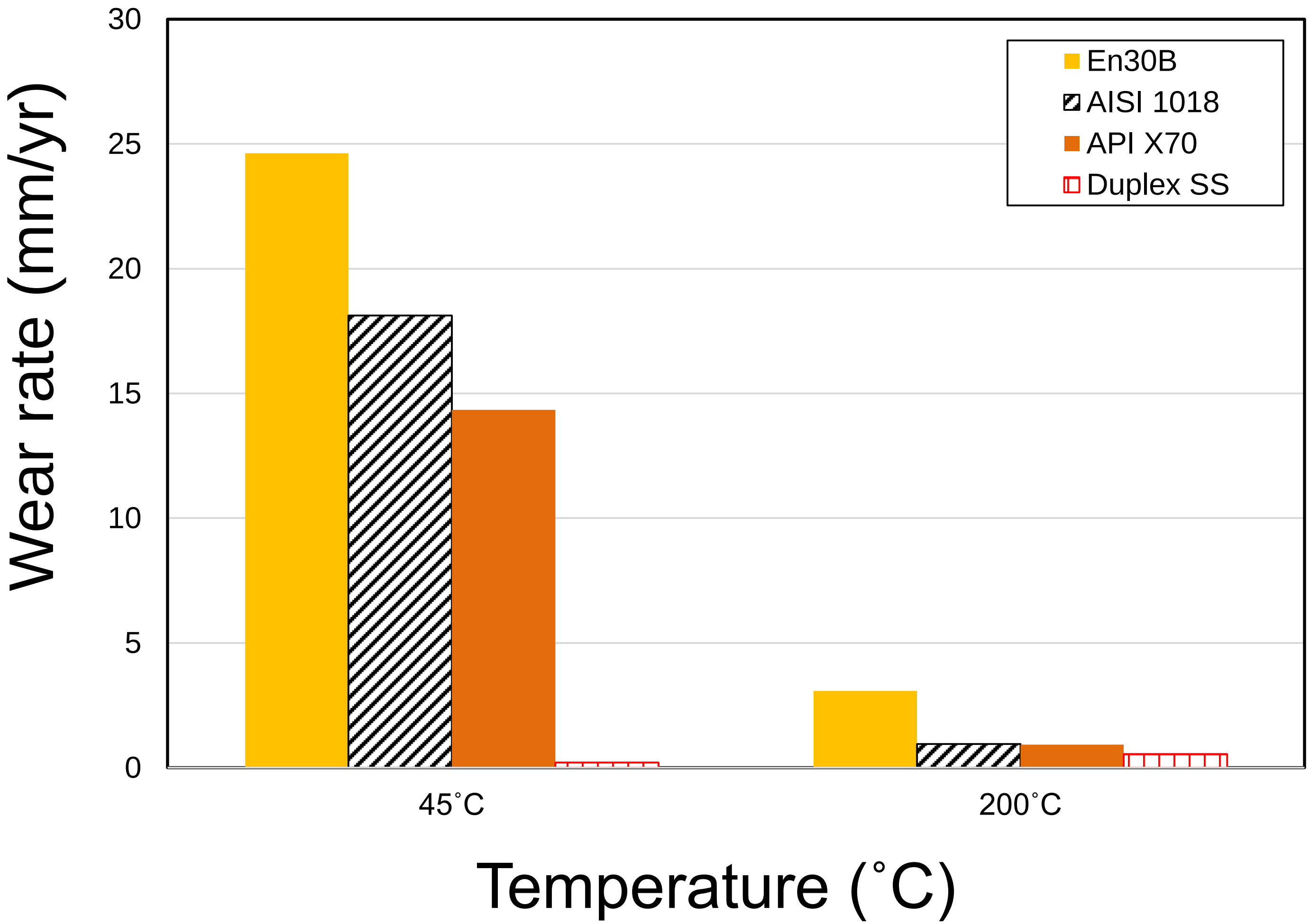




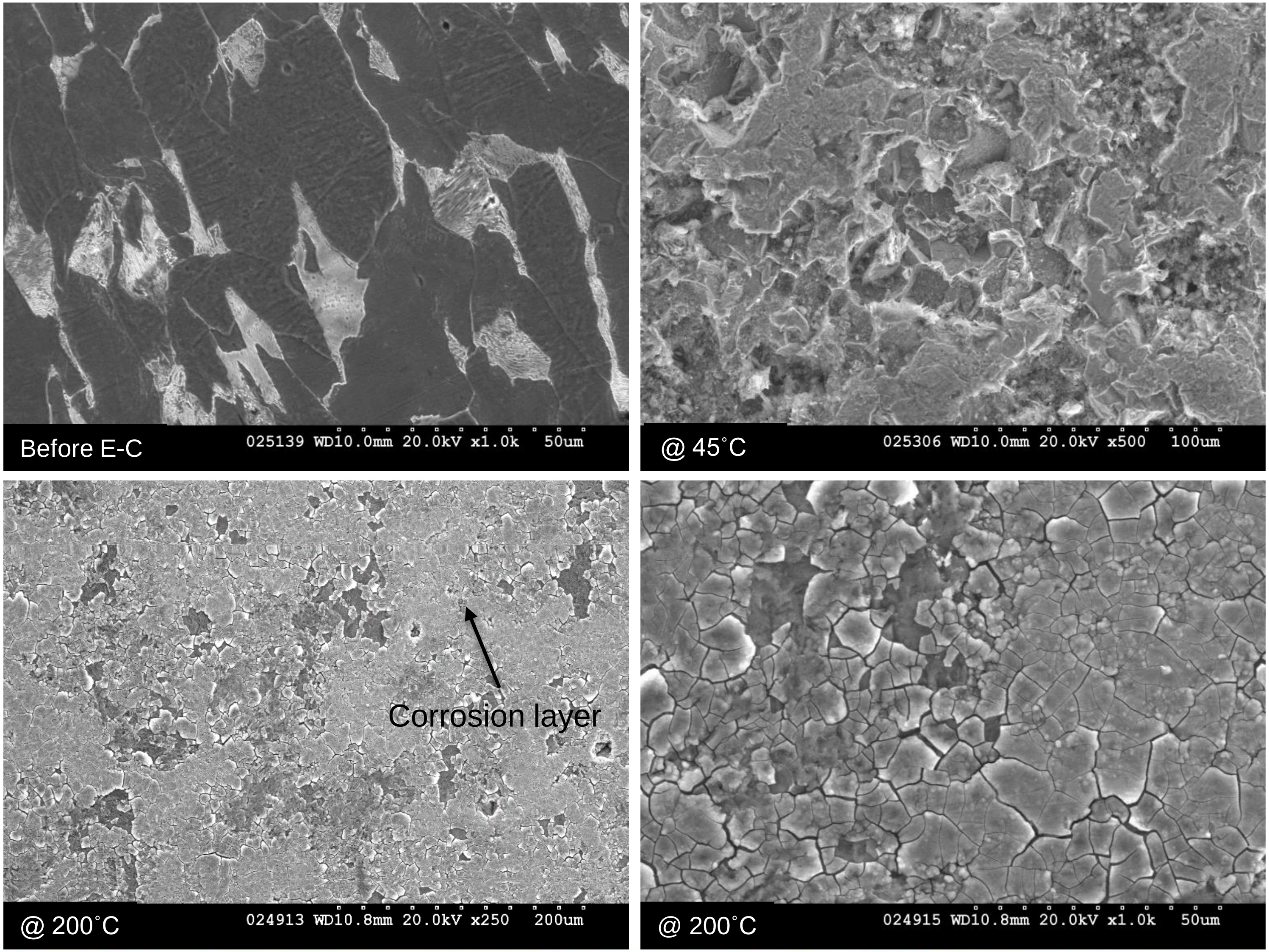


- Duplex SS exhibits inferior slurry jet erosion resistance at all impact angles
- En30B displays better low stress abrasion resistance than Duplex SS
- En30B shows better erosion resistance than AISI 1018 @23˚C

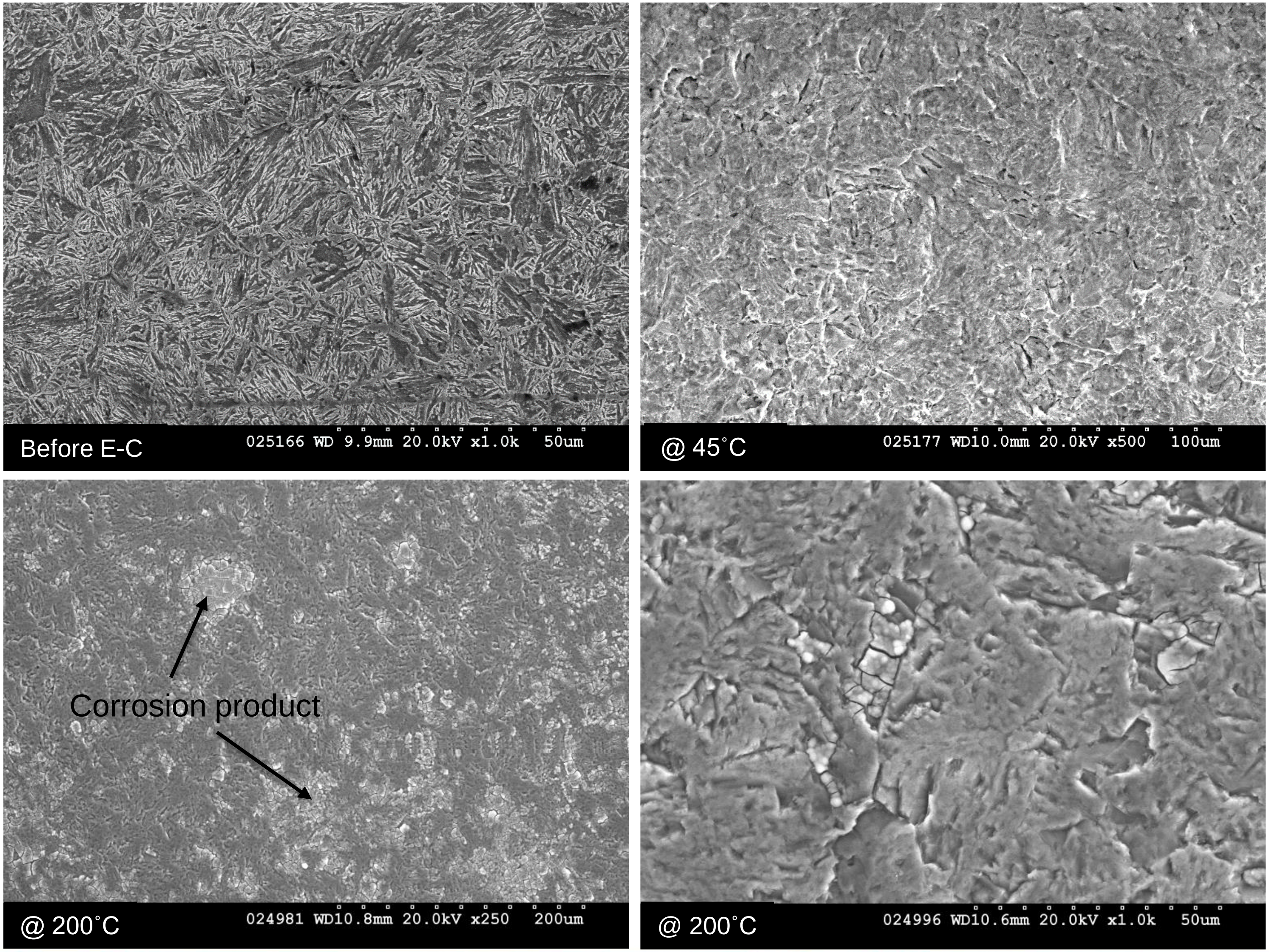
Results and discussion



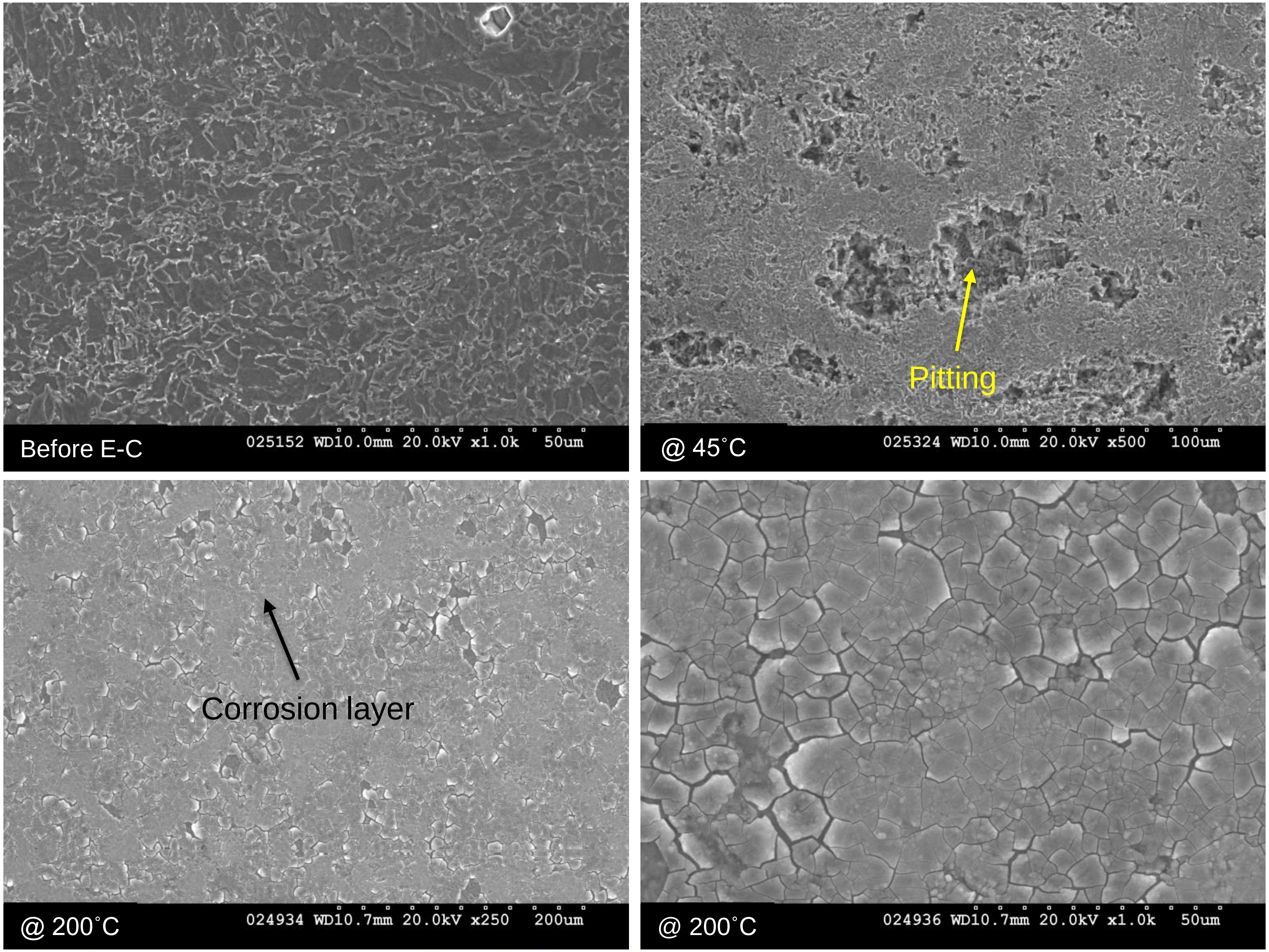
Wear scar after E-C (1018)



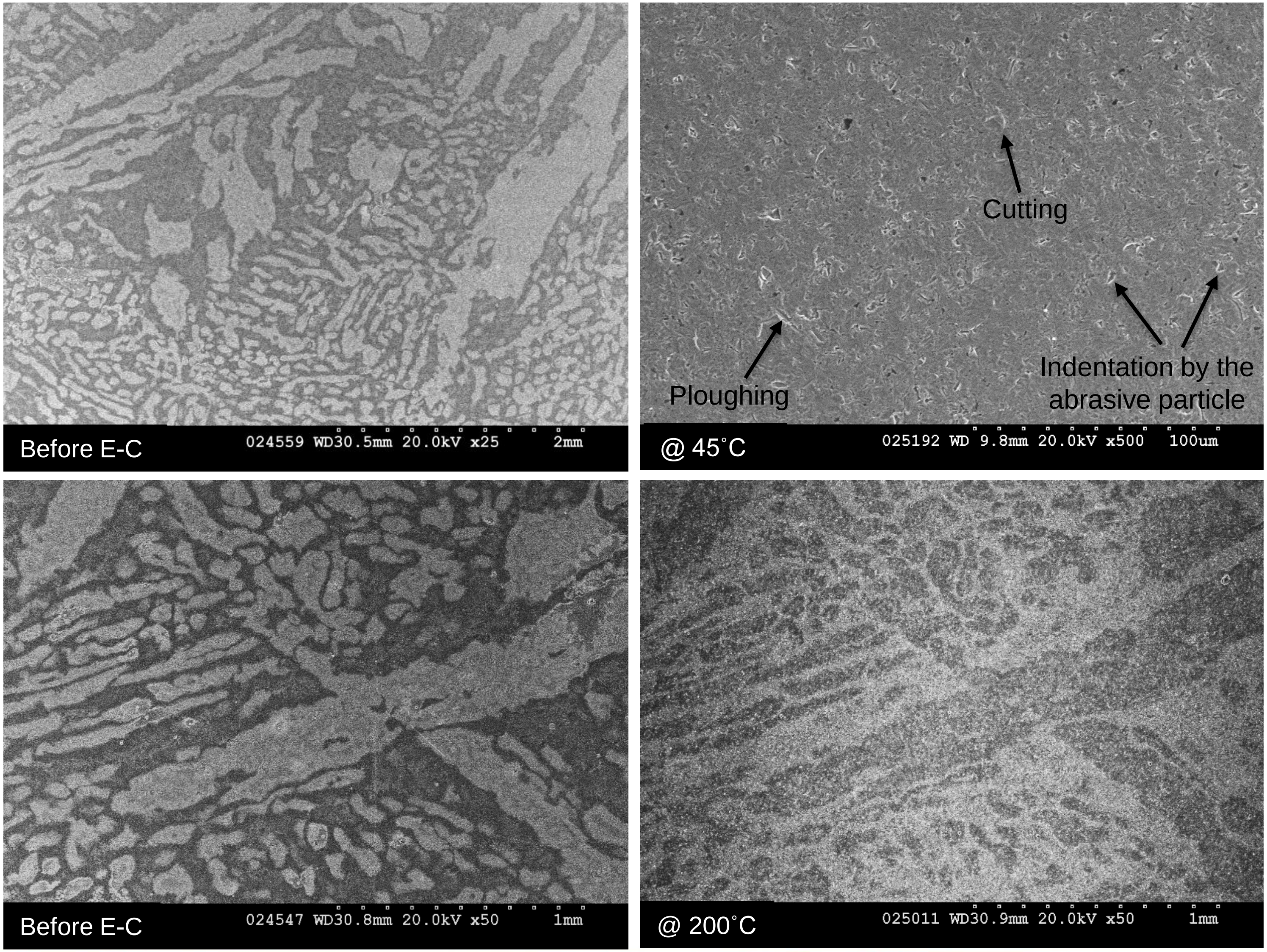
Wear scar after E-C (En30B)



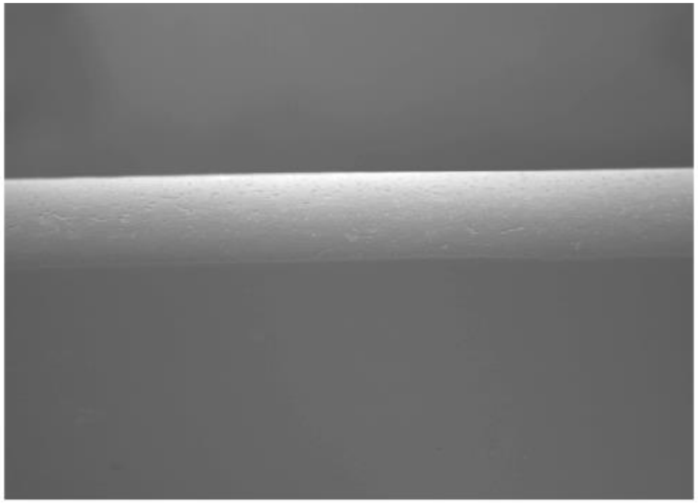
Wear scar after E-C (API X70)



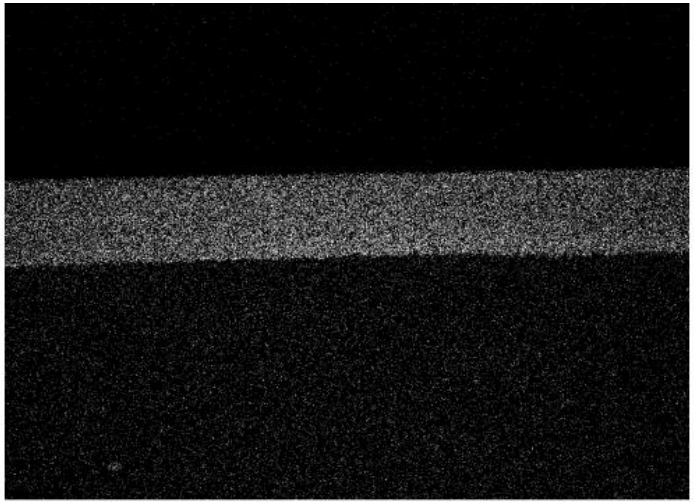
Wear scar after E-C (Duplex SS)



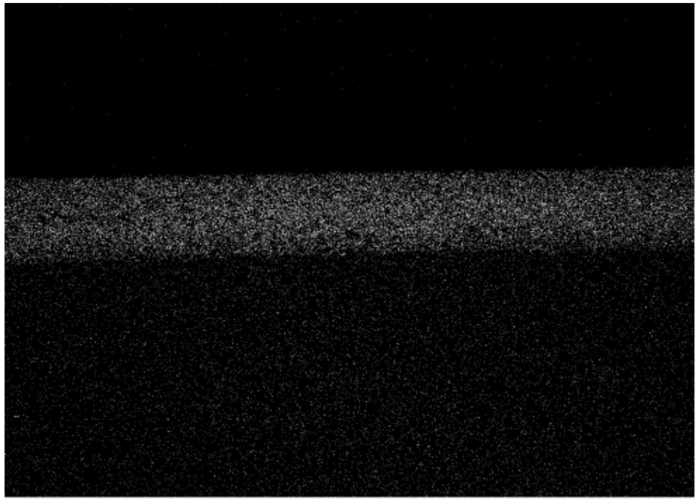
EDS mapping after E-C (X-section)



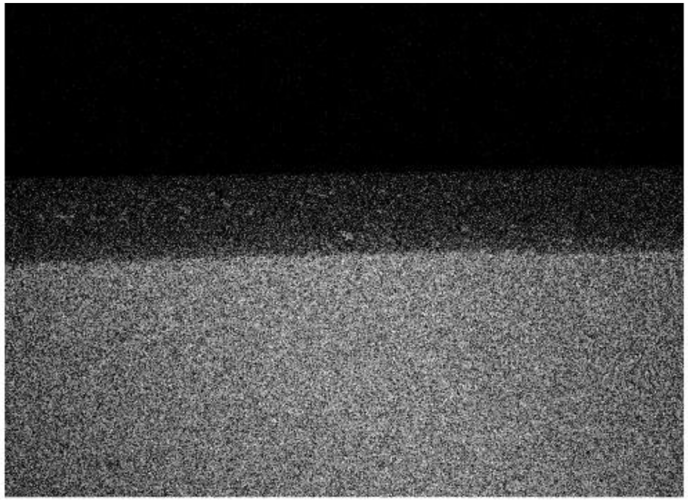
Electron Image 1



O Ka1

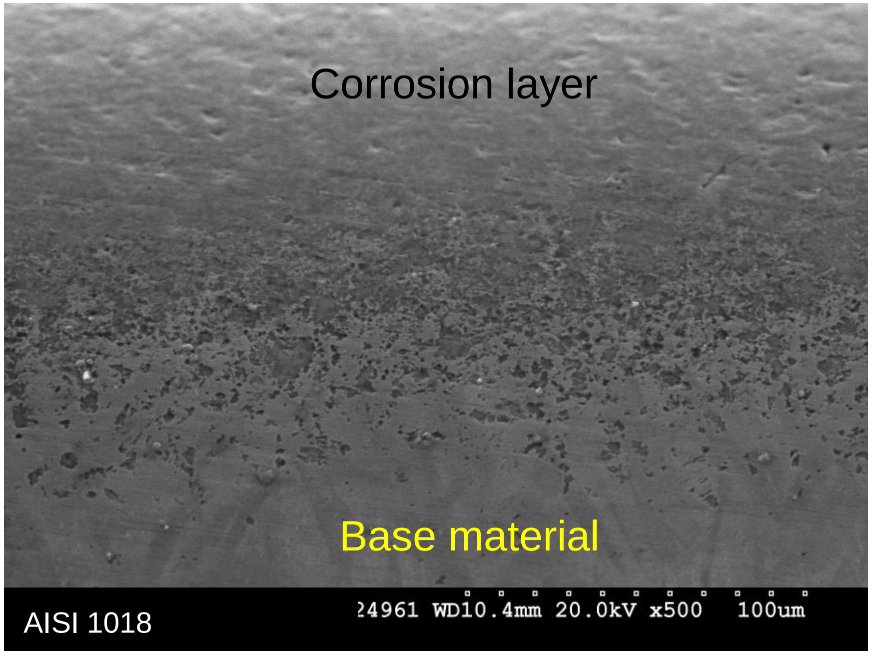


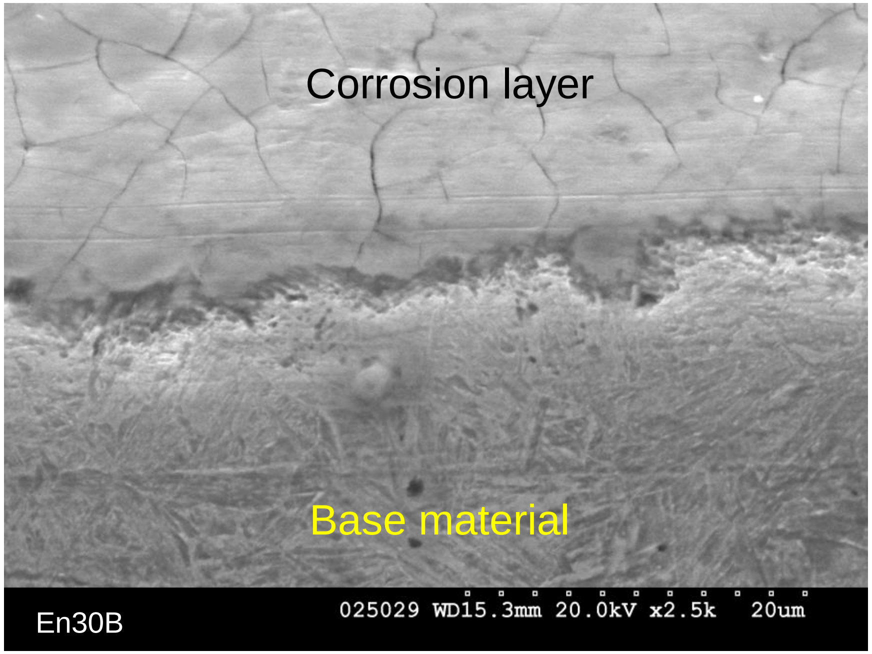
Mo La1



Fe Ka1

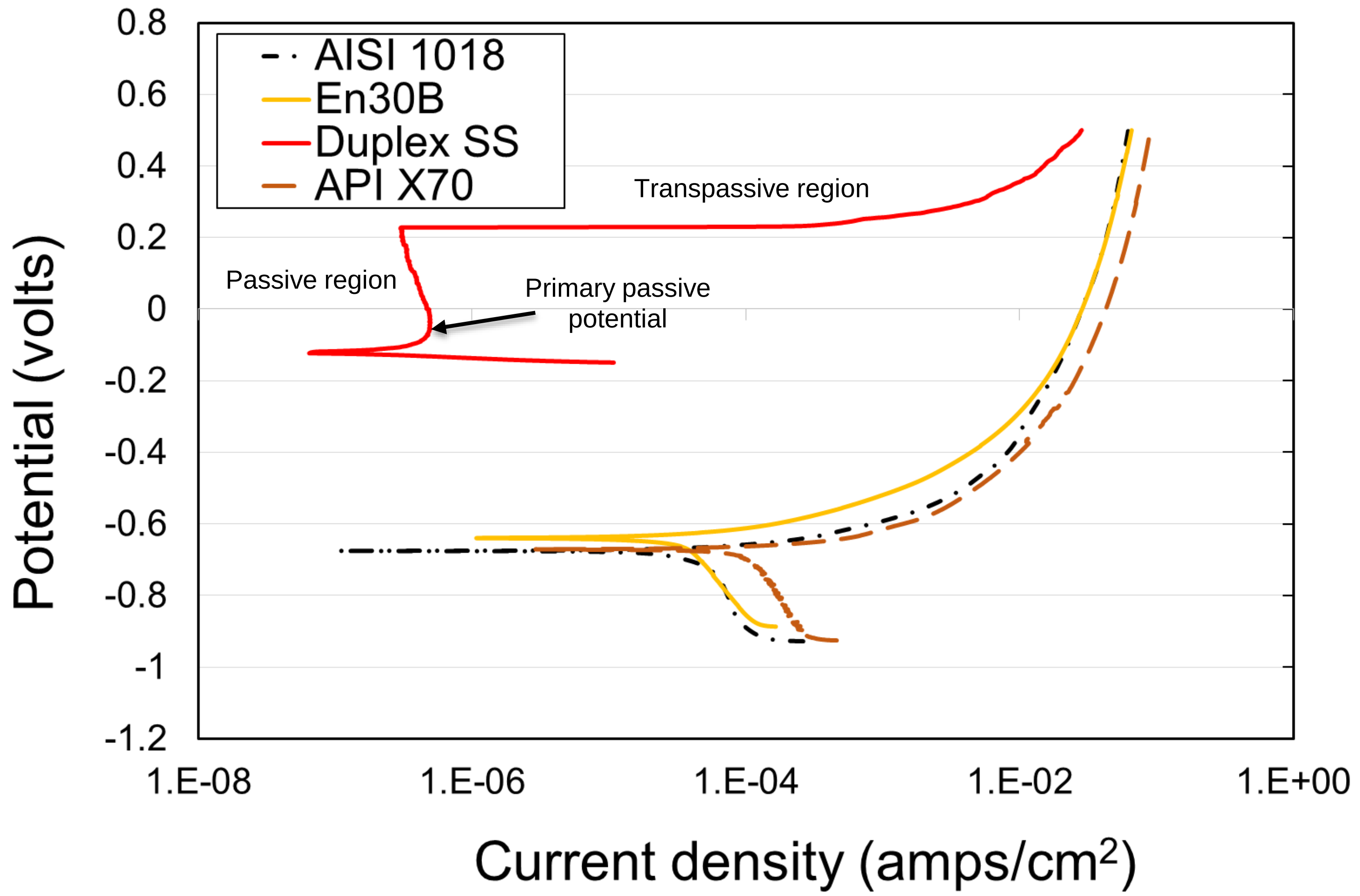
X-section after E-C @200˚C





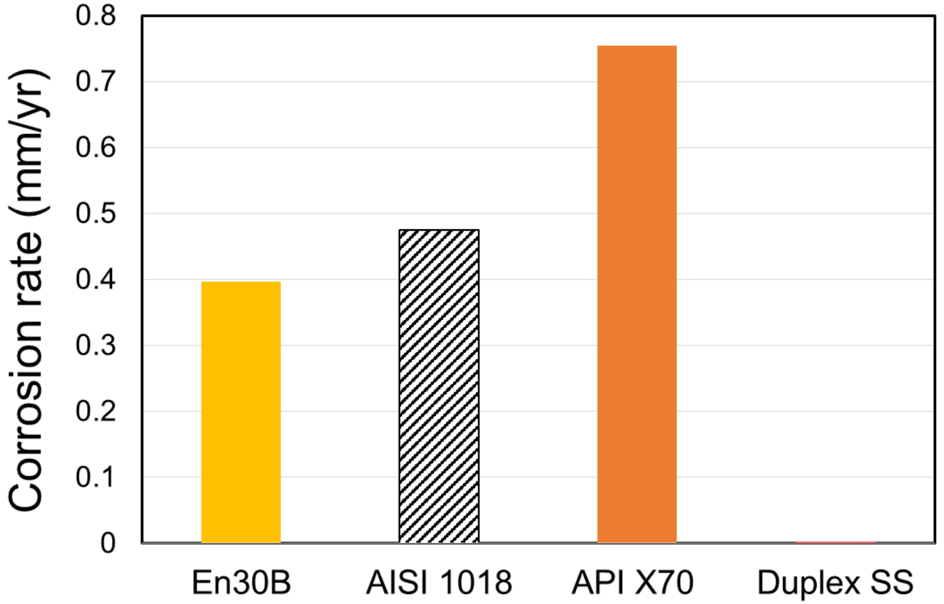
- AISI 1018 exhibits thicker and more adherent corrosion layer than En30B steel

Electrochemical corrosion



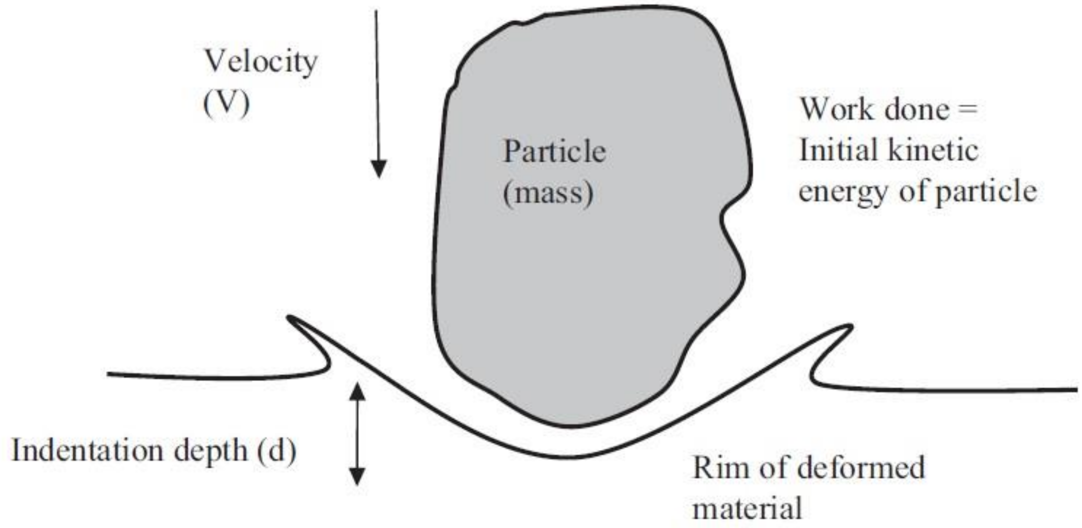
Electrochemical corrosion

Materials	E_{corr} (mV)	I_{corr} ($\mu A/cm^2$)	Corrosion rate (mm/yr)
En30B	-639.7	34.08	0.3969
AISI 1018	-675.8	40.82	0.4754
API X70	-672.2	64.75	0.7540
Duplex SS	-121.7	0.11	0.0012



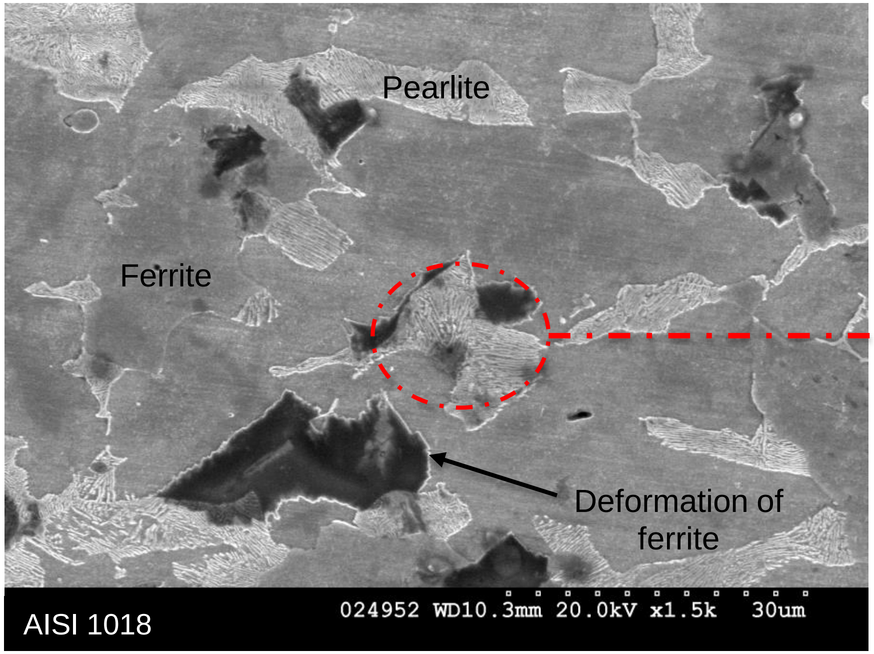
Elements	AISI 1018	En30B	API X70	Duplex SS
C	0.182	0.26 – 0.34	0.061	0.03
Si	0.095	0.1 – .04	0.150	0.70
Mn	0.754	-	1.223	1.50
Mo	-	0.2 – 0.4	-	0.20-0.35
Cr	0.181	1.1 – 1.4	0.018	11.0-12.5
P	0.040	-	0.010	0.04
Cu	0.186	-	0.008	-
Ti	0.008	-	0.015	-
Ni	-	3.9 – 4.3	-	1.00
V	0.001	-	0.056	-
Nb	-	-	0.05	-
S	0.021	-	0.002	0.01
Fe	Balance	Balance	Balance	Balance

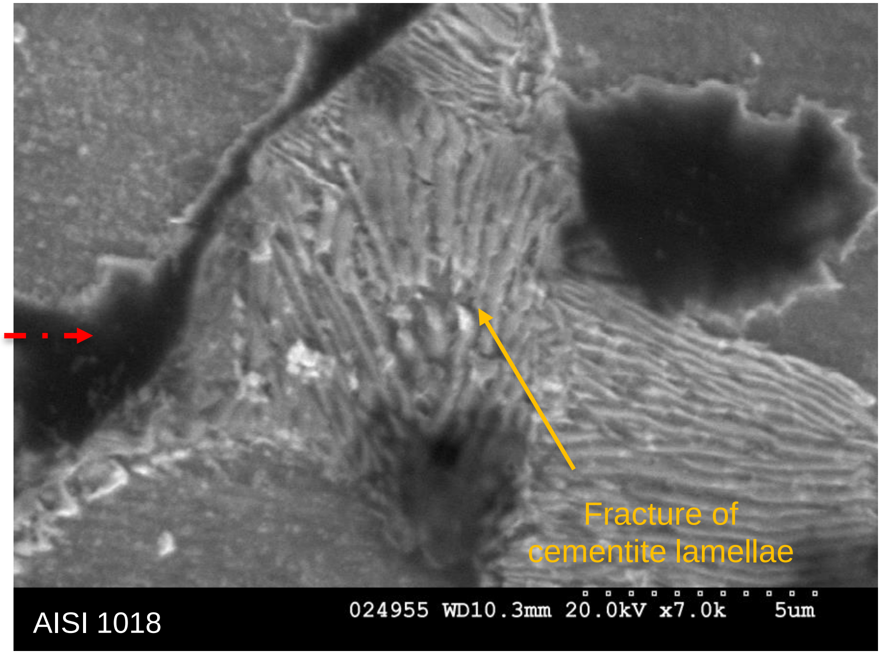
Effect of abrasive particle



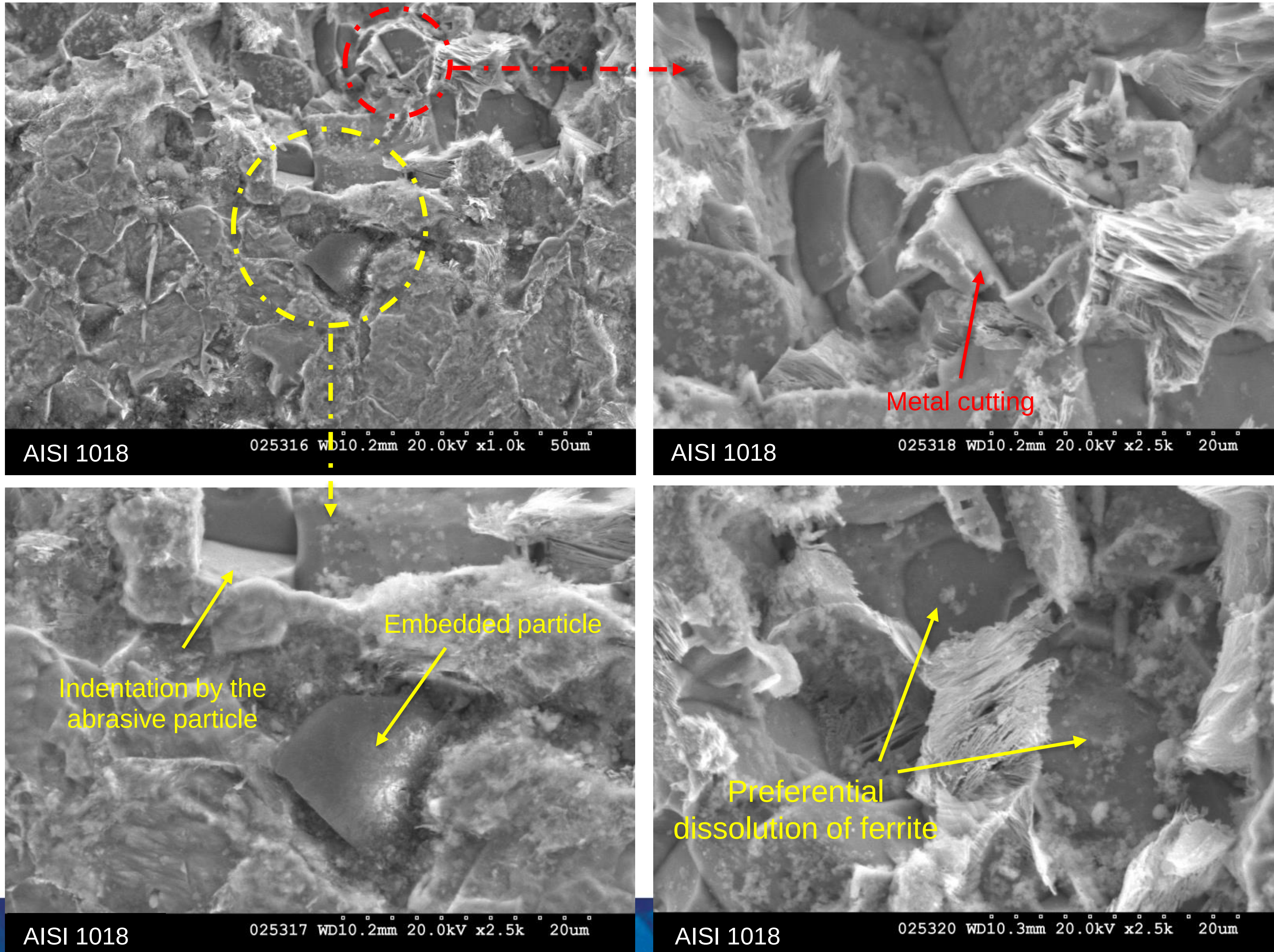
- The kinetic energy of an impact is absorbed as local deformation
- Each impact displace material from the indentation
- Materials are removed as wear debris once it has undergone several cycles of plastic deformation/ severely work hardened

Wear mechanisms





Wear mechanisms



Conclusions

- Among 4 evaluated steels, duplex SS displays best high temperature-high pressure erosion-corrosion resistance in sweet environment.
- Except for duplex SS, wear rate decreases with increase in temperature. This is mainly due to the formation of adherent corrosive layer which protects the surface from further erosion.
- Material loss rate of duplex SS is dominated by erosion.
- Simultaneous action of corrosive layer formation and removal of the corrosive layer by abrasive particle impact determines final wear rate.

Thank you!