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STRESS CORROSION CRACKING OF A 52M WELD OVERLAY IN A PWR ENVIRONMENT

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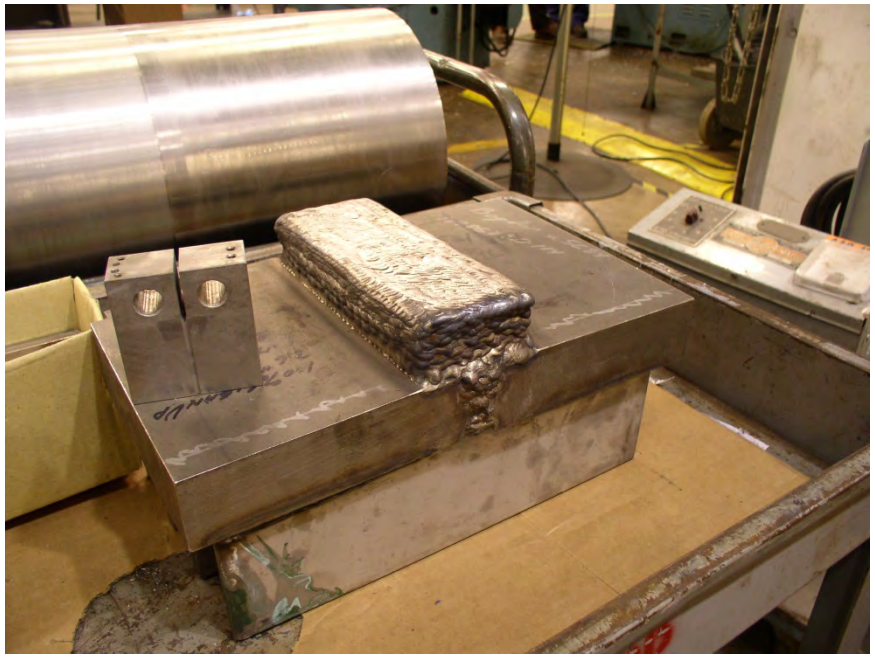
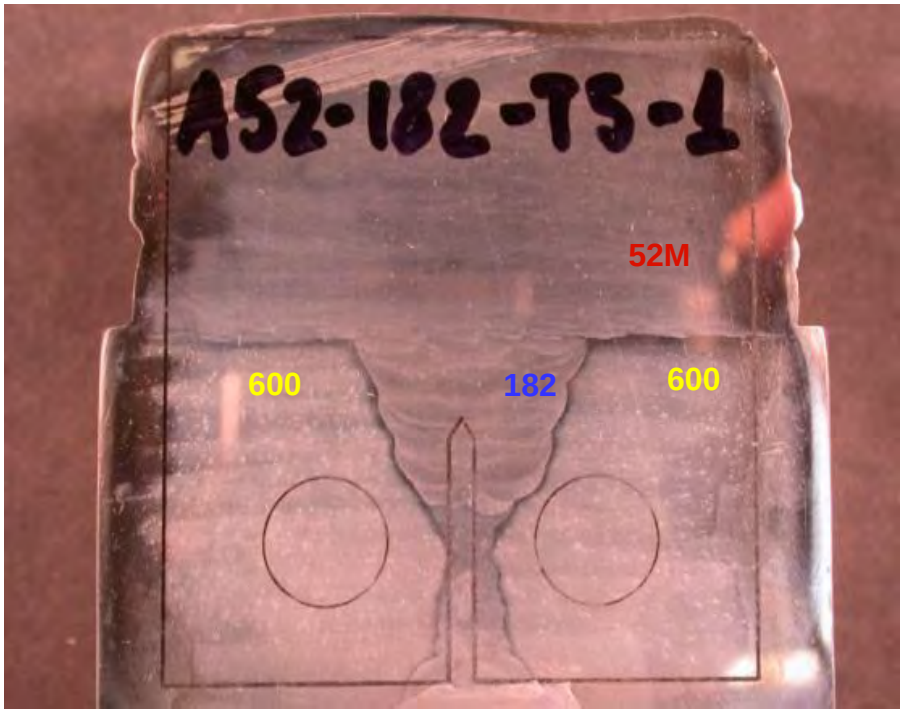
Presentation Outline

- Alloy 52-182 WOL produced at ANL Central Shops
- Initial results: SCC CGR tests in TS orientation
- Confirmatory results: SCC CGR tests in ST orientation
  - Test management
- Summary of results
- Conclusions

Alloy 52M-182 Weld Overlay

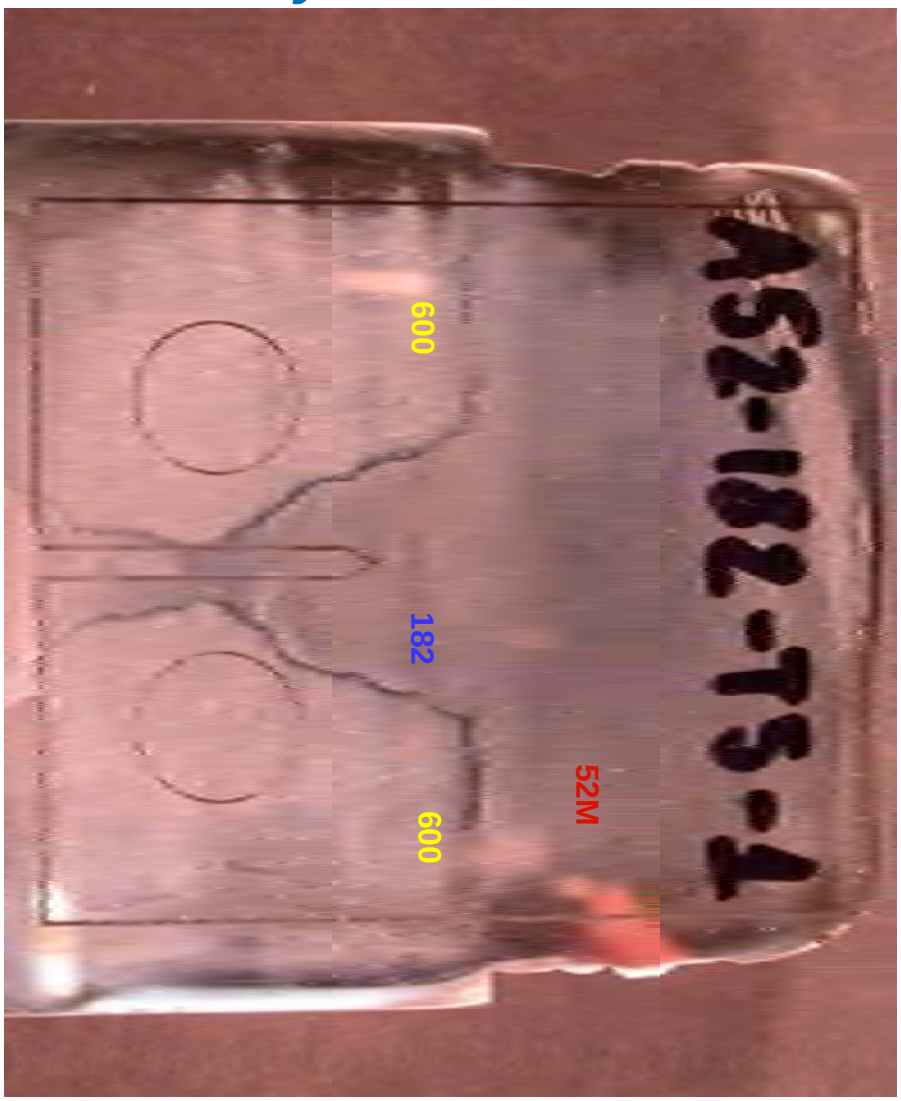




- Used an Alloy 182 double-J weld (tested previously)
- Alloy 52M (Special Metals, Heat NX75W1TK) welded at ANL Central Shops using parameters used by industry
- Characterization: general metallography, hardness, Cr profiling (PVP 2011);

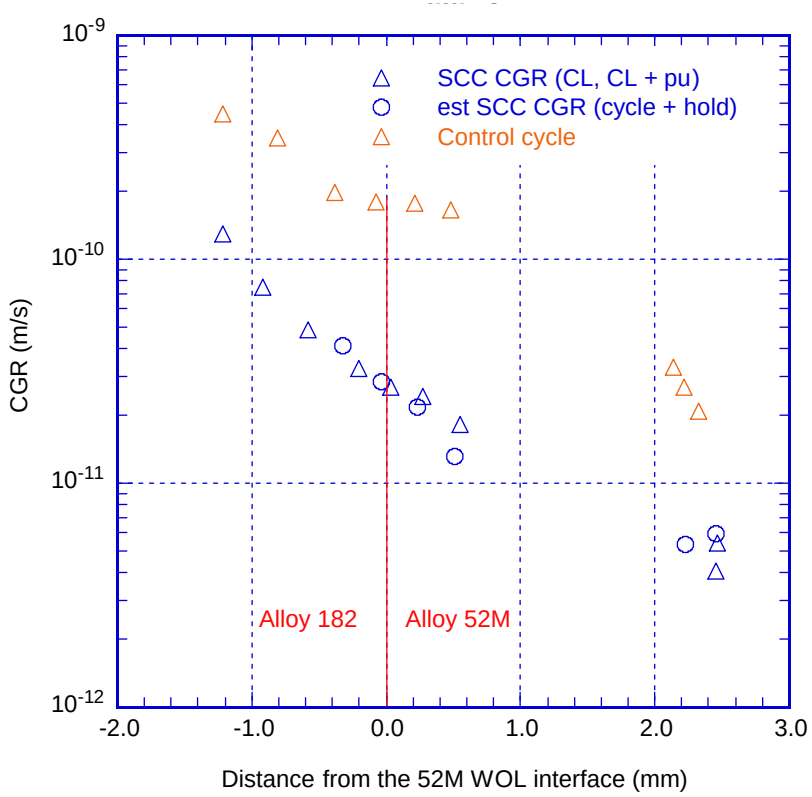
  FE modeling, residual stress measurements (Kerr et al., PVP 2011)

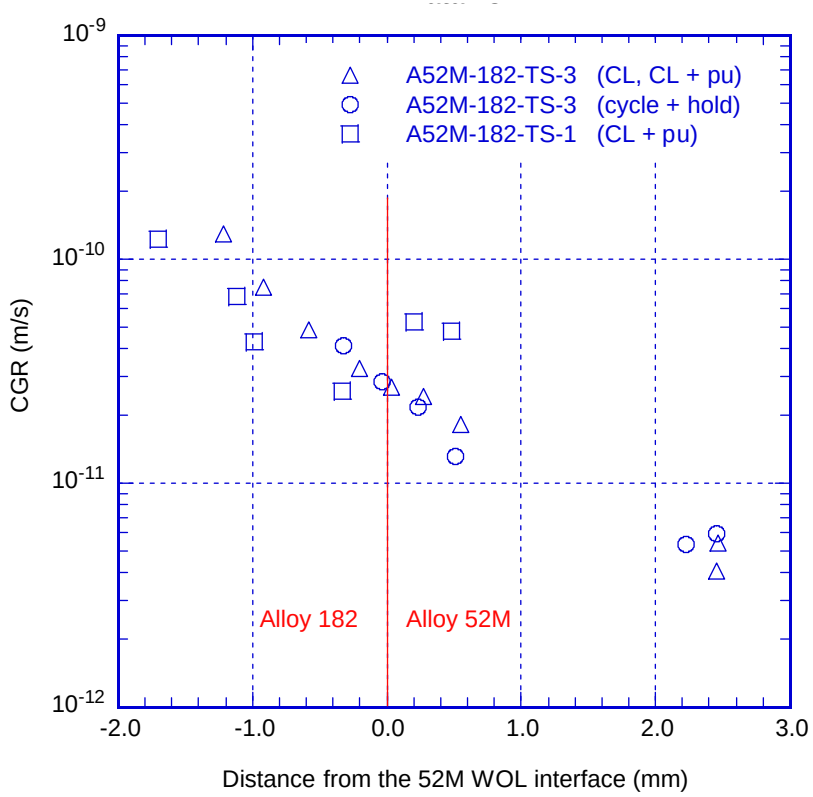
Alloy 52M-182 Weld Overlay – Initial tests in the TS orientation



- CGR test objective: attempt to transition an SCC crack from Alloy 182 into 52M (two tests in TS orientation completed)

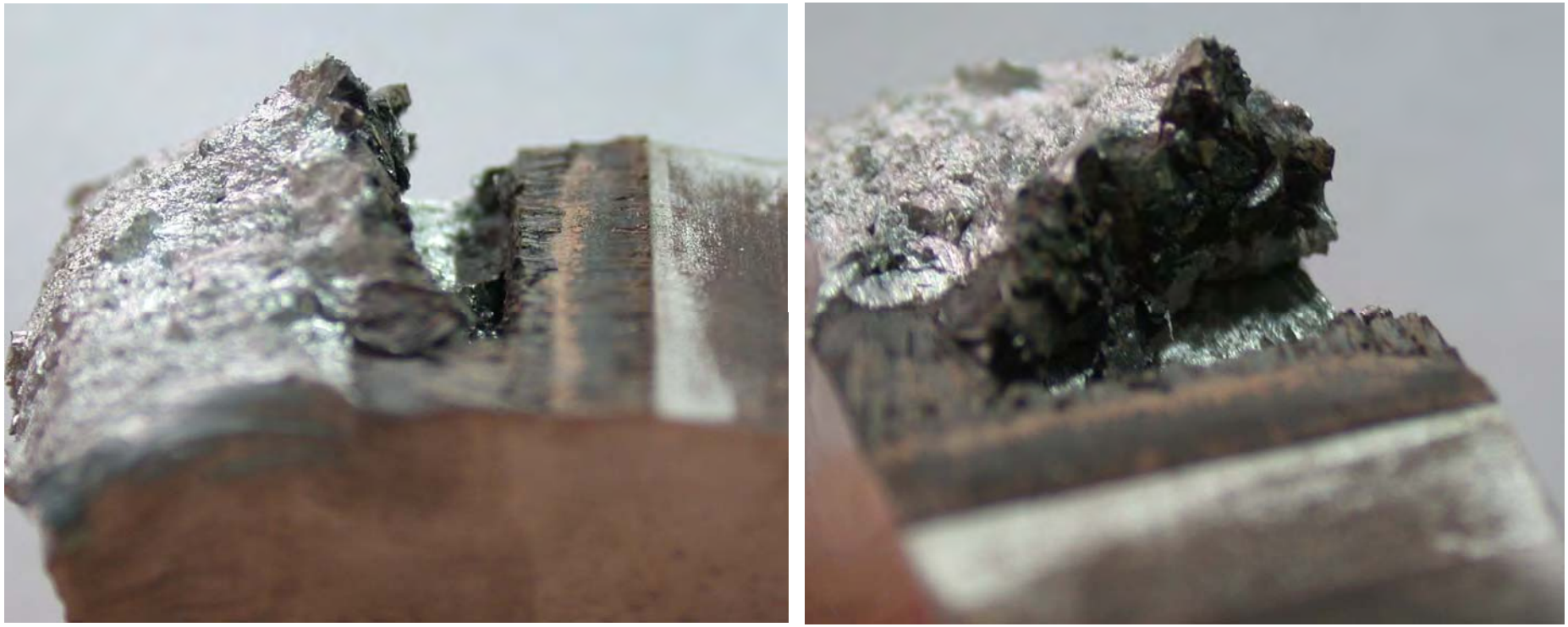
Alloy 52M-182 WOL – SCC and Cyclic CGR vs. distance to the interface





- Exact location is critical: SCC CGRs determined under PPU and cycle + hold
- SCC CGRs decrease 10x as the crack approaches the interface, continues to decrease past the interface
- Control cyclic rates show the same trend as the SCC CGRs
- Behavior reproduced in a 2nd test

Alloy 52M-182 WOL Specimen A52M-182-TS-3 – fracture



- Growth along the interface appears more severe than initially thought (based on the cross section): 2.2 mm (3000h), CGR $\approx 2 \times 10^{-10}$ m/s

Alloy 52M/182 WOL Specimen A52M-182-TS-3 – Fracture Surface 1

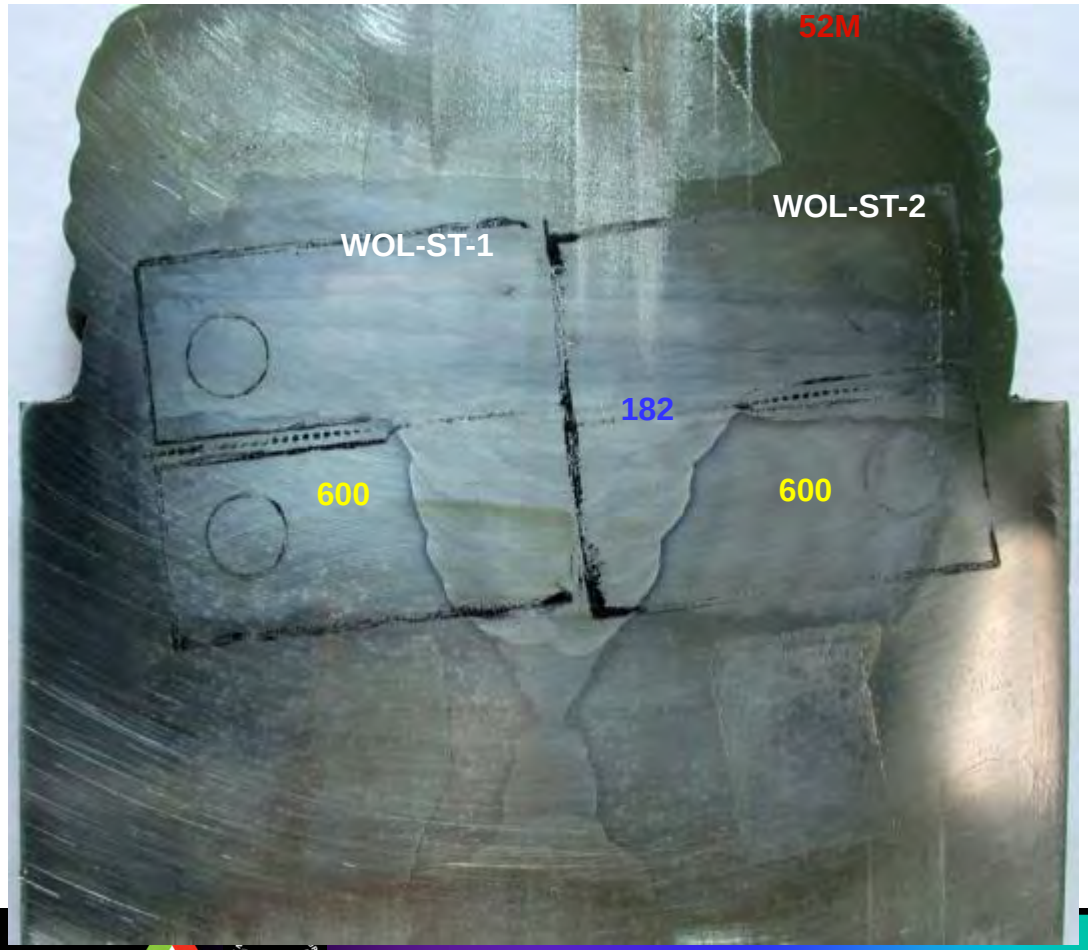
- Uniform, fully-engaged SCC crack front in Alloy 182 ahead of the interface
- Partial, “finger”-like growth into Alloy 52M
- Max growth 2.5 mm, max CGR $\approx 2 \times 10^{-10}$ m/s (6 mm/y)

Alloy 52M-182 WOL ST Specimens

- TS tests suggest SCC CGRs ≈ 2×10^{-10} m/s

along the Alloy 52M-182 interface and in Alloy 52M near the interface

- Objective of ST tests: measure the SCC CGRs directly



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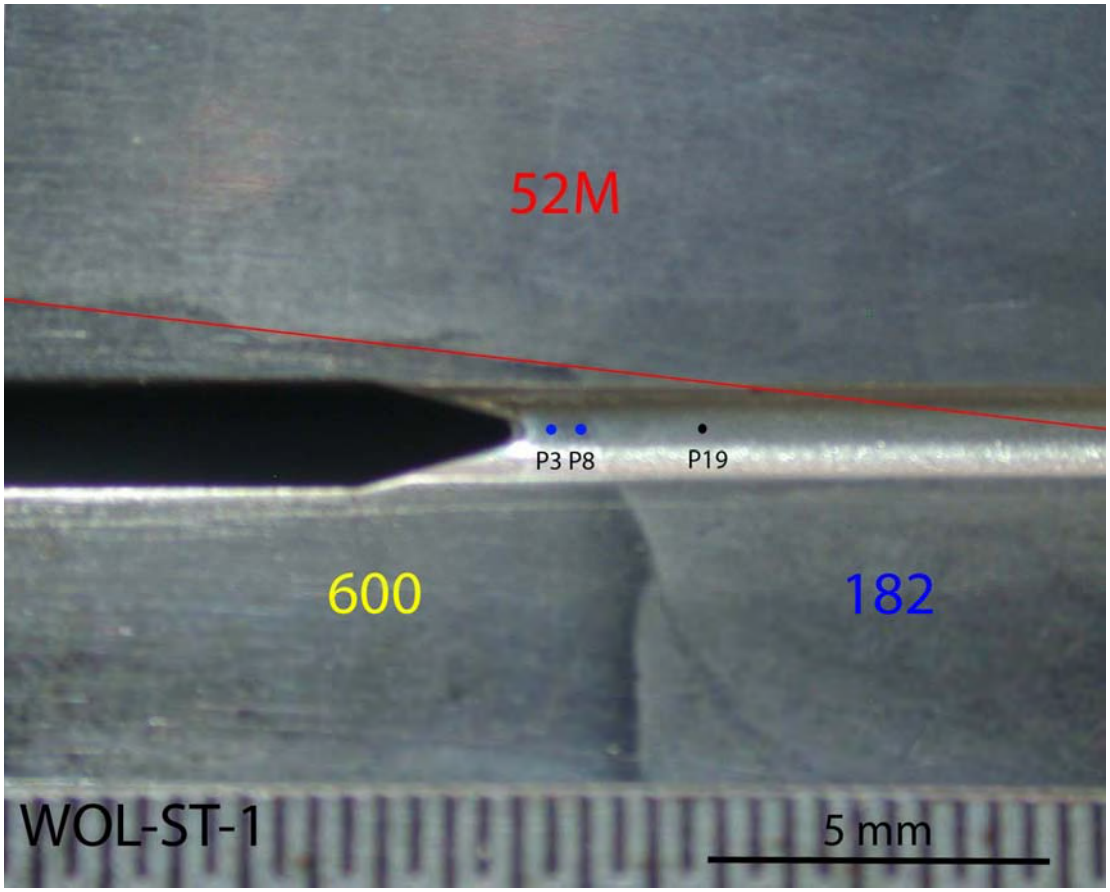
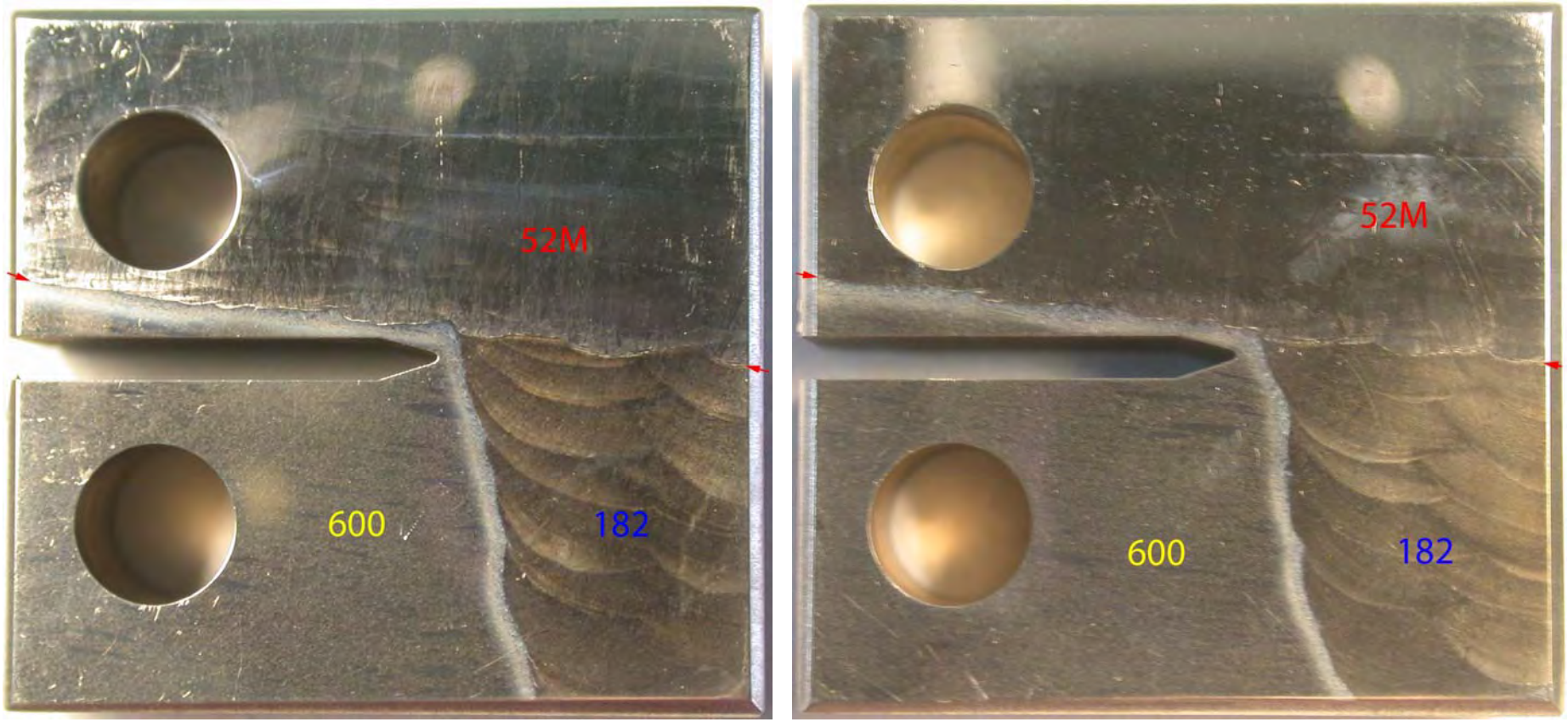
Alloy 52M-182 Weld Overlay Specimen WOL-ST-1



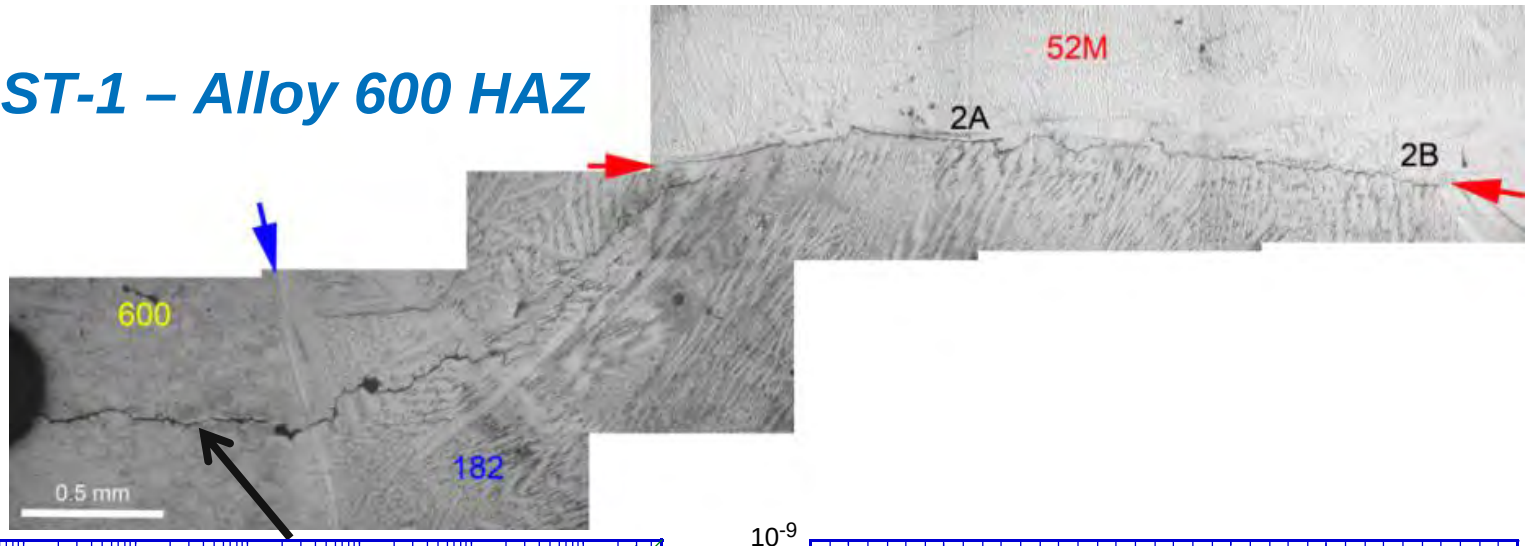
- Obtain Alloy 600 HAZ data first (P8, P8 = CL test periods in Alloy 600 HAZ)
- Advance in Alloy 182 towards the 52M WOL interface, and set at CL at the interface

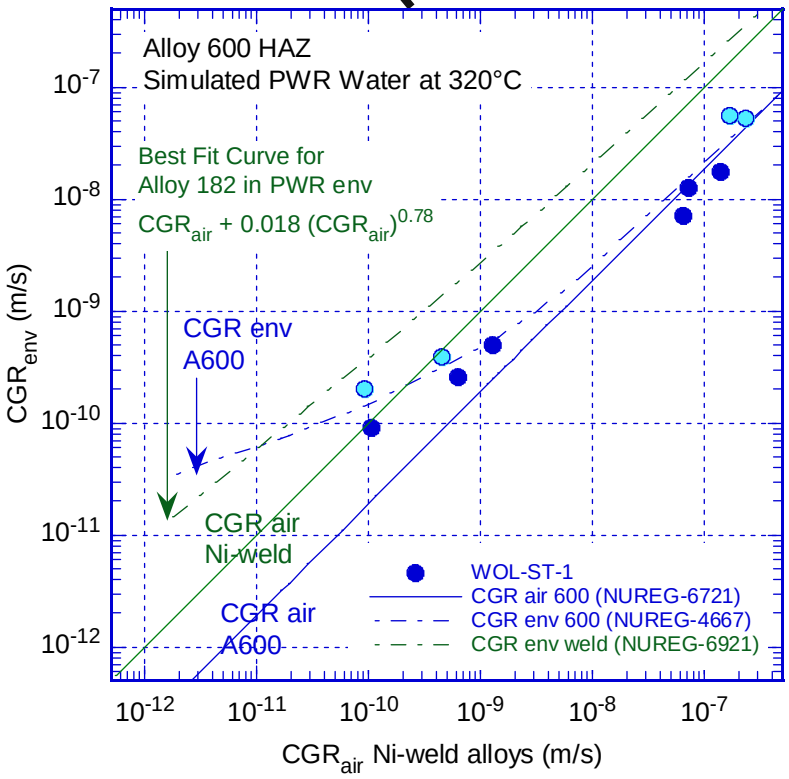
Alloy 52M-182 Weld Overlay Specimen WOL-ST-1 – Side surfaces

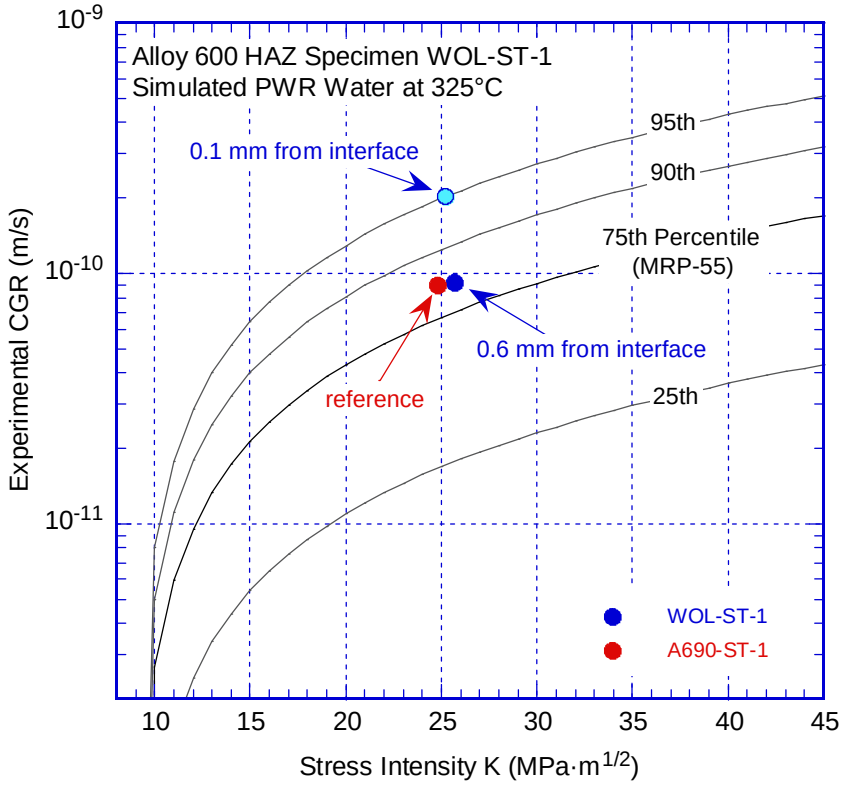


- Test evolved as anticipated

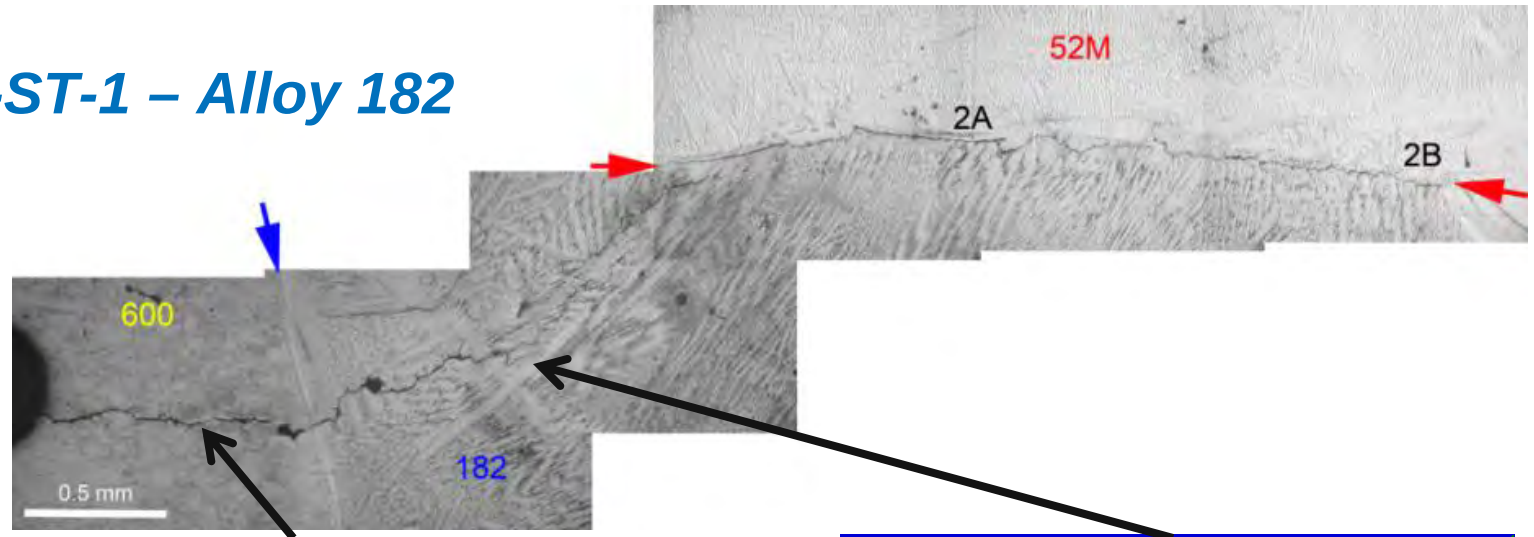
WOL-ST-1 – Alloy 600 HAZ

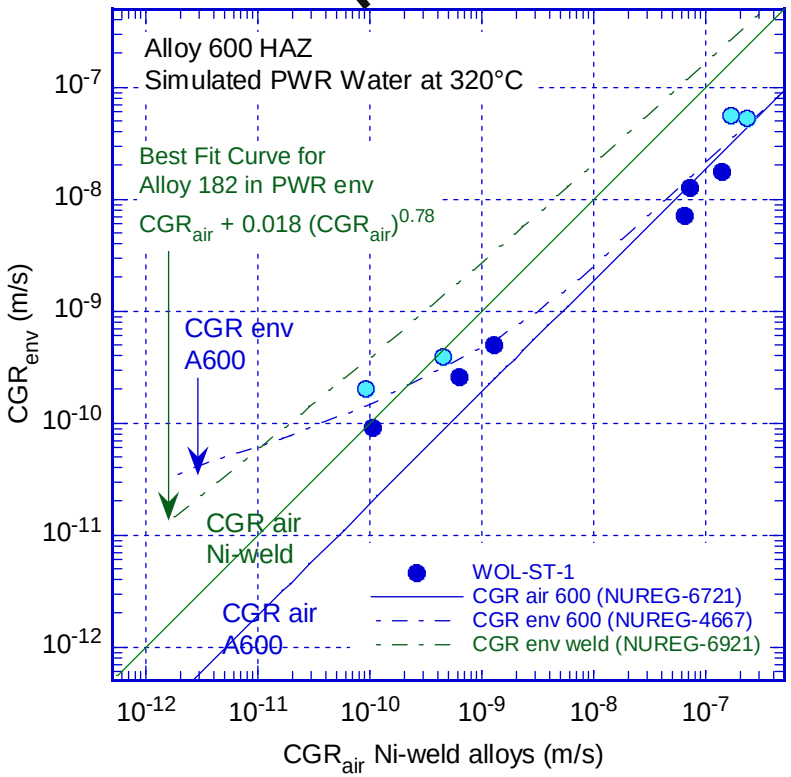


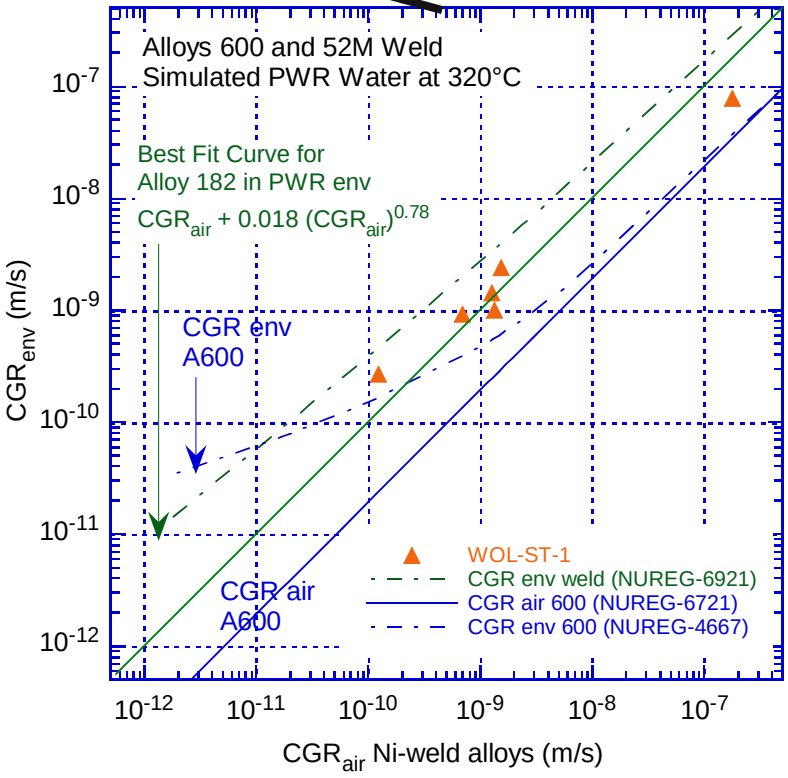




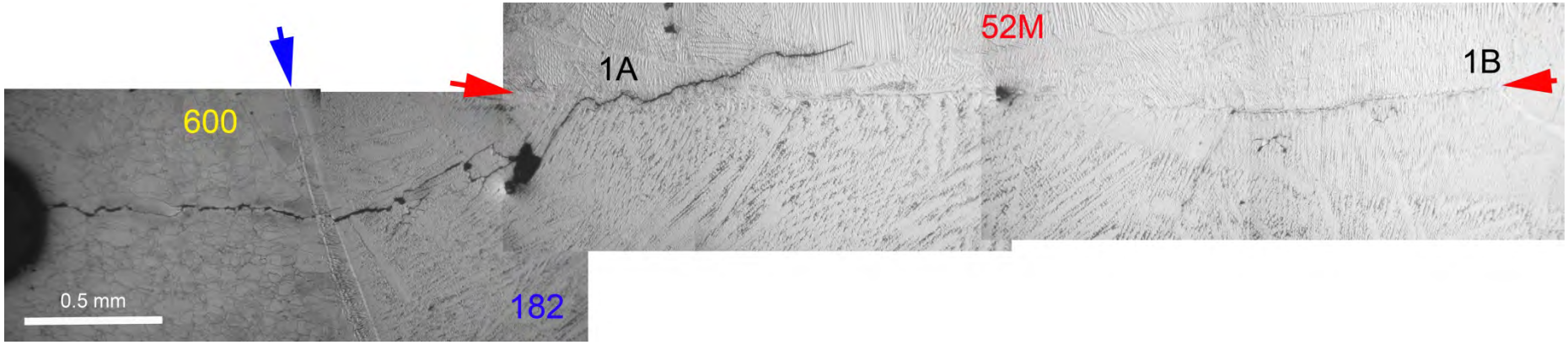
WOL-ST-1 – Alloy 182



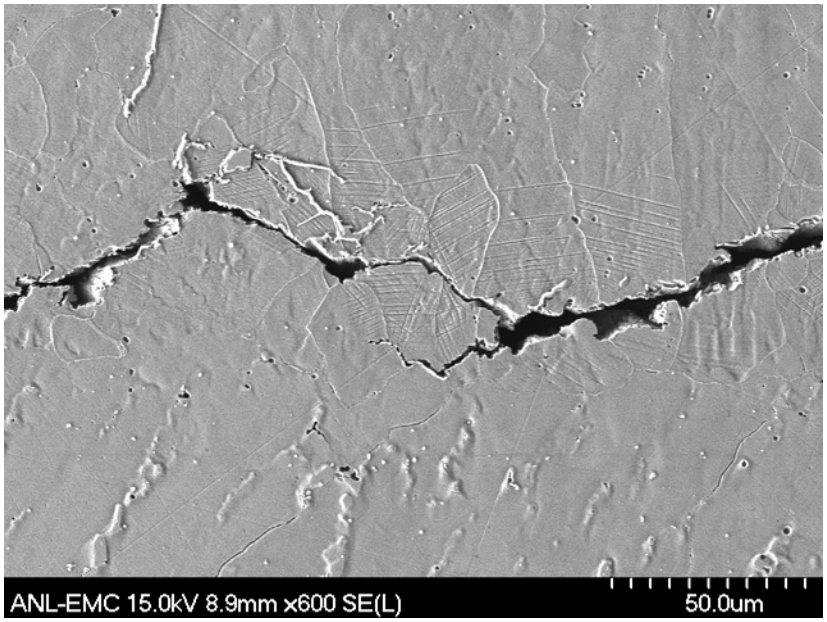


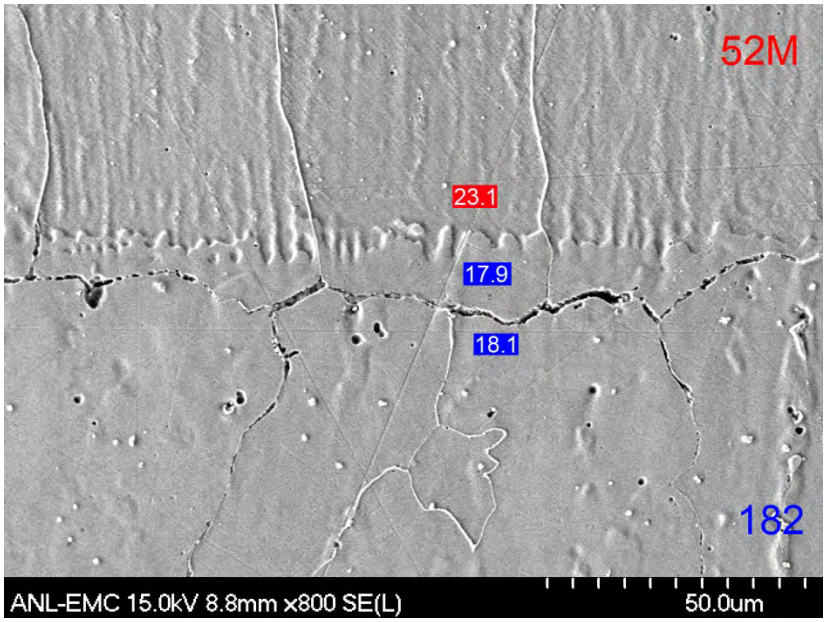


Alloy 52M-182 Weld Overlay Specimen WOL-ST-1 – Side surface



1A

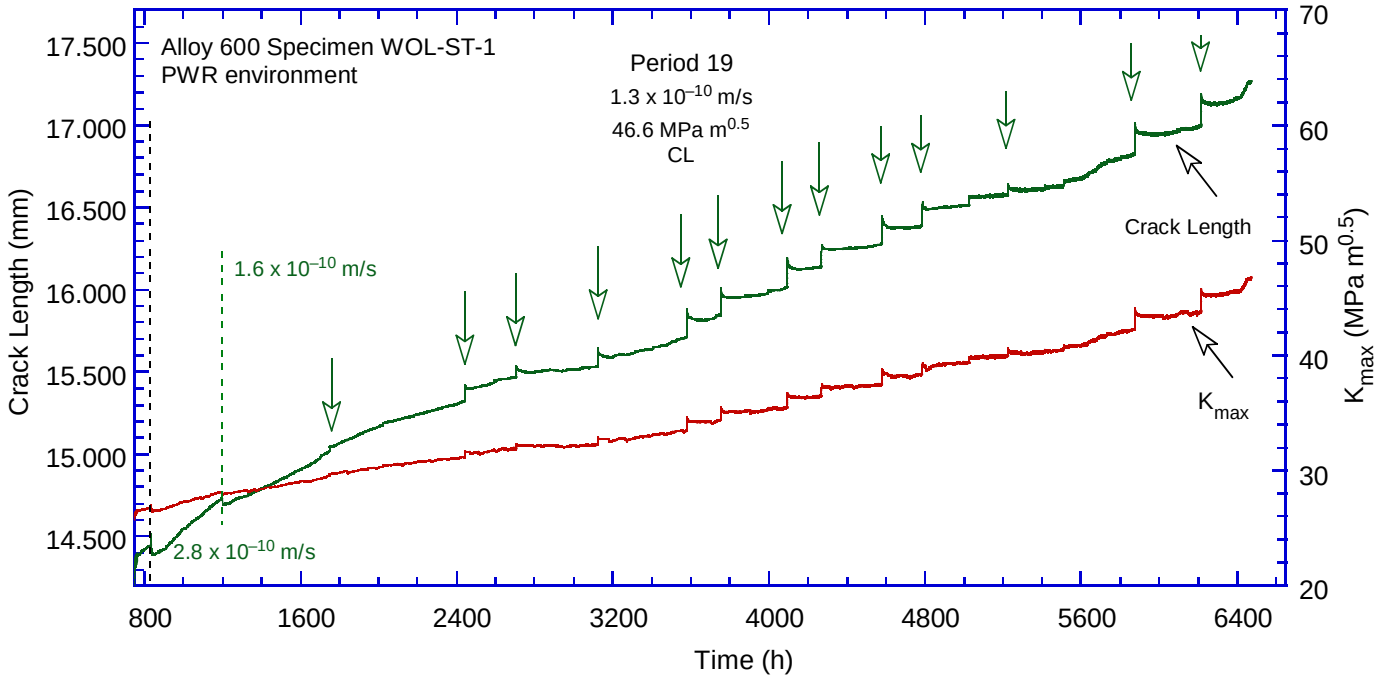




1B

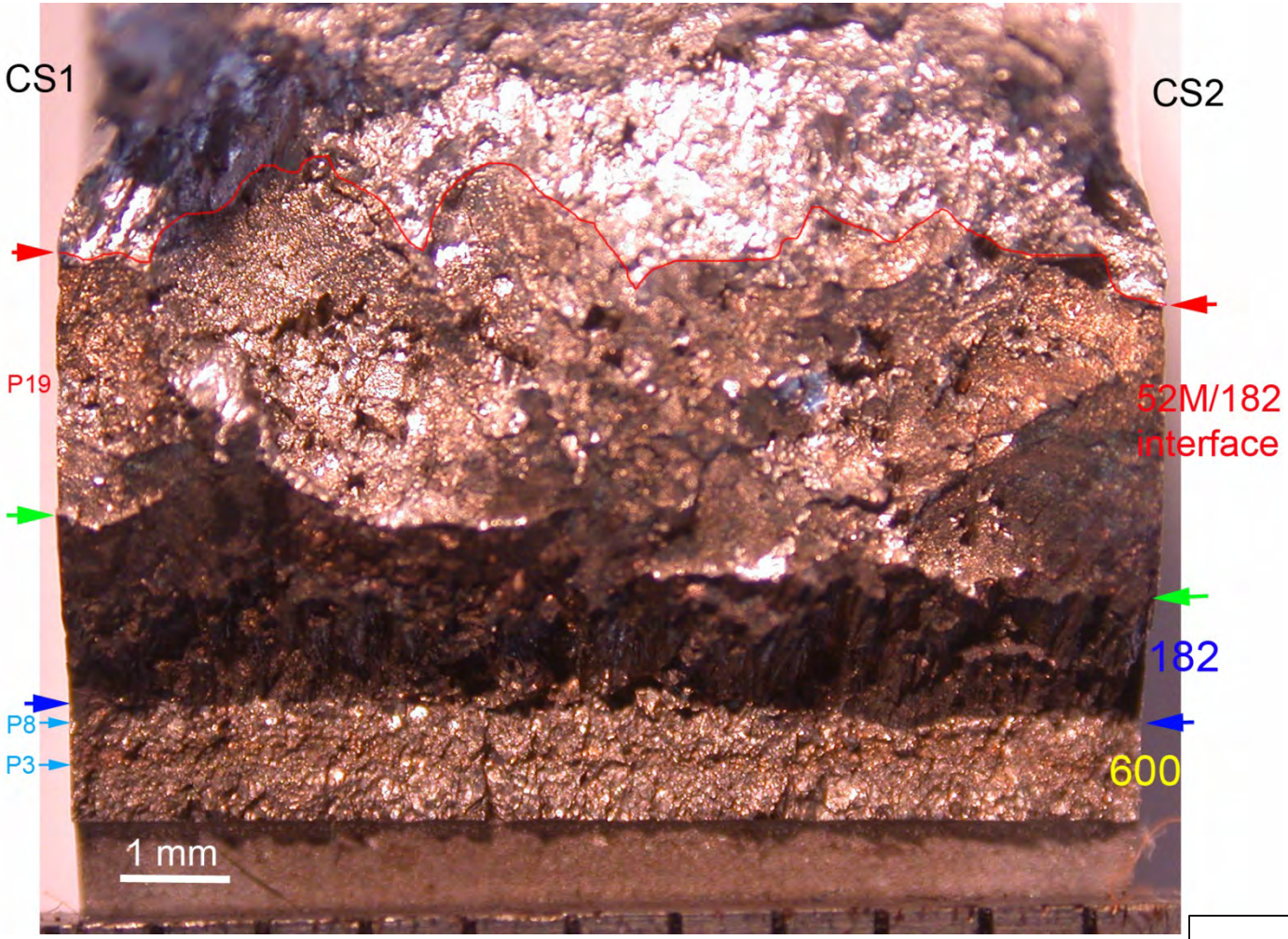
- Preferred path: interface, 18 wt. % Cr

Alloy 52M-182 Weld Overlay Specimen WOL-ST-1



- Corrected data
- Alloy 52M-182 interface SCC CGR = 1.3E-10 m/s, confirms prior estimations
- Jumps are “real”, actually regions of fast growth, 10E-8 m/s over 20-30 min

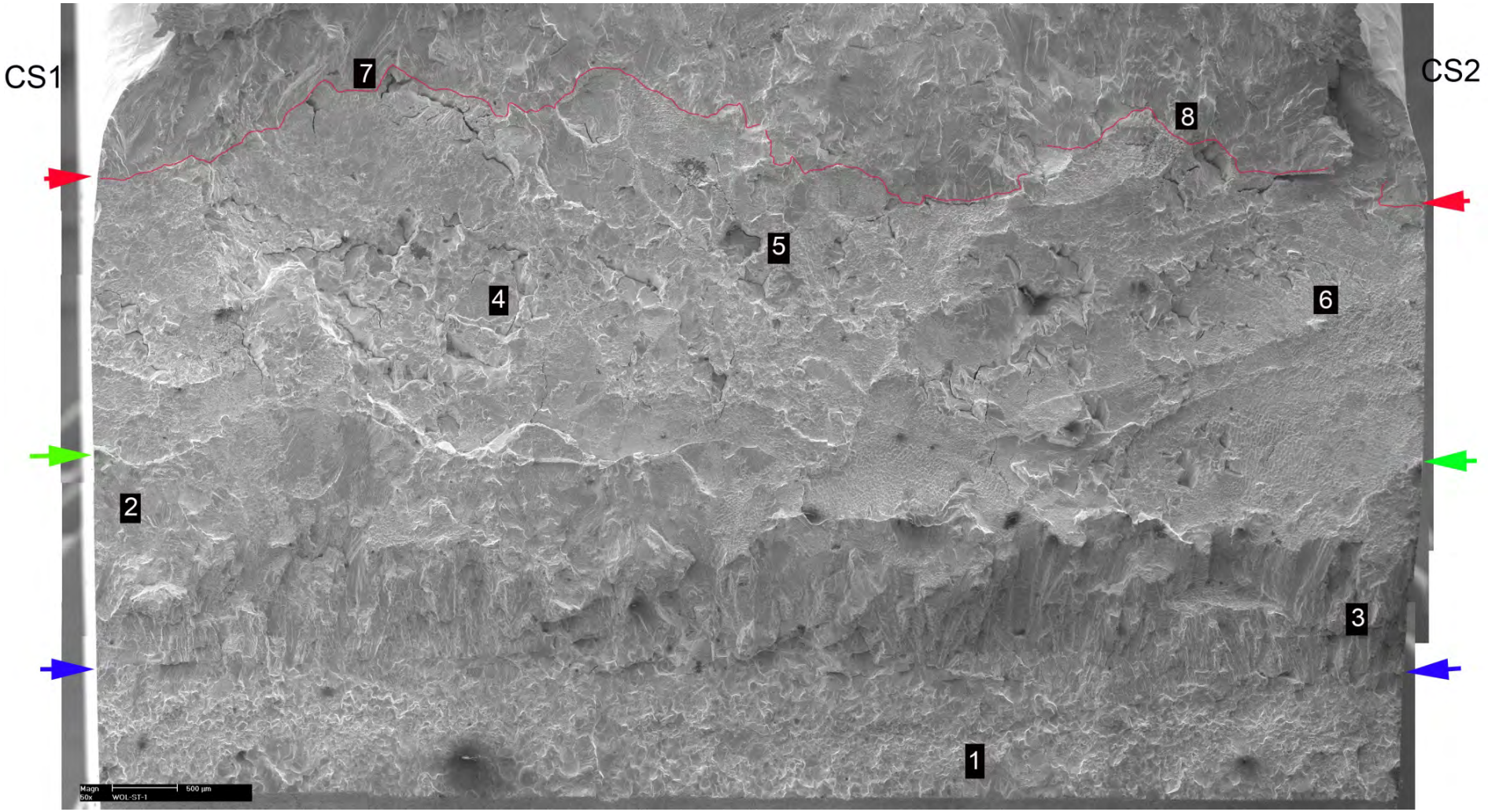
Alloy 52M-182 Weld Overlay Specimen WOL-ST-1 – Fracture



- Interface growth: 2.9 mm (8.2x higher than anticipated)

600/182 interface
182/52M interface
End of test

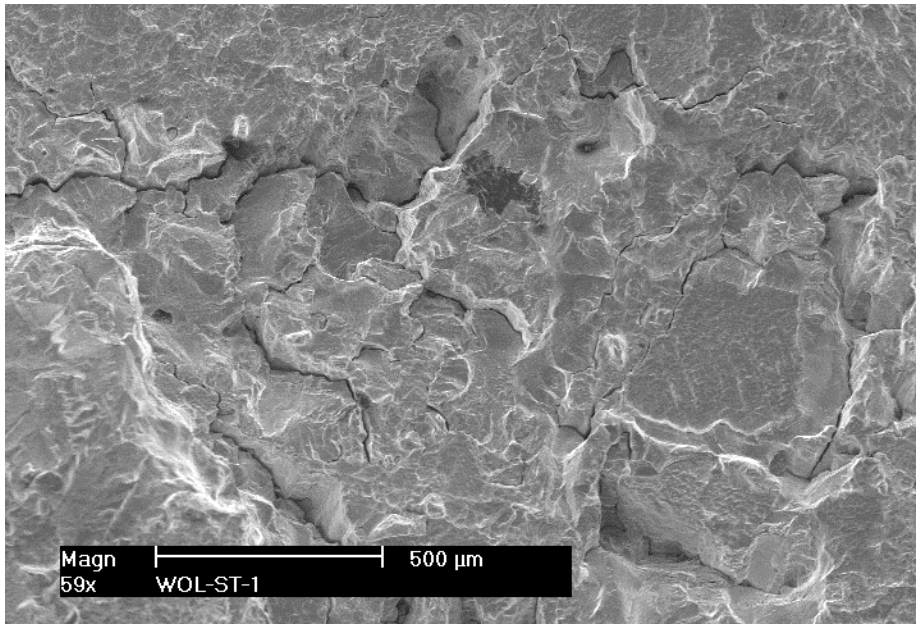
Alloy 52M-182 Weld Overlay Specimen WOL-ST-1 – Fracture

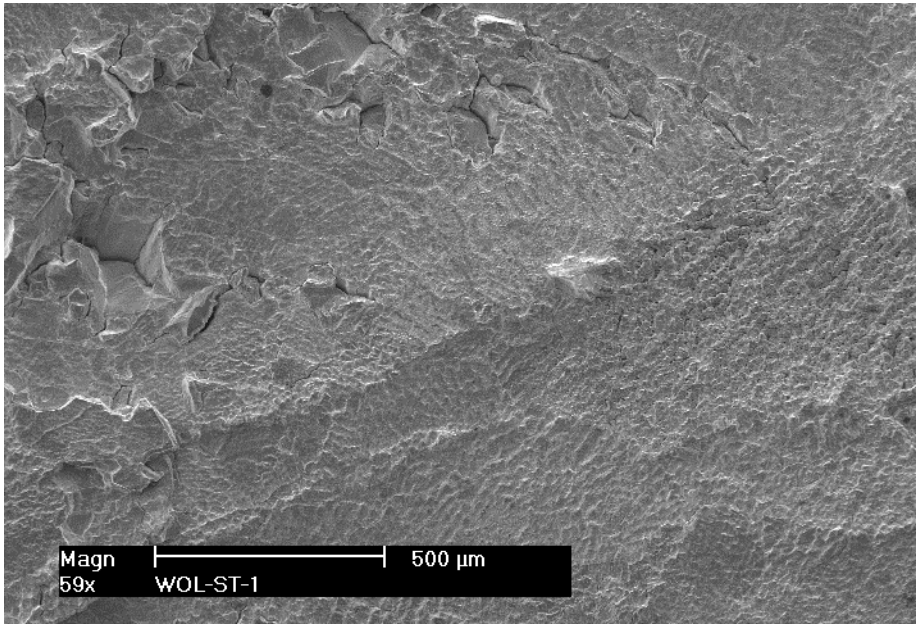


- Interface growth: 2.9 mm (8.2x higher than anticipated)

600/182 interface
182/52M interface
End of test

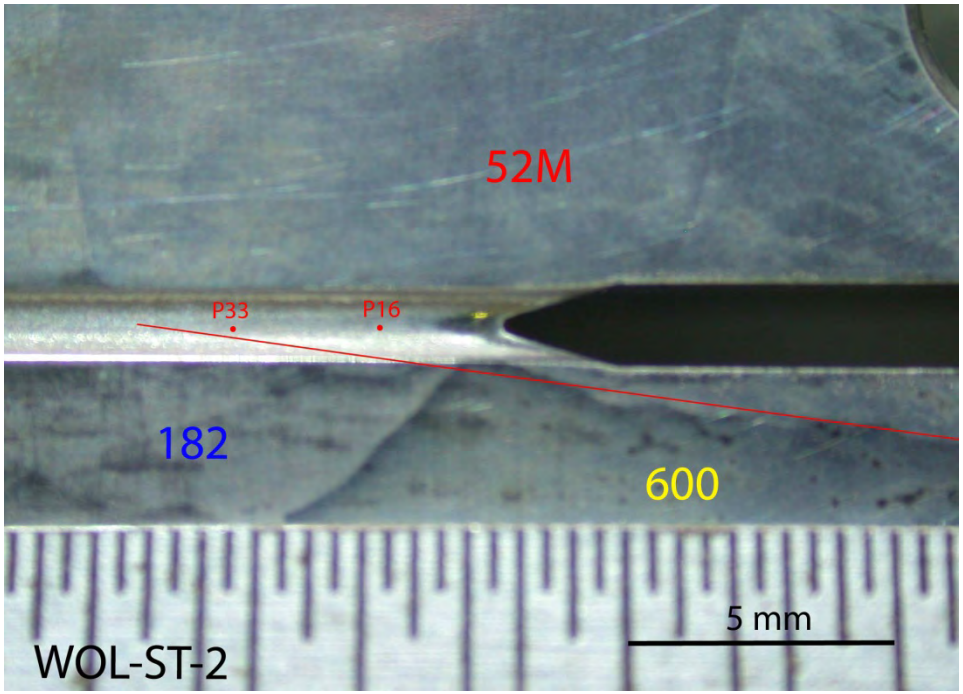
Alloy 52M/182 Weld Overlay Specimen WOL-ST-1 – Fracture

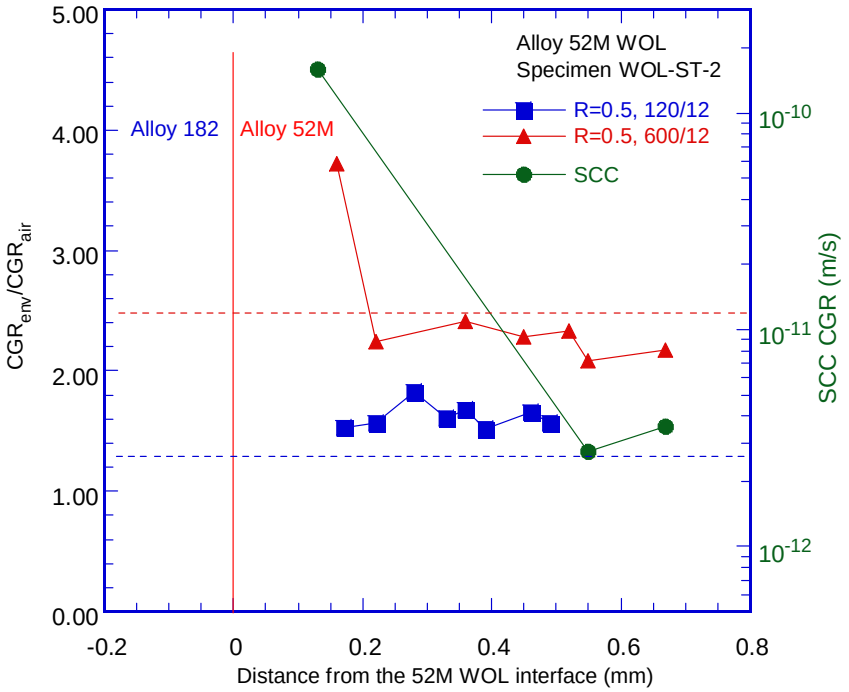




- Alloy 600 – Alloy 182 (loc. 7)
- Alloy 182 – WOL interface (loc. 8)
- IG interdendritic growth in ST orientation

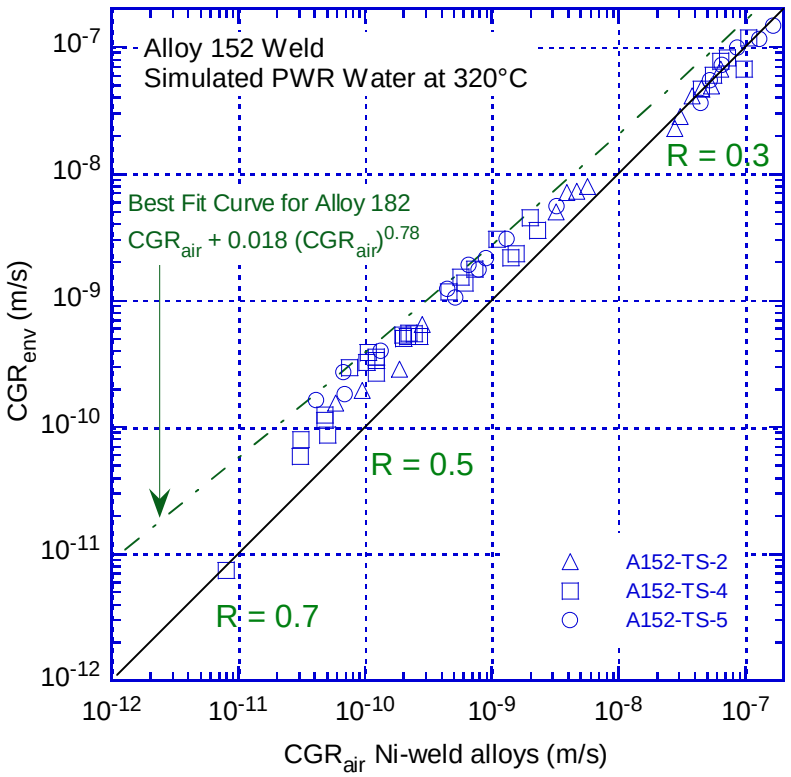
Alloy 52M-182 Weld Overlay Specimen WOL-ST-2

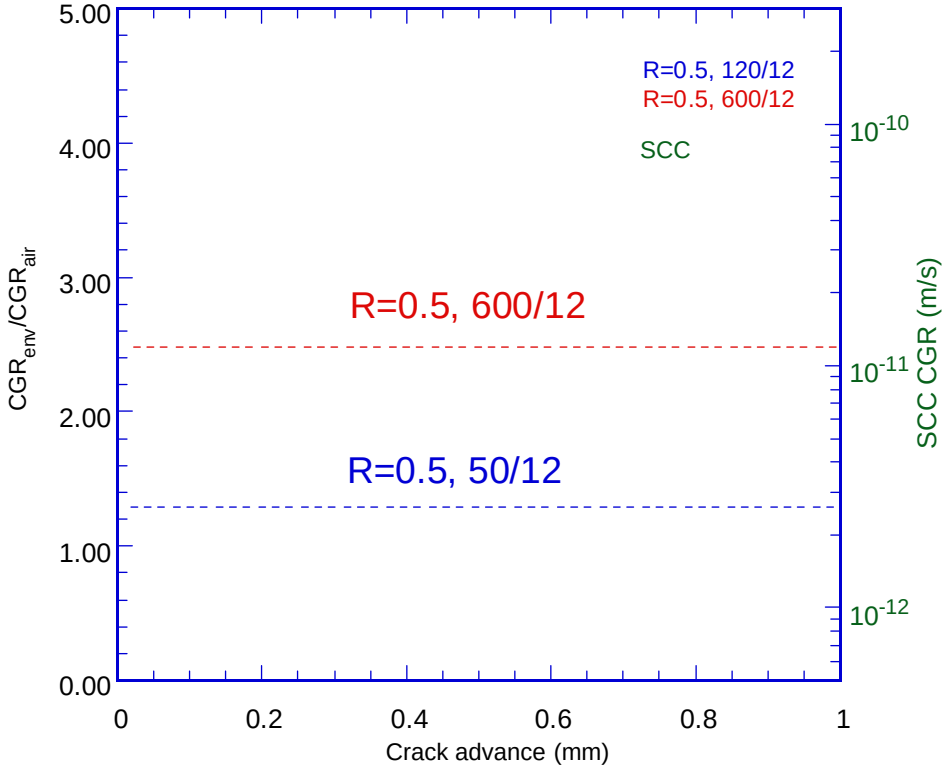




- Challenge: crack direction vs. orientation of the dendritic grains
- Experimental approach: track environmental enhancement of two “known” conditions vs. (calculated) distance to the interface
- Sequence: advance + probe for enhancement
- Set at constant load at “favorable” location

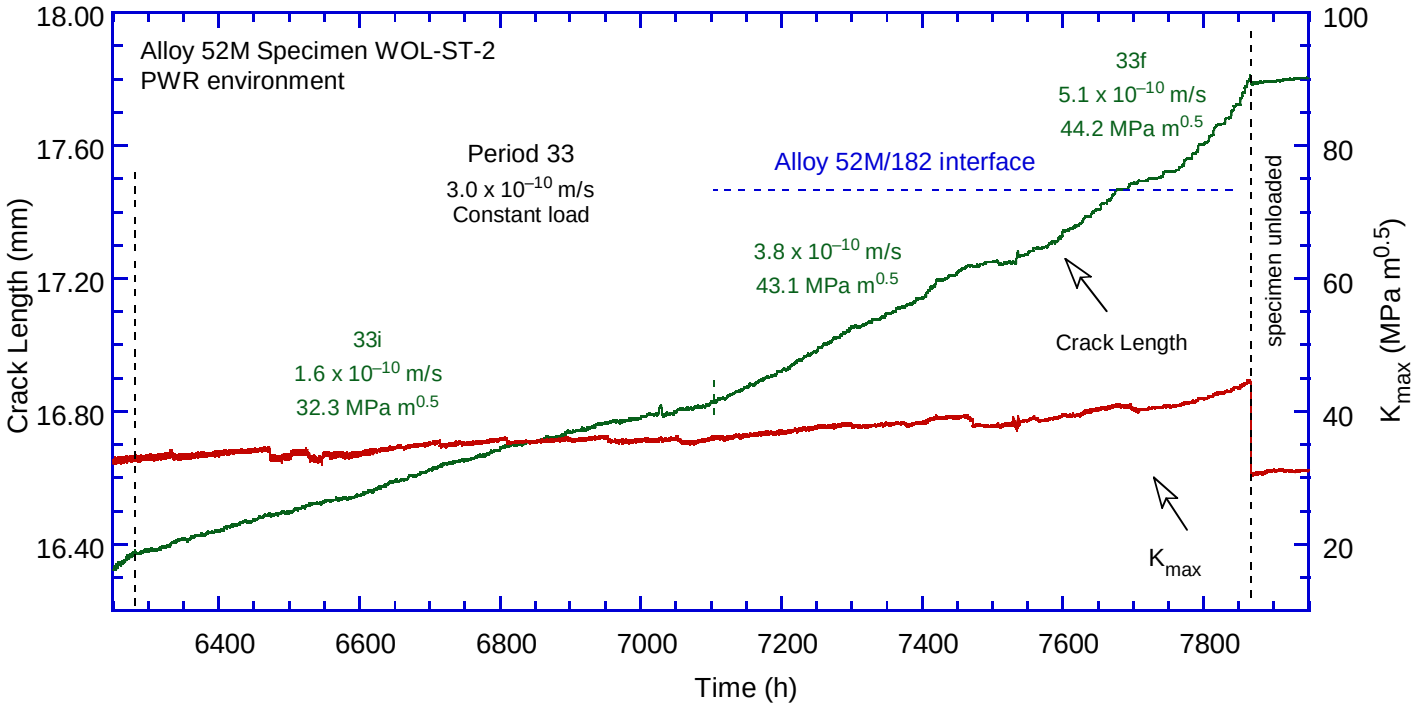
"Known" behavior: Alloy 152 cyclic response of a symmetrical double-J weld





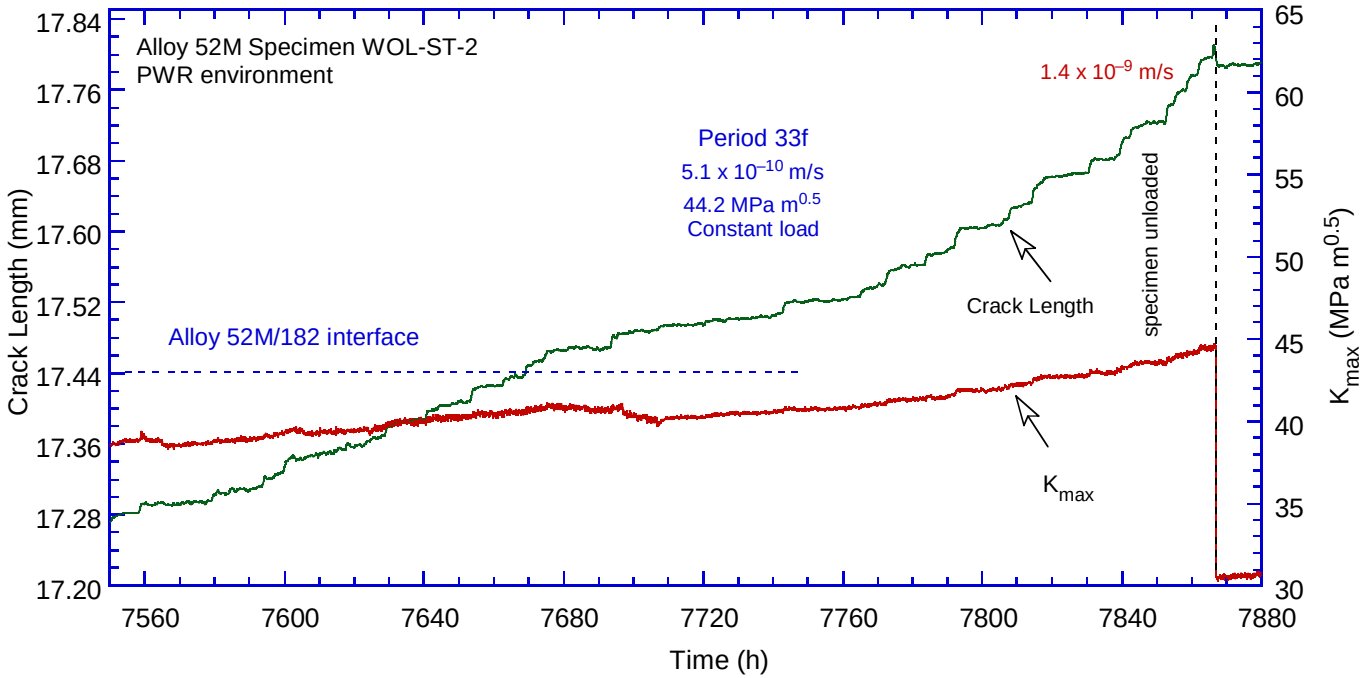
- Good understanding of Alloy 152 response vs. R and rise time in TS specimens
- "Favorable" location = response consistent with IG SCC propagation in Alloy 152 (crack front aligned with the dendritic grains)

Alloy 52M/182 Weld Overlay Specimen WOL-ST-2



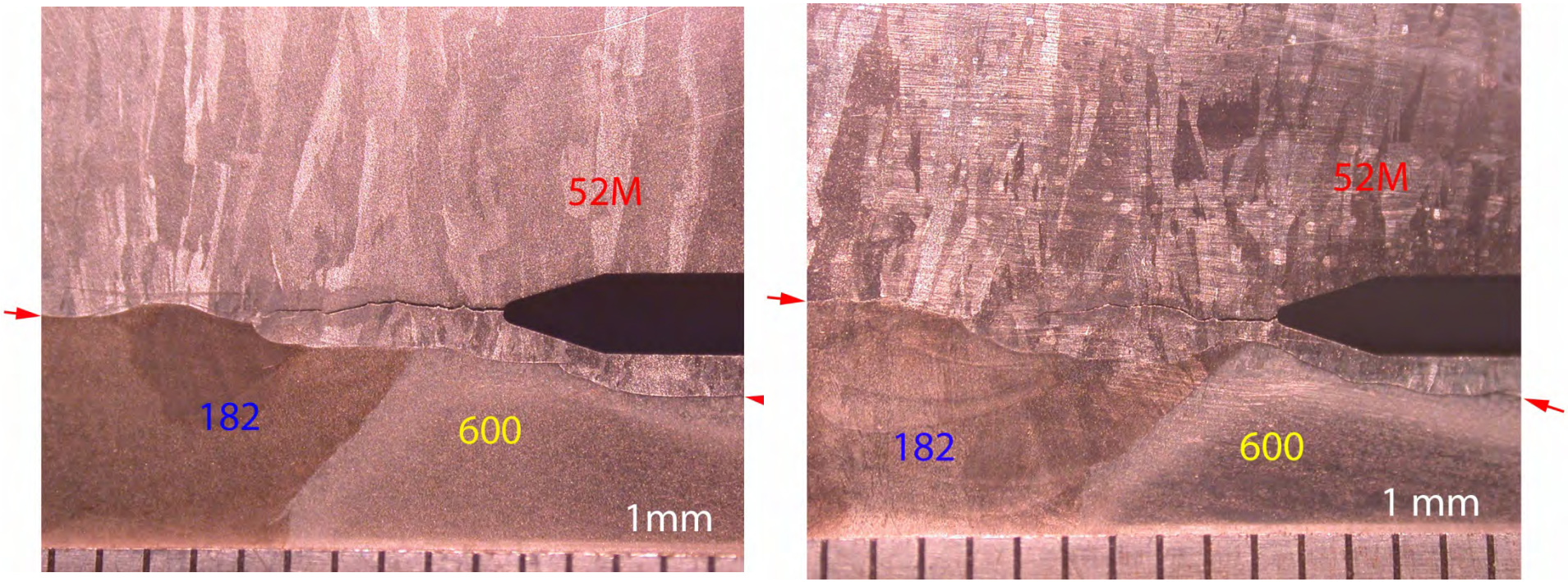
- Corrected data
- Set at constant load approx. 0.8 mm from the interface (post-test evaluation)
- Alloy 52M WOL SCC CGR = 1.6E-10 mm/s (calculated on the first 0.46 mm of growth), confirms prior estimations

Alloy 52M/182 Weld Overlay Specimen WOL-ST-2



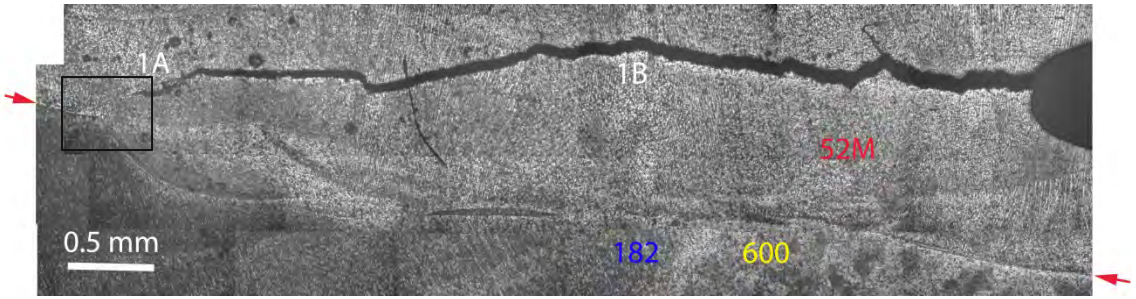
- Corrected data
- "Jumps" (regions of fast growth) start appearing in the vicinity of the interface (similarity to WOL-ST-1)
- Alloy 52M/182 WOL interface appears to be highly susceptible to IG SCC (note the E-9 m/s rate for the last 0.1 mm of growth at the end)

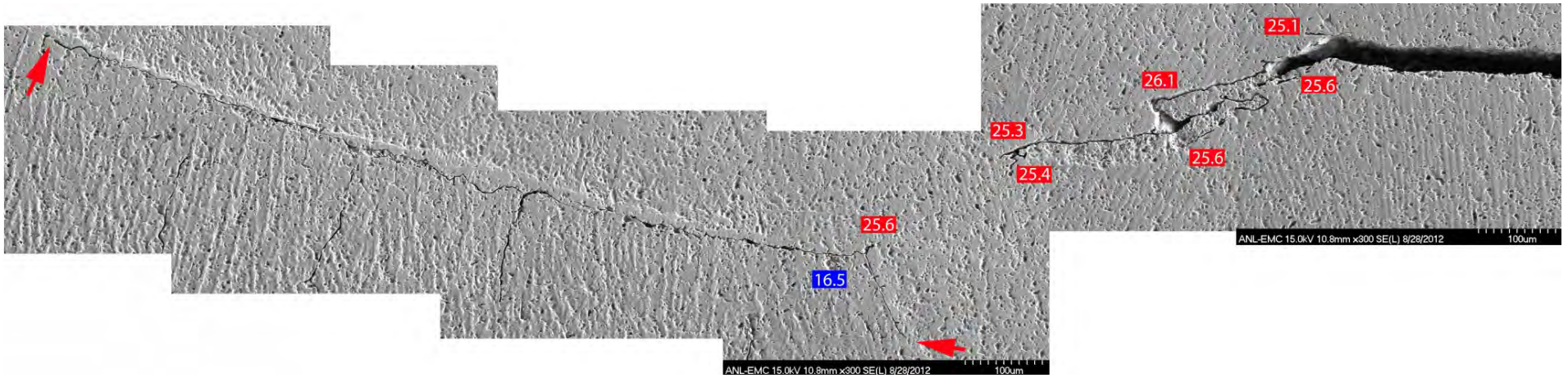
Alloy 52M/182 Weld Overlay Specimen WOL-ST-2 – Side Surfaces



- Test evolved as anticipated

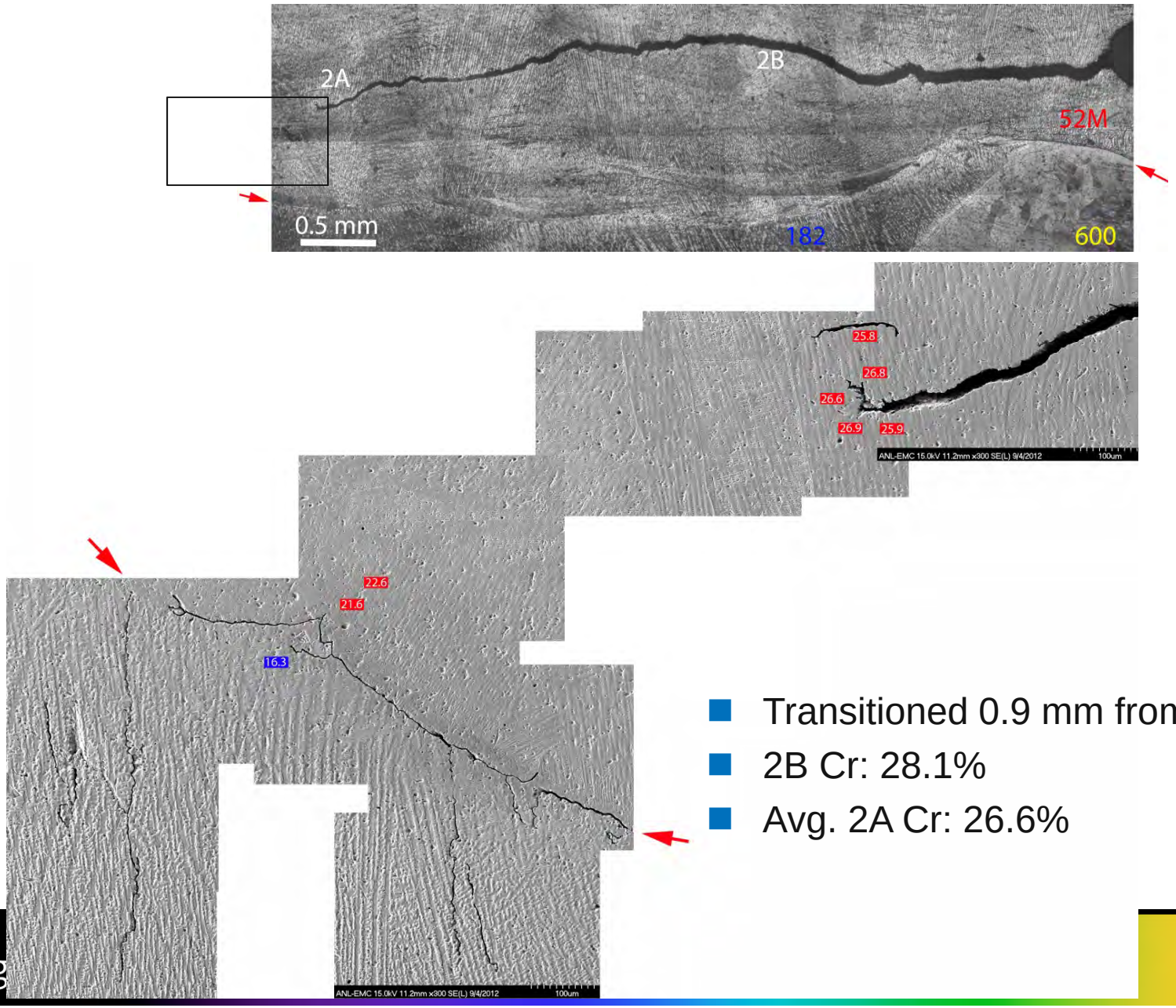
Alloy 52M/182 Weld Overlay Specimen WOL-ST-2 – Side Surfaces





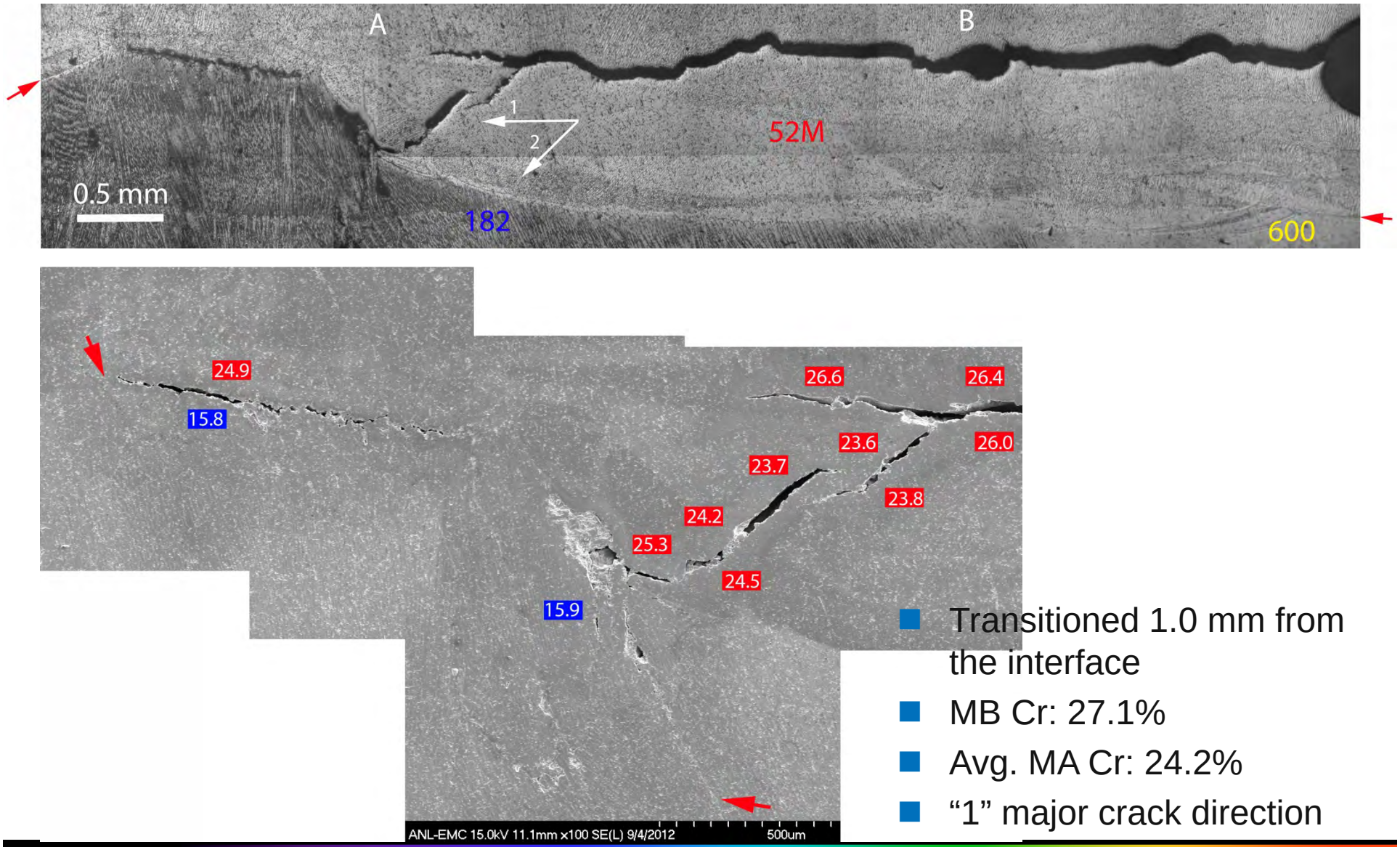
- SCC initiated in Alloy 52M, transitioned 0.6 mm from the interface
- Loc. 1B Cr: 27.1% (CMTR: 29.98%, Ind: XX.X)
- Avg. 1A Cr: 25.5%

Alloy 52M/182 Weld Overlay Specimen WOL-ST-2 – Side Surfaces



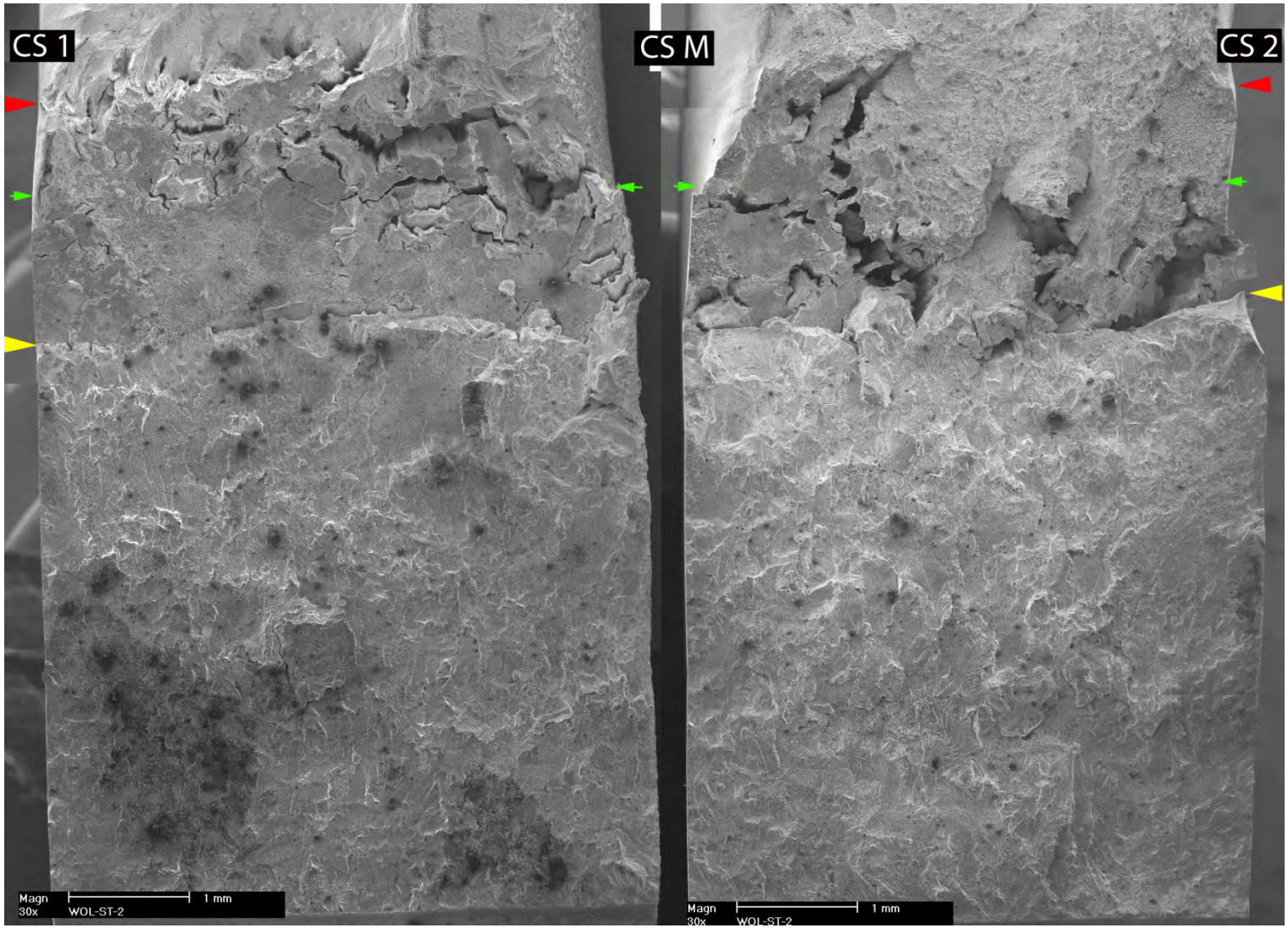
- Transitioned 0.9 mm from the interface
- 2B Cr: 28.1%
- Avg. 2A Cr: 26.6%

Alloy 52M/182 Weld Overlay Specimen WOL-ST-2 – Middle



- Transitioned 1.0 mm from the interface
- MB Cr: 27.1%
- Avg. MA Cr: 24.2%
- “1” major crack direction

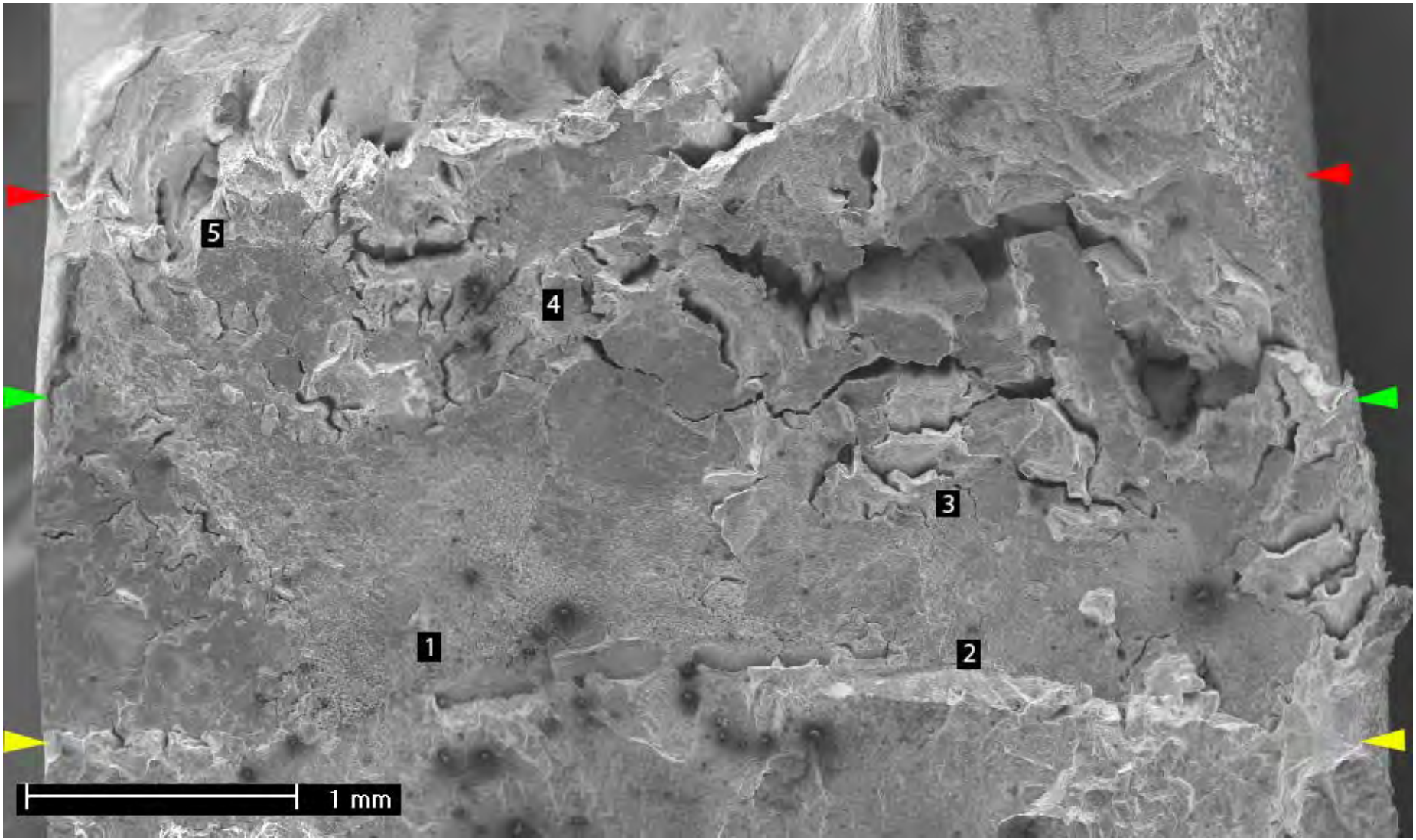
Alloy 52M/182 Weld Overlay Specimen WOL-ST-2 – Fracture



- SCC growth: 1.7 mm (4.2x higher than anticipated)

End precracking/transitioning
182/52M interface
End of test

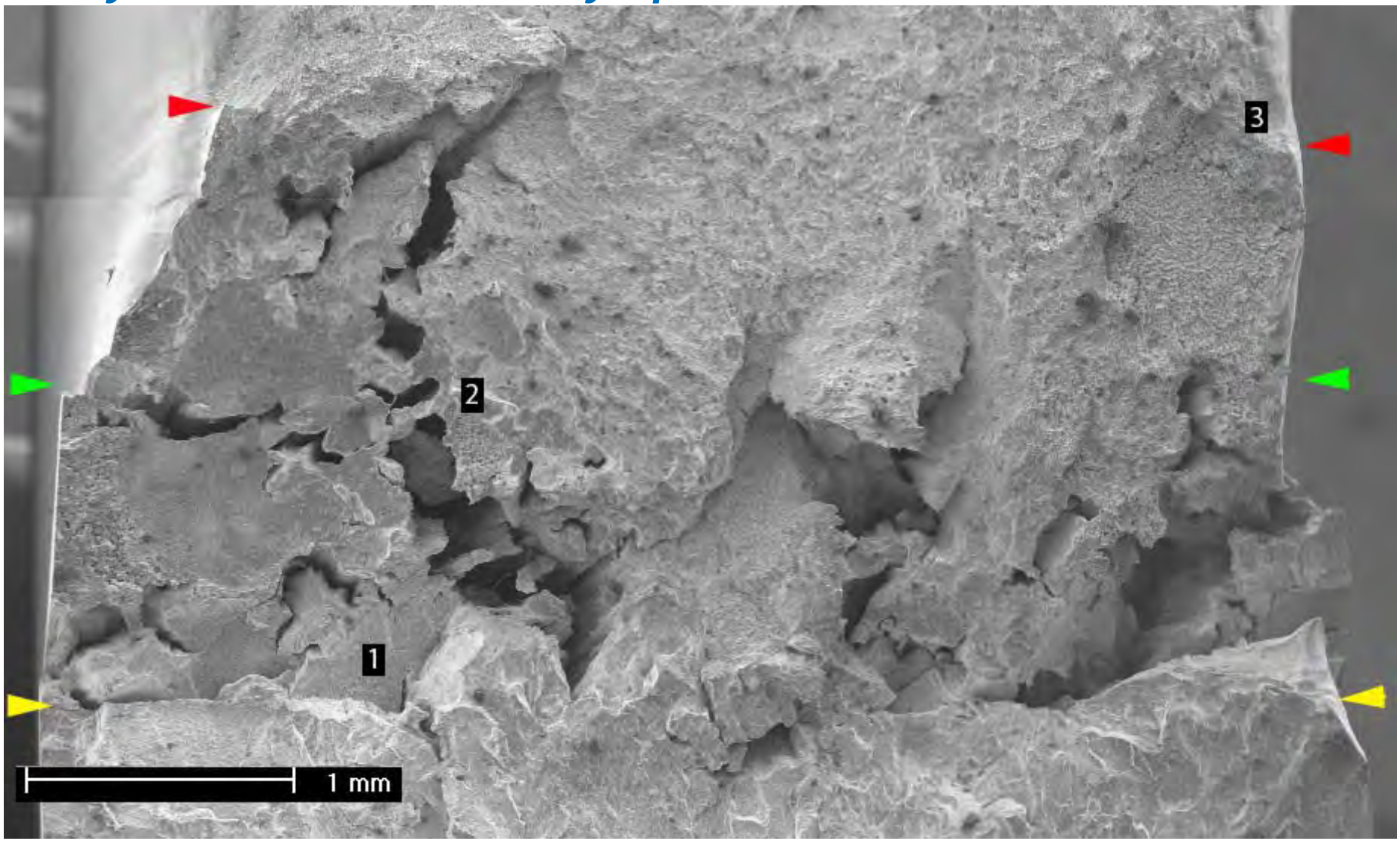
Alloy 52M/182 Weld Overlay Specimen WOL-ST-2 – Fracture A



- SCC growth: 1.7 mm (4.2x higher than anticipated)

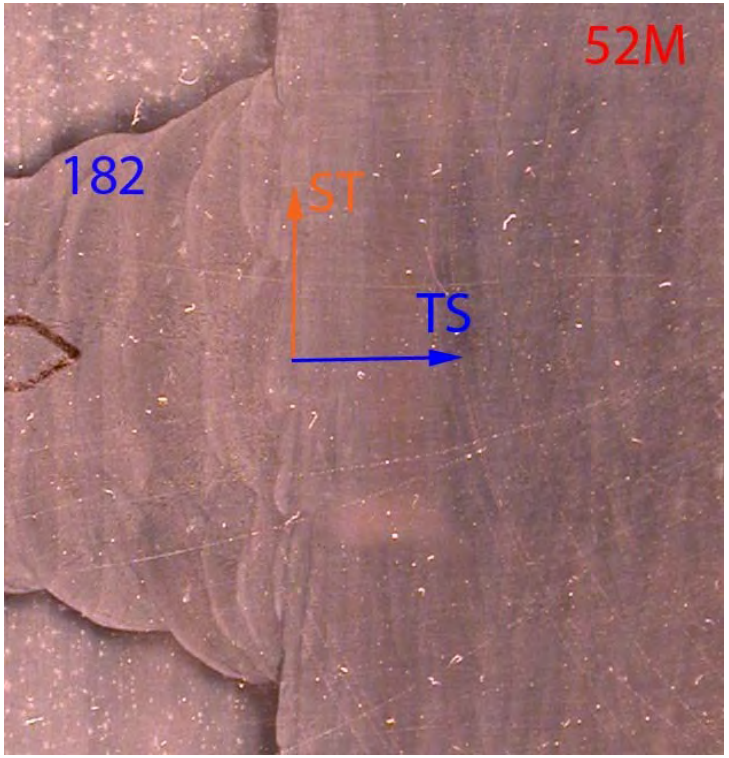
End precracking/transitioning
182/52M interface
End of test

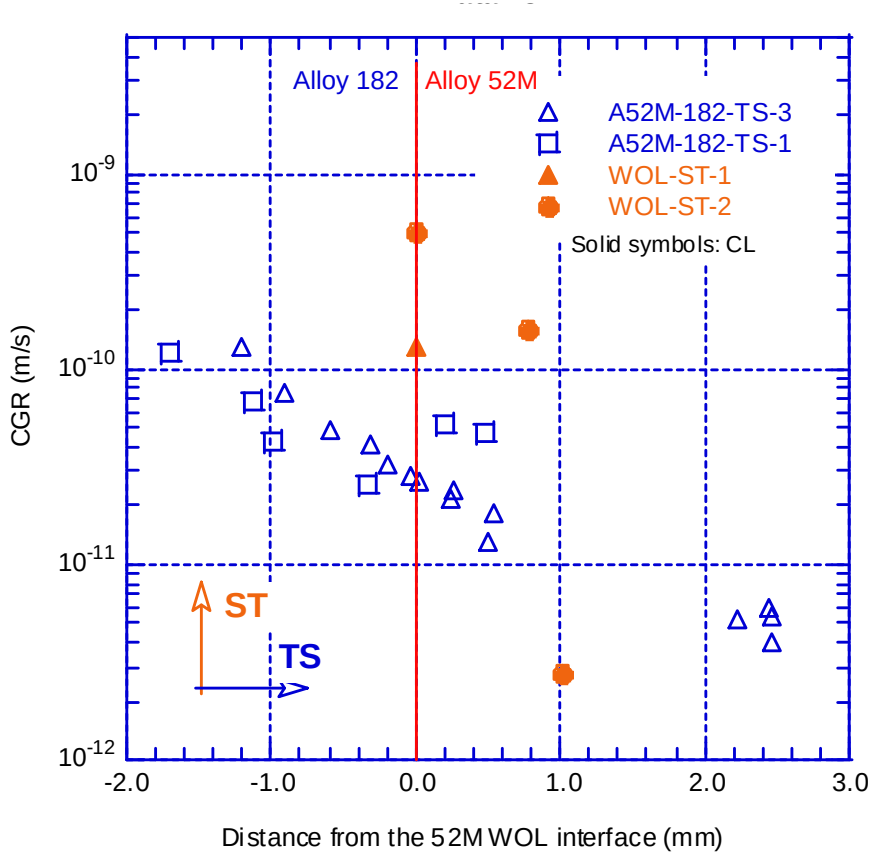
Alloy 52M/182 Weld Overlay Specimen WOL-ST-2 – Fracture B



- SCC growth: 1.7 mm (4.2x higher than anticipated)

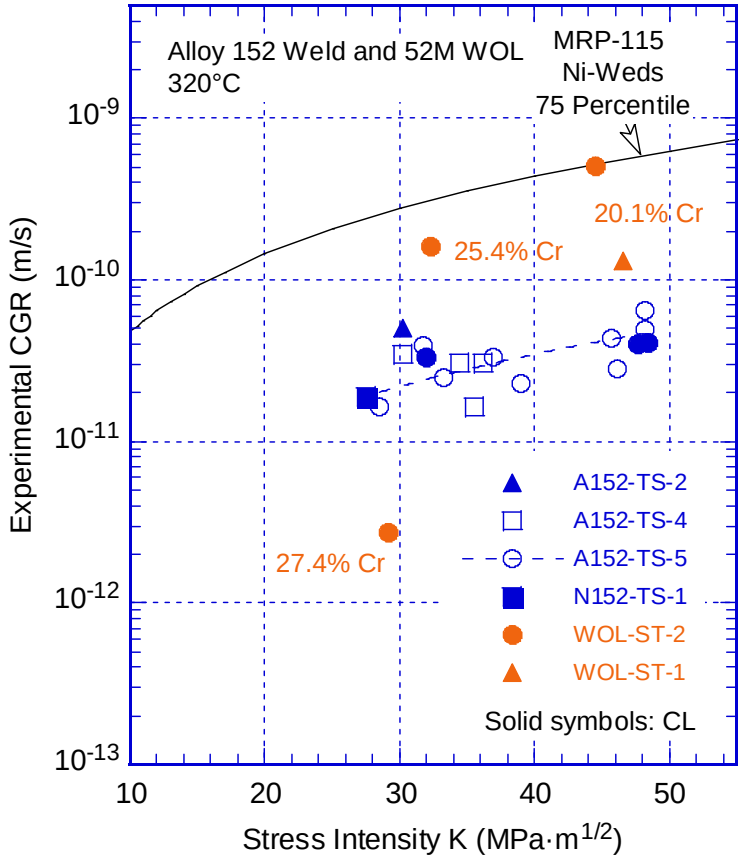
Summary of SCC CGR data for Alloy 52M-182 WOL





- TS: SCC CGRs decrease in Alloy 182 ahead of the WOL
- ST: High SCC CGRs in the 1st 52M layer, highest along the 52M-182 interface

SCC CGRs for Alloy 52M-182 WOL



- Alloy 52M WOL (25.4% Cr) vs. Alloy 152 (CMTR 28.7% Cr)
- Alloy 52M first layer: 2.5x improvement vs. MRP-115 75th pct. curve
- Alloy 52M-182 interface: no improvement vs. MRP-115 75th pct. curve

Conclusions

- SCC CGR testing in ST orientation was undertaken to substantiate prior observations

- Test management was key: the ability to reproduce and interpret cyclic CGR response was critical for the success of those tests

- SCC CGR data for TS-oriented specimens confirms the prior observations:

- SCC CGR data for Alloy 52M first layer showed 2.5x improvement vs. MRP-115 75th pct. curve;

- SCC CGR response for Alloy 52M-182 interface showed no improvement vs. MRP-115 75th pct. curve

- Fast SCC occurred in a direction normal to the dendritic grains