Effect of Cold Working on the Corrosion Resistance of JPCA Steel in Flowing Pb-Bi at 450ºC

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Outline

- Motivation Concept
- Purpose
- Experiment and Procedure
- Results & Discussion
- Conclusions

Motivation Concept

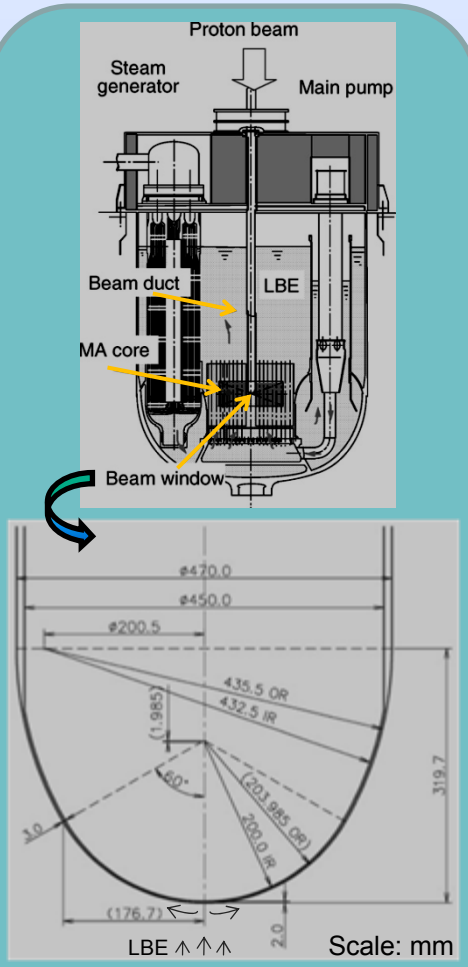
LBE (Pb-Bi eutectic) is the candidate for ADS (Accelerator Driven System) spallation target and core coolant (JAEA`s design).

Materials Issues:

1.Corrosion attack of Pb-Bi to metals.

2.Hydrostatic pressure of Pb-Bi.

3.Protons bombardment to beam window.



Developing Solutions:

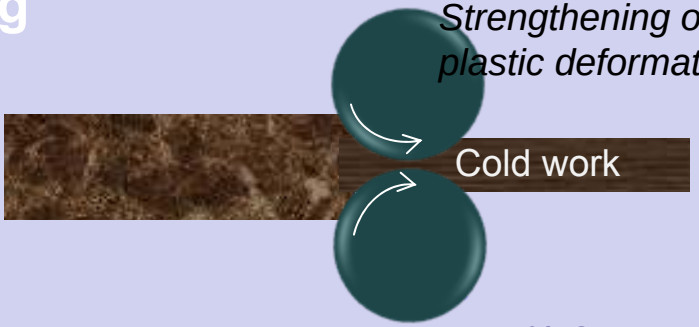
1. **JPCA steel:** the candidate material for the proton beam window.

2. **Cold worked-JPCA steel:** expected to be stronger to endure protons bombardment and Pb-Bi`s pressure.

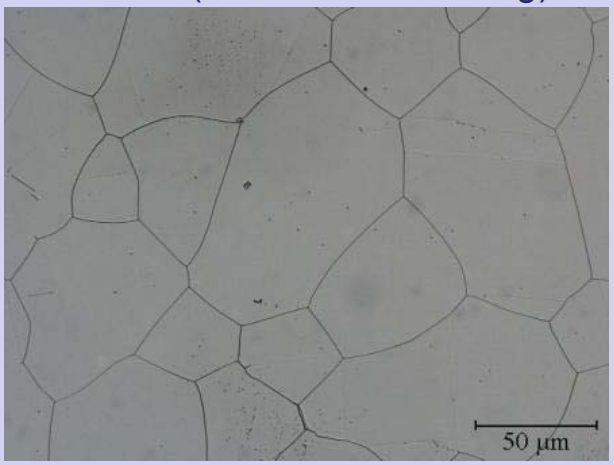
Motivation Concept

Cold working

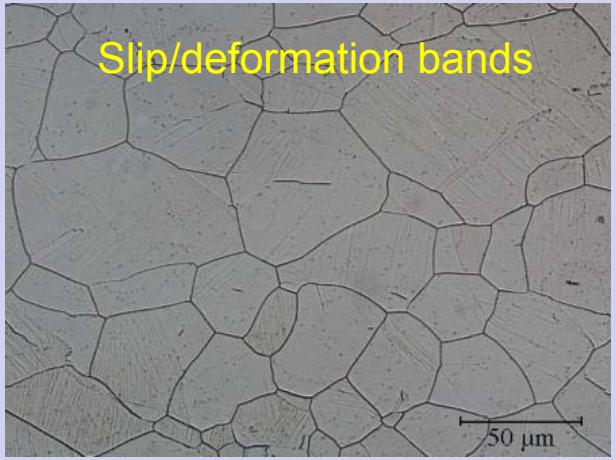
Strengthening of a metal by plastic deformation



JPCA (without cold working)



20% Cold worked-JPCA

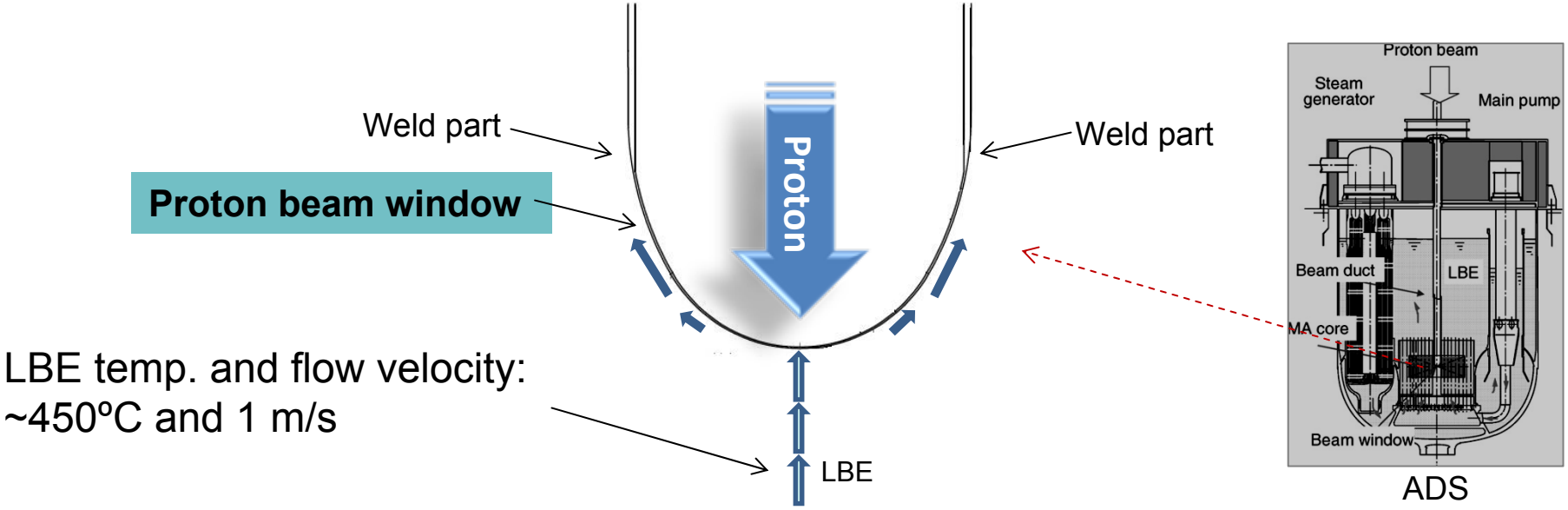


Cold working (austenitic steel) process induces:

1. Increasing the strength and hardness.
2. Dislocation movement within the crystal.
3. Transformation from fcc austinite (γ) to bcc martensite (α`, *magnetic*).

Purpose

To investigate the effect of cold working on the corrosion resistance of JPCA steel in flowing Pb-Bi at 450ºC of temperature and 1 m/s of flow velocity.



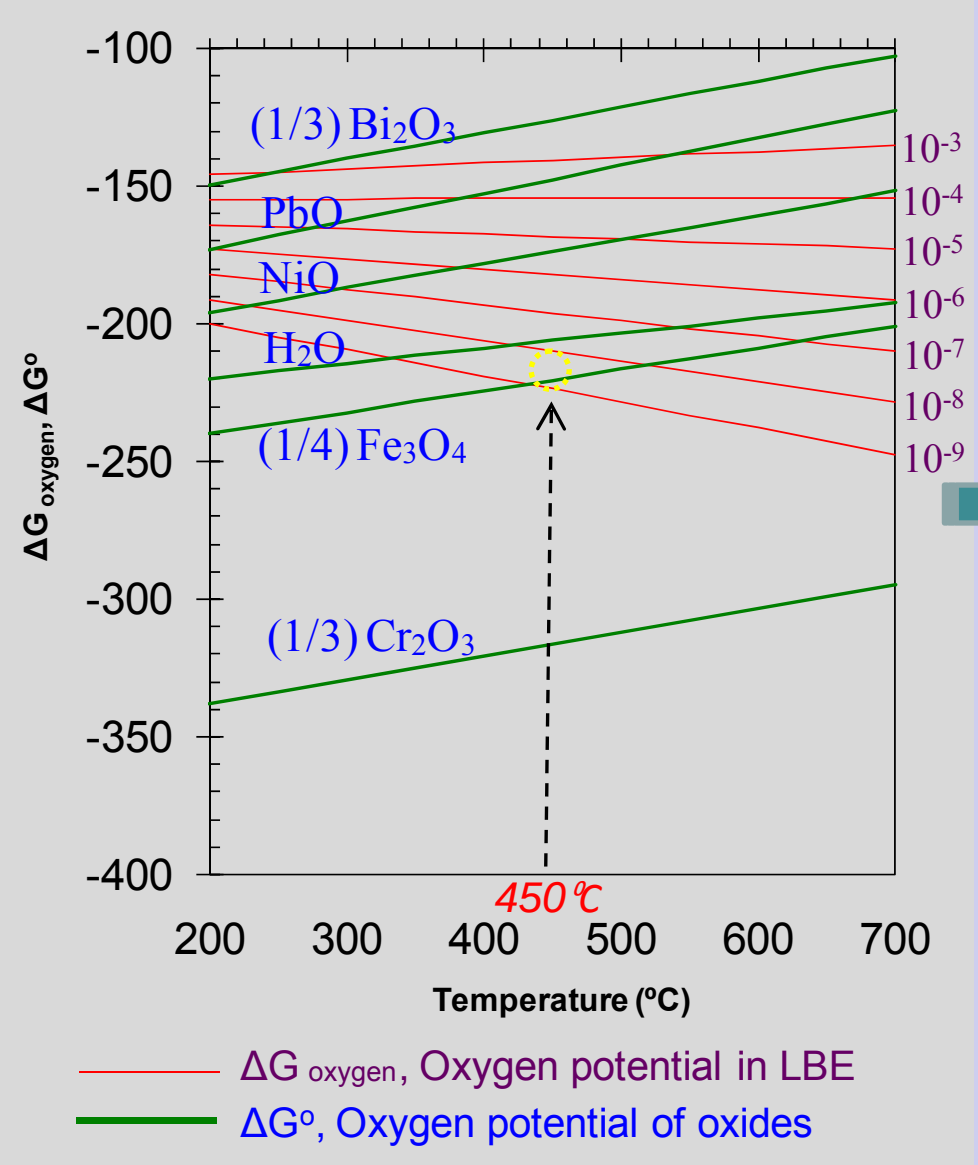
Experimental & Procedure

Parameter	Conditions
Type of liquid	LBE (Pb-Bi eutectic)
Flow velocity (m/s)	1
Temp. of hot and cold part (°C)	450 and 350
Oxygen concentration (wt.%)	~10^{-8} - ~10^{-9}
Time immersion (hrs)	**1000**
Materials	20% Cold worked (CW)-JPCA No CW-JPCA (as comparison)

JPCA-Chemical Compositions (wt.%)

Fe	**Ni**	**Cr**	Mo	Mn	Si	Ti	C	B	P	Co	S	N
Balance	**15.50**	**14.50**	2.50	1.50	0.50	0.25	0.055	0.004	<0.035	<0.02	<0.01	<0.01

Experimental & Procedure

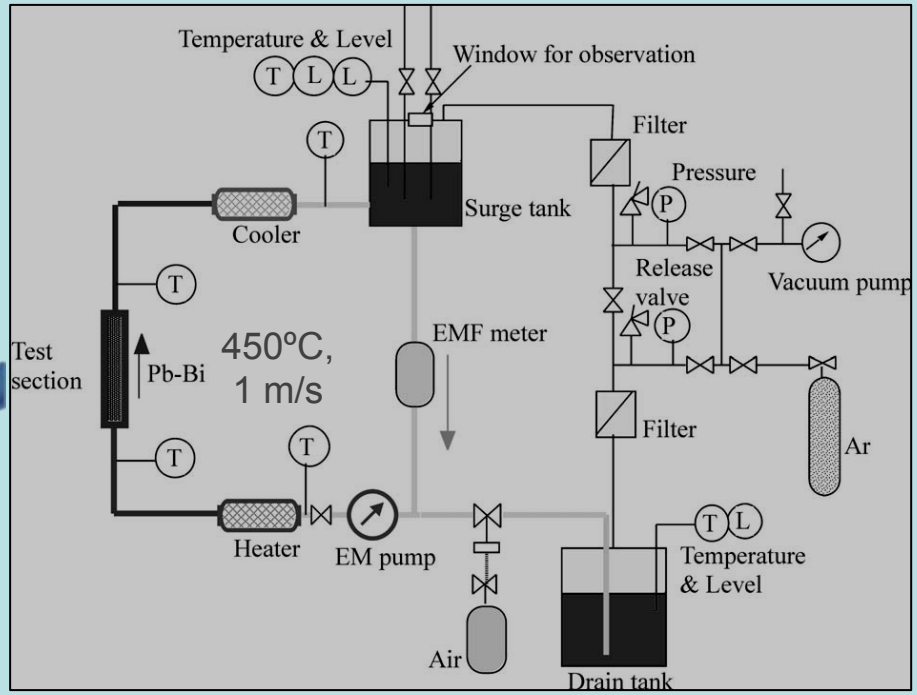


Oxygen concentration:

~10^{-8} - ~10^{-9} wt.%

Experimental Apparatus

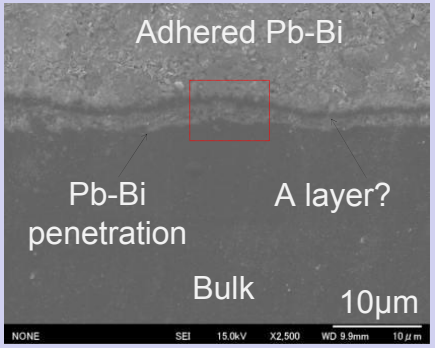
JLBL-1 (JAEA Lead-Bismuth Loop for material corrosion)

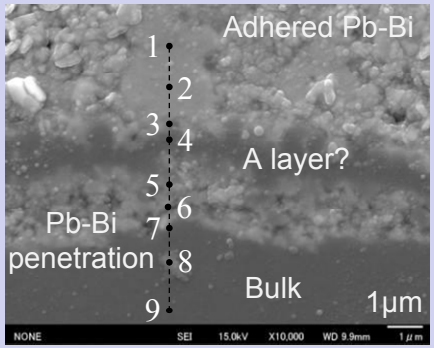


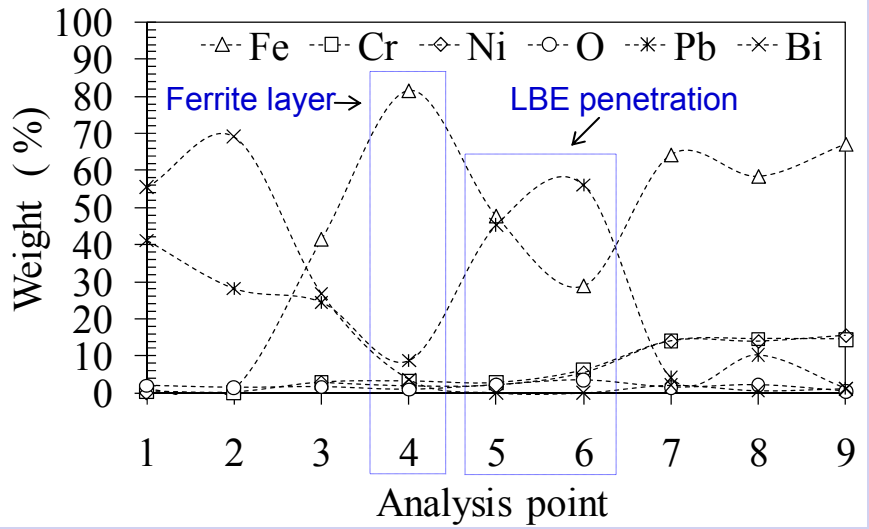
Results & Discussions

Results: SEM-EDS

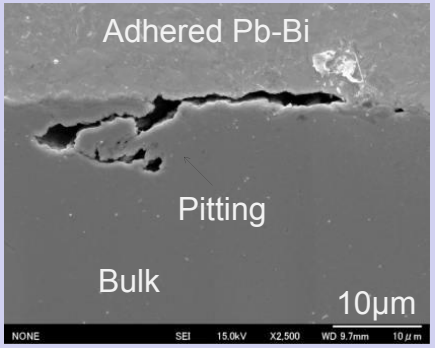
JPCA (no CW)

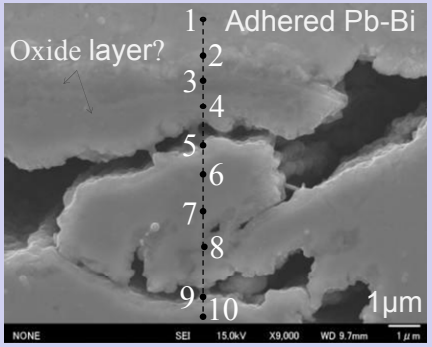


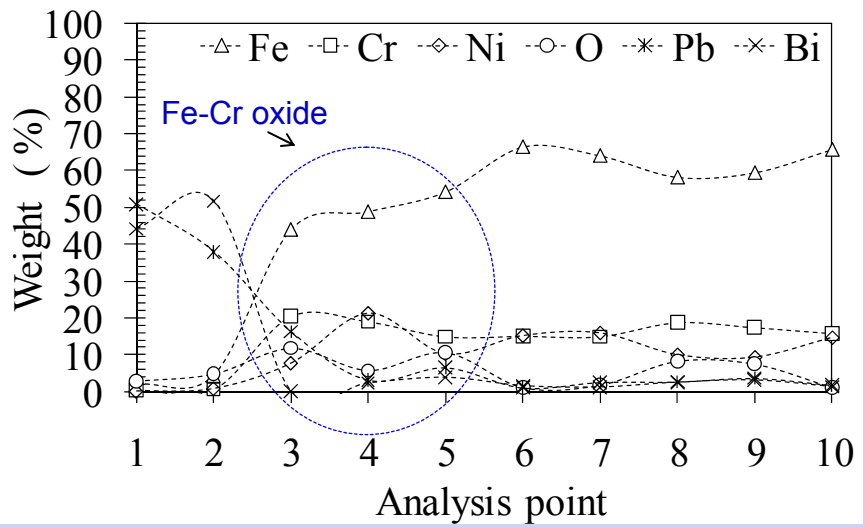




20%CW-JPCA



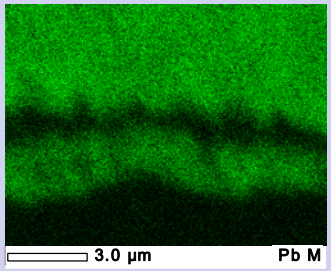


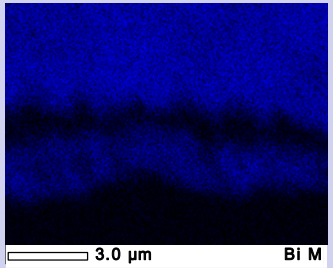


Results: EDS (mapping)

JPCA (no CW)

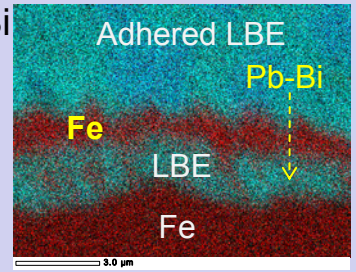
Pb

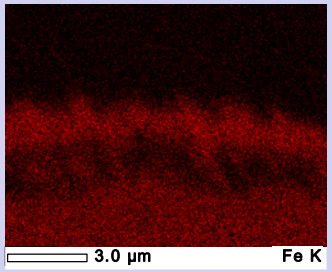




Bi

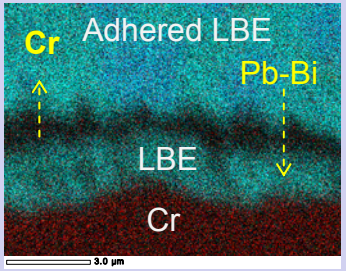
Fe-Pb-Bi

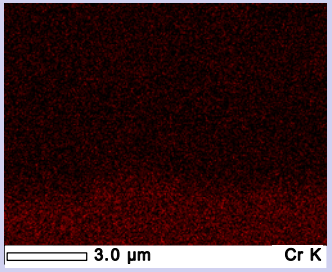




Fe

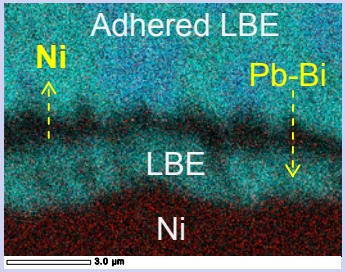
Cr-Pb-Bi

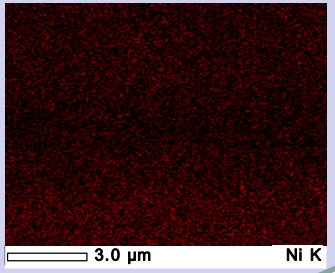




Cr

Ni-Pb-Bi

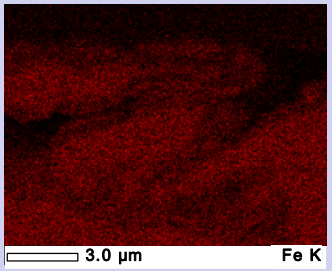


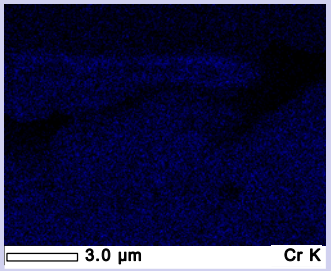


Ni

20%CW-JPCA

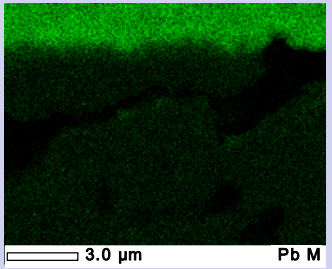
Fe

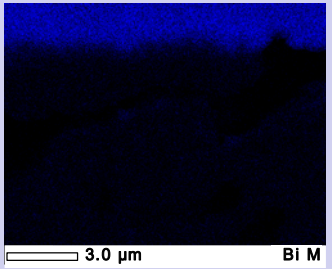




Cr

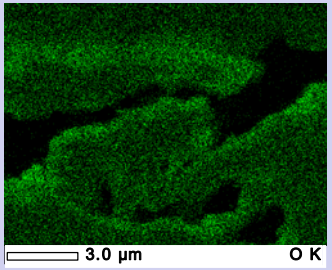
Pb

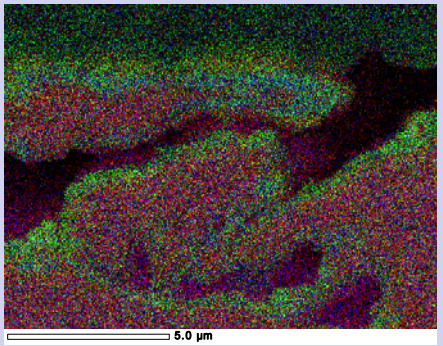




Bi

O

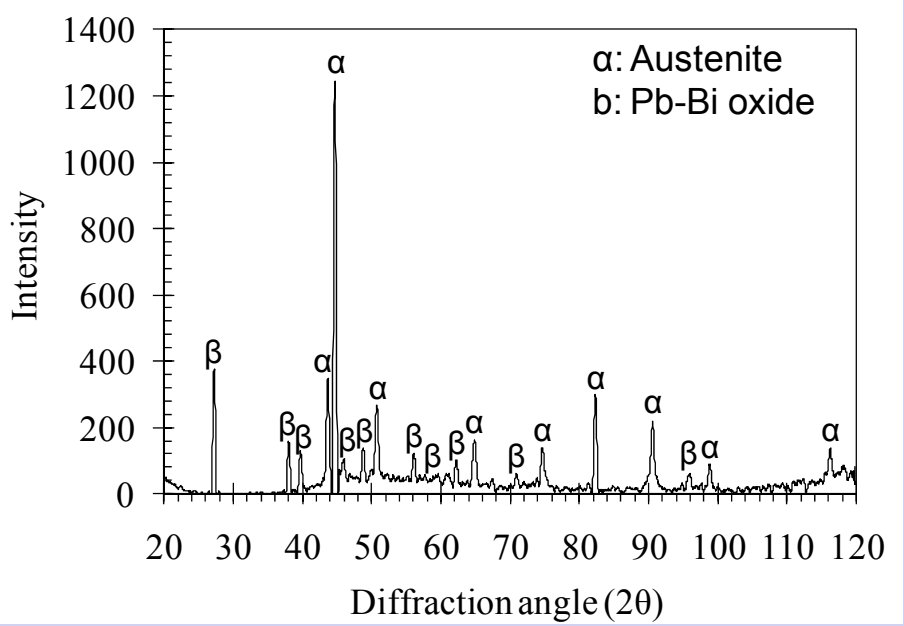




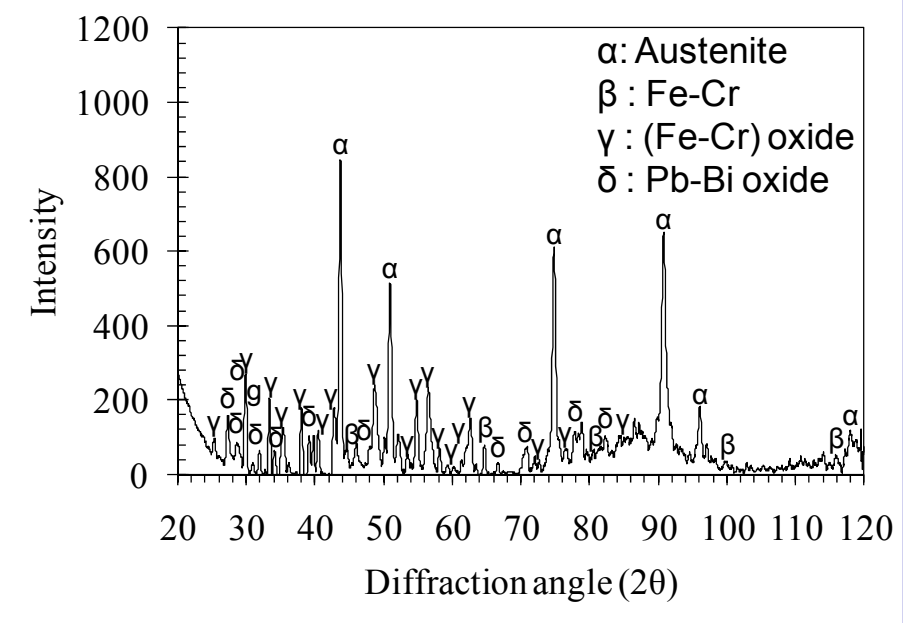
Fe-Cr-O

Results: XRD

JPCA (no CW)

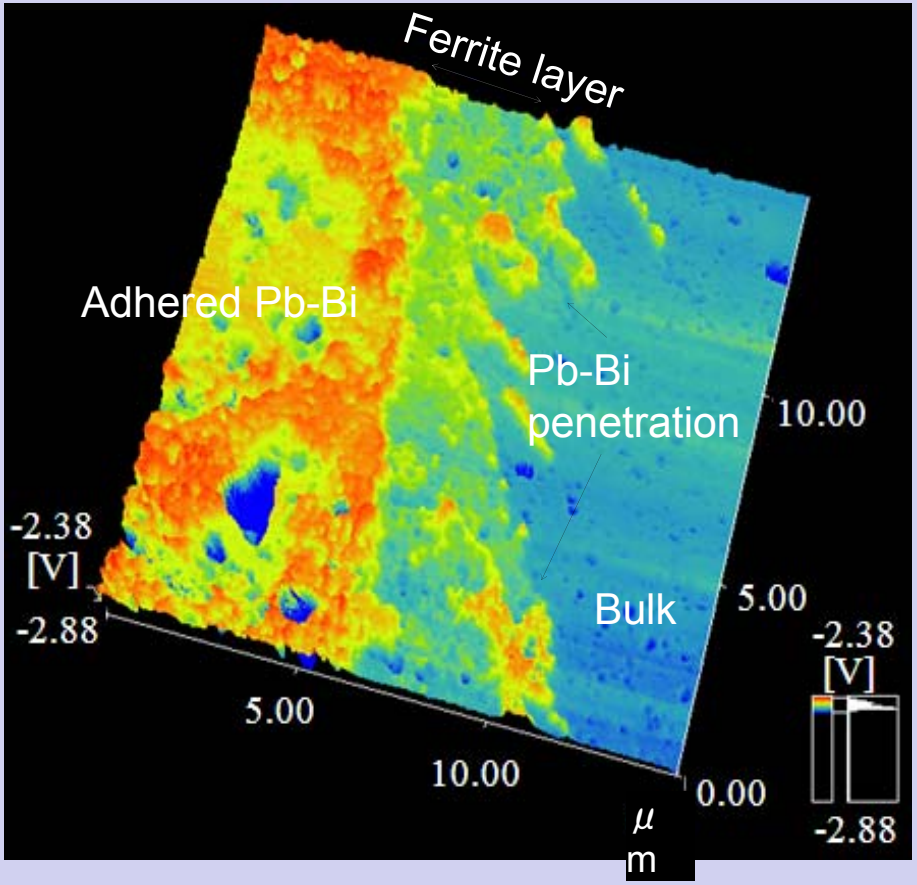


20%CW-JPCA

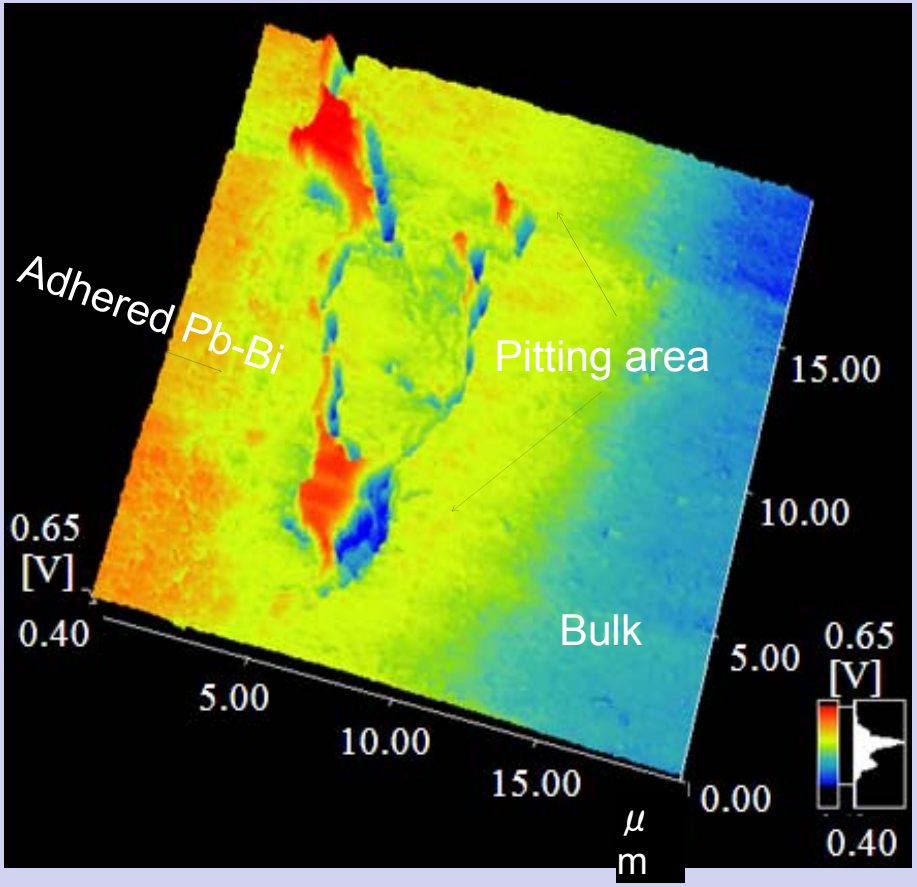


Results: AFM - KFM*

JPCA (no CW)



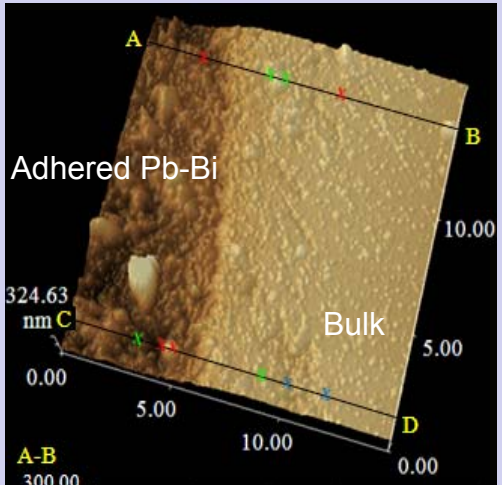
20%CW-JPCA



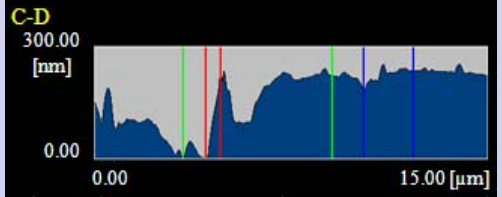
*Alternating voltage is applied to a conductive cantilever. The electromagnetic forces acting between the sample surface and the cantilever are detected to measure the potential across the sample surface.

Results: AFM - KFM

JPCA (no CW)

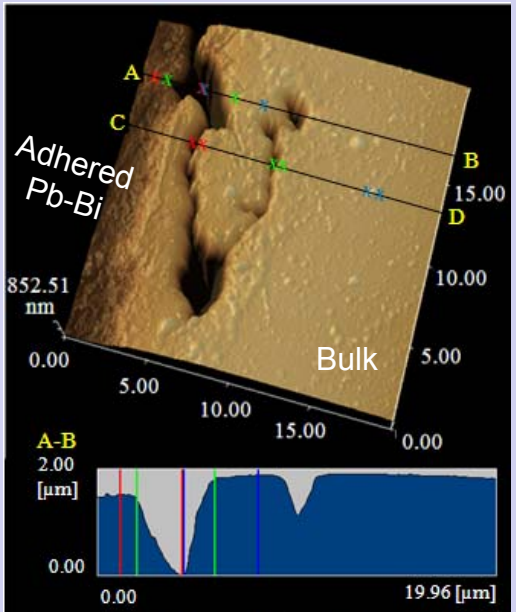


	Width [µm]	Height [nm]
x-x	5.71	171.51
x-x	0.53	8.75

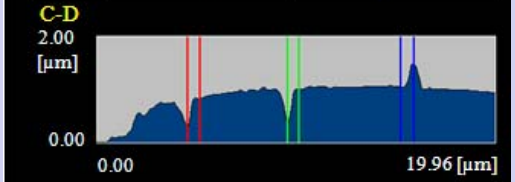


	Width [µm]	Height [nm]
x-x	0.57	230.43
x-x	5.71	221.15
x-x	1.90	53.85

20%CW-JPCA



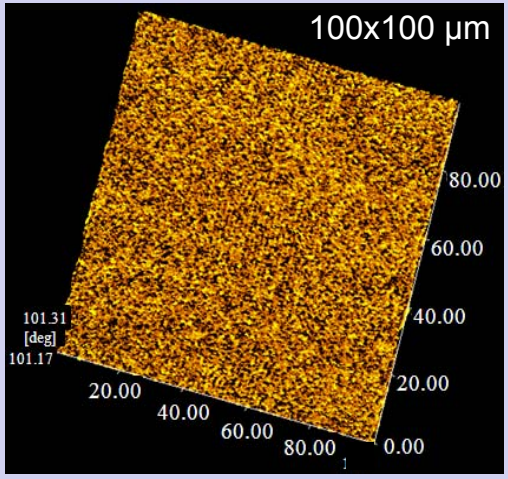
	Width [µm]	Height [µm]
x-x	3.11	1.52
x-x	3.91	0.38
x-x	3.73	1.89

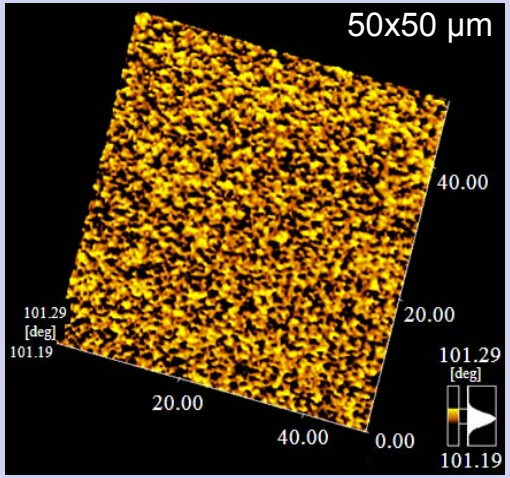


	Width [µm]	Height [nm]
x-x	0.62	278.97
x-x	0.58	318.07
x-x	0.67	212.13

Results: AFM – MFM*

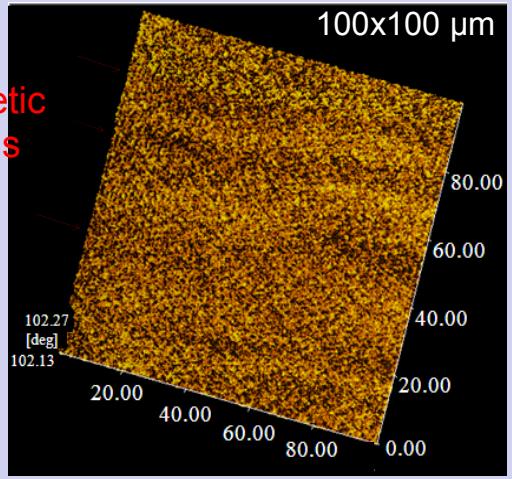
JPCA (no CW)



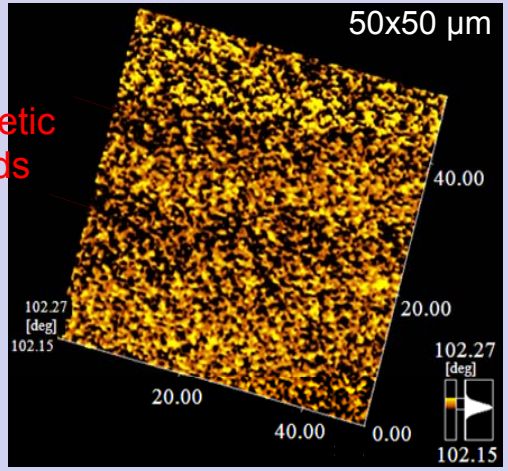


20%CW-JPCA

Magnetic bands



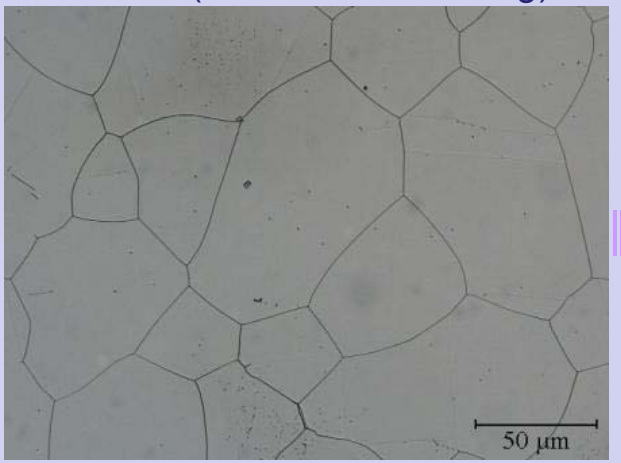
Magnetic bands



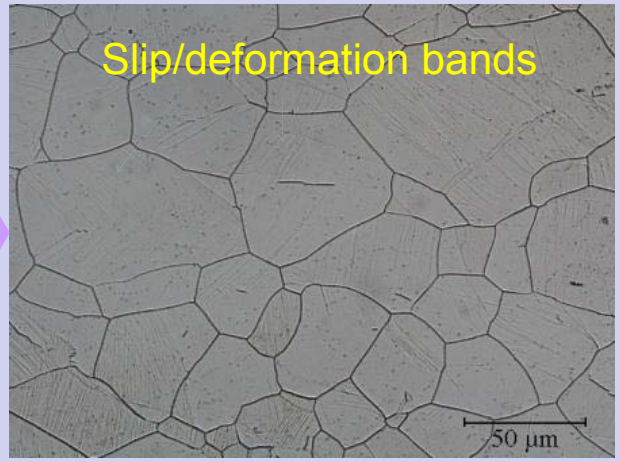
*A magnetized probe is scanned at a constant distance from the sample surface. Magnetic forces due to the leakage field are detected and magnetic information about the sample surface is displayed visually.

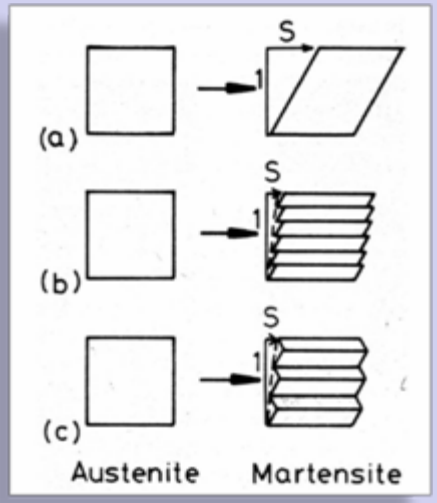
Discussion: Effect of Cold Working

JPCA (without cold working)



20% Cold worked-JPCA





*

*Porter DA, Easterling KE, ***"Phase transformations in metals and alloys"***, 2nd edition: Chapman & Hall, London, 1993.

Summary

Corrosion behavior of 20%CW- JPCA and SA-JPCA in flowing Pb-Bi at 450ºC for 1000 hours

Parameter	20% CW–JPCA	No CW–JPCA
Ferritization	-	✓
Oxide layer	✓	-
Pitting	✓ (localized)	-
Penetration of Pb-Bi	✓ (localized)	✓

Conclusion

- In the present study, superficial ferritization accompanied with penetration of Pb-Bi through the ferrite layer occurred for JPCA without cold working.

- On the other hand, dissolution attack occurred only partially (localized superficial pitting) for the 20% cold worked-JPCA steel with no ferritization observed. Therefore, cold working limited a dissolution attack from flowing Pb-Bi. However, for the beam window material application the pitting corrosion problem has to be solved.

Thank you for your attention