

# Use of the Autocorrelation Function to Describe Corrosion Topography

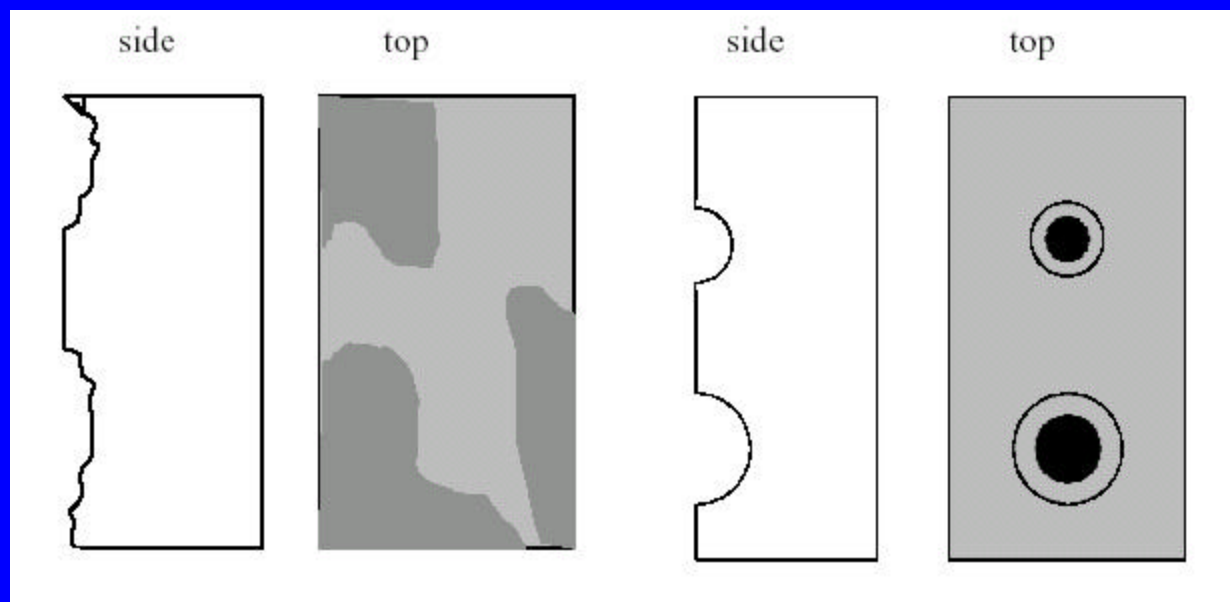
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Charlottesville, VA 22904 USA

*Critical Factors in Localized Corrosion IV:  
A Symposium in Honor of the 65th Birthday of Hans Bohni*

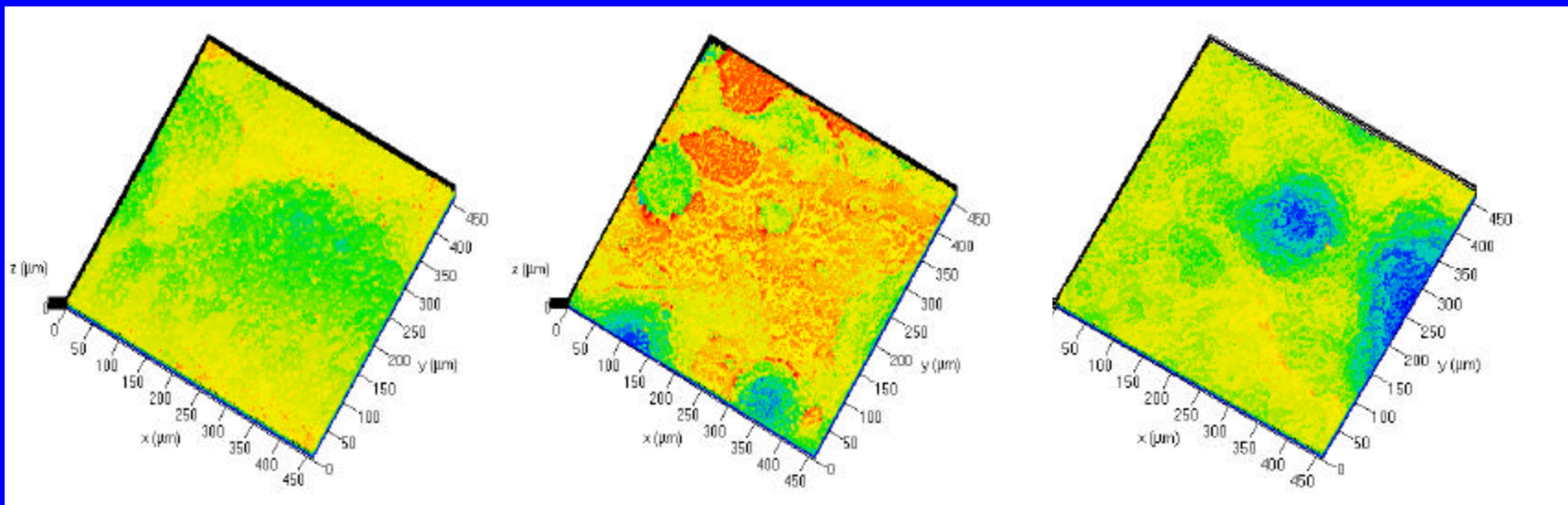
# Descriptions of Corrosion Topography

- Qualitative classification of corrosion *type* seems obvious



# AA2024-T3 Corrosion

- But in reality, mixed modes often occur or evolution from one form to another



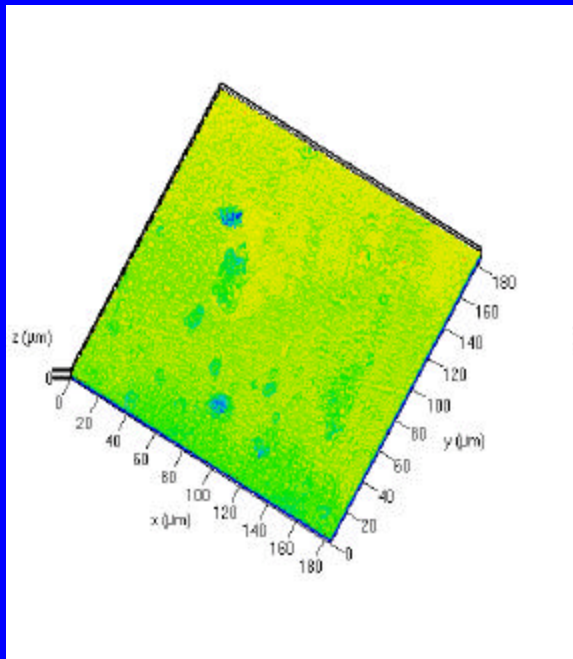
Simulant solution

0.6 M NaCl

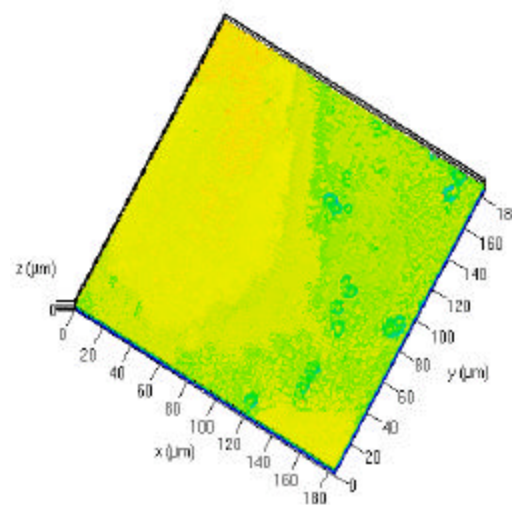
minimal CO<sub>x</sub>

450 mm in x & y, 150 mm in z

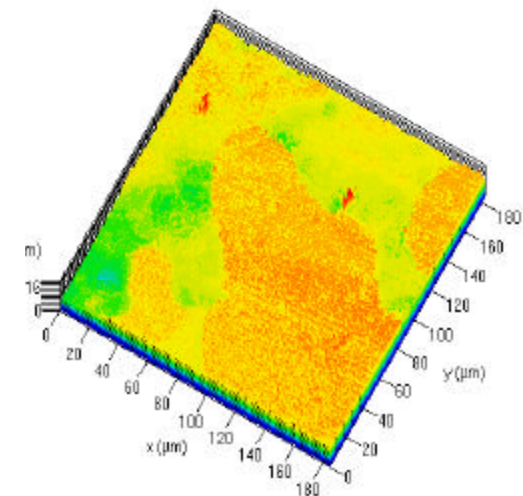
# Faying Surface of AA2024-T3 Occluded Region



3 weeks



4 weeks



12 weeks

**180 mm in x & y, 28 mm in z**

# “Pits occur at Constituent Particles”

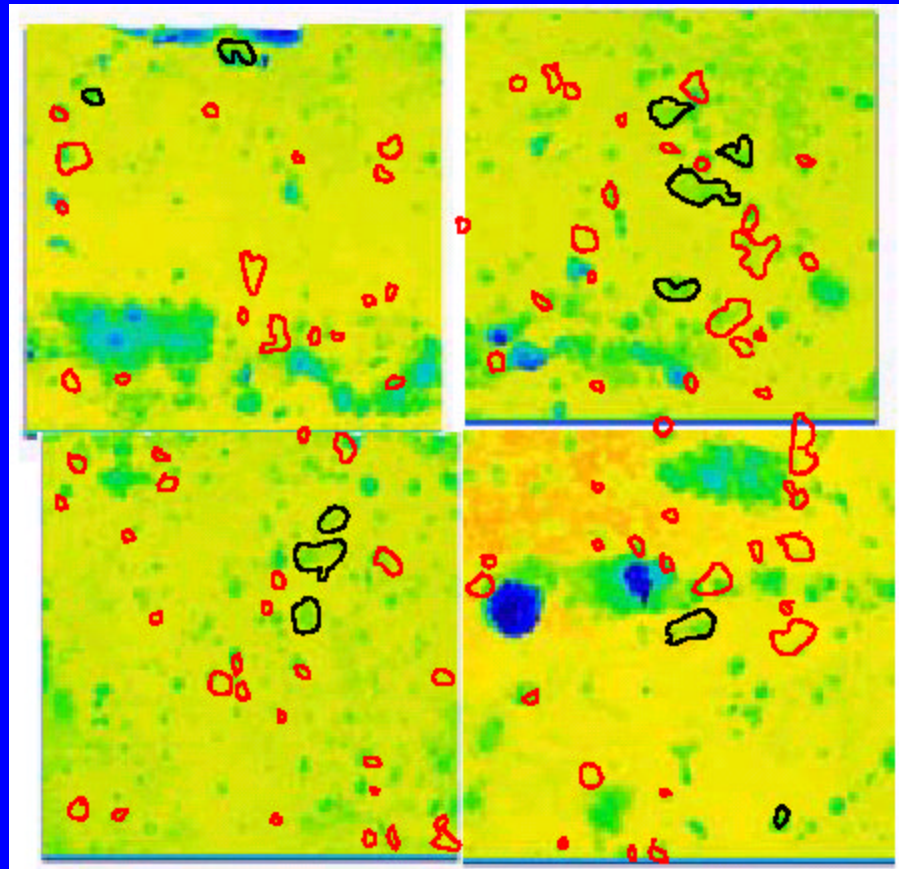
5 weeks Exposure to LJSS

Large pits = blue

Small pits = green

Ptcl sites = red

Ptcl sites + pitting events = black



# Methods of Image Analysis

- Conventional Methods
  - Area Corroded
  - Max Depth
  - RMS Roughness
- Surface Metrology: Autocorrelation Fn

# Autocorrelation Function

- Analysis of surface *height* distribution

$$A(\mathbf{t}) = E[z_1, z_2] = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} z_1 z_2 p(z_1, z_2) dz_1 dz_2$$

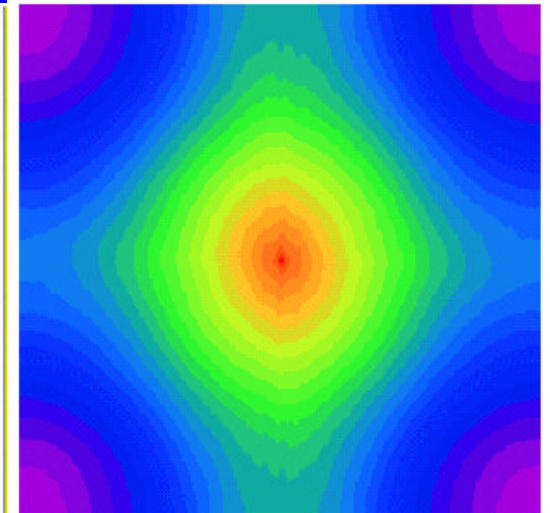
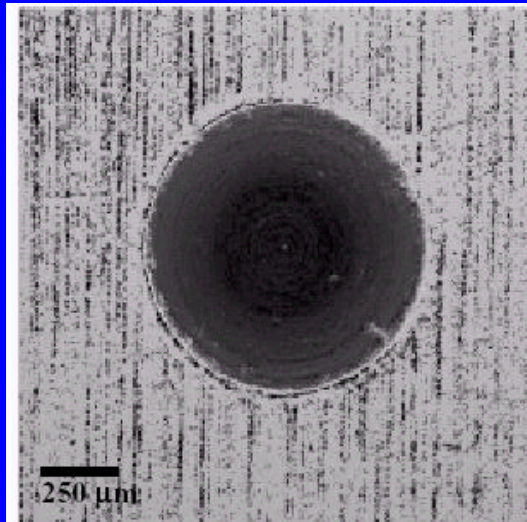
Where:

$z_1$  and  $z_2$  are two measurements

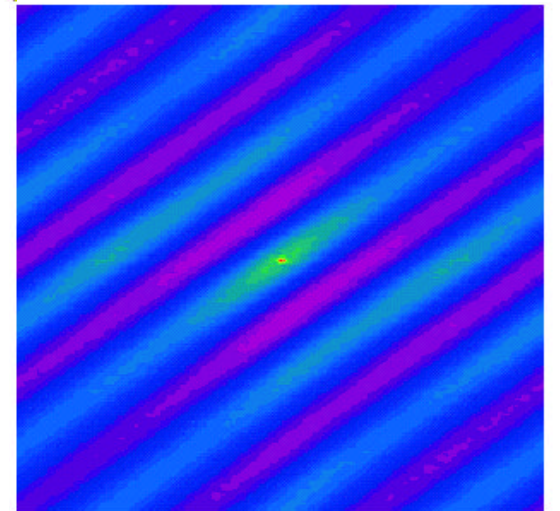
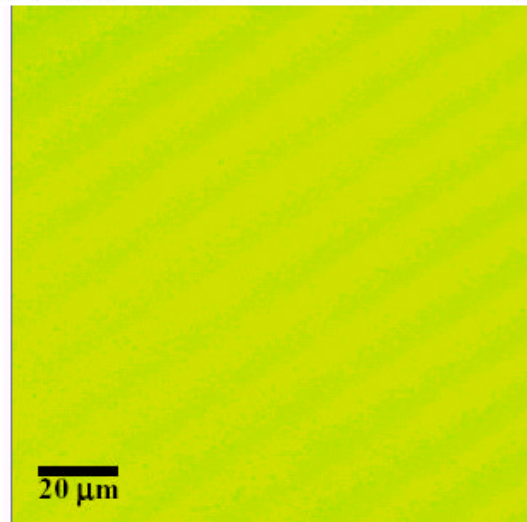
$p(z)$  is the amplitude probability density function.

# Testing the ACF

Simulated Pit

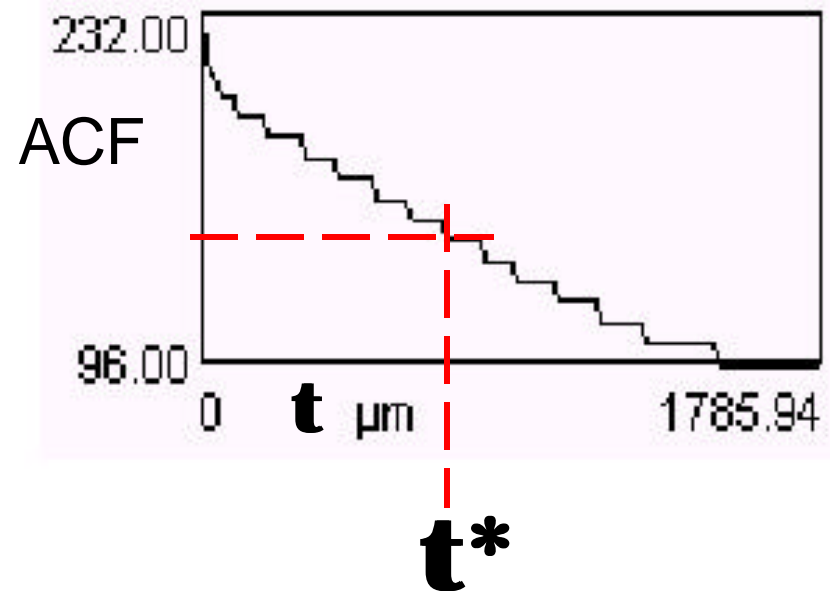
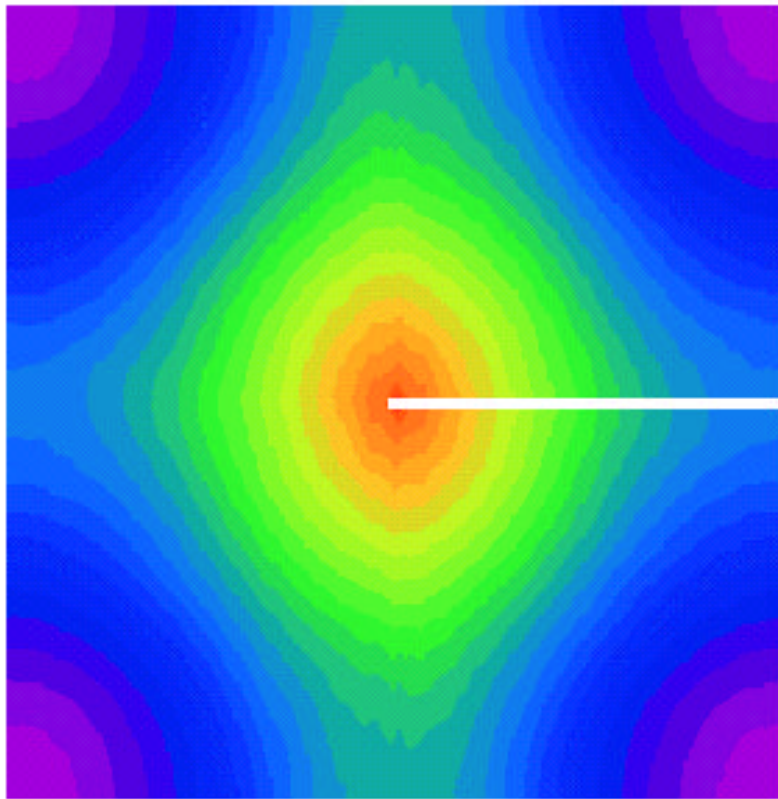


1200 grit surface

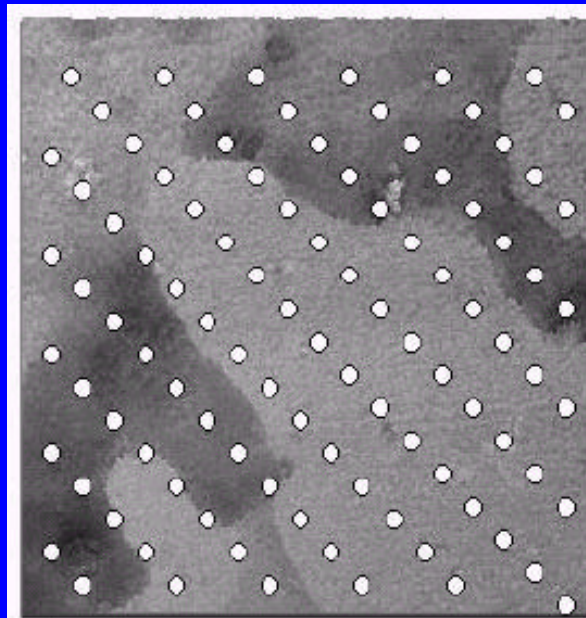


# Correlation Length ( $\tau^*$ )

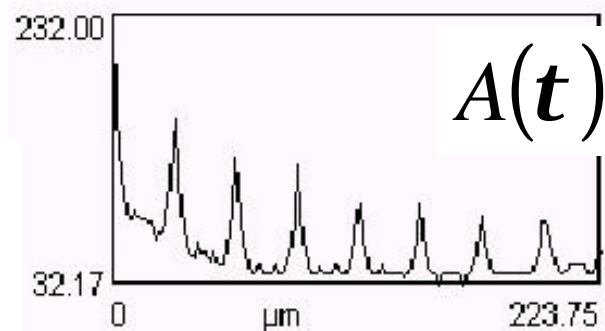
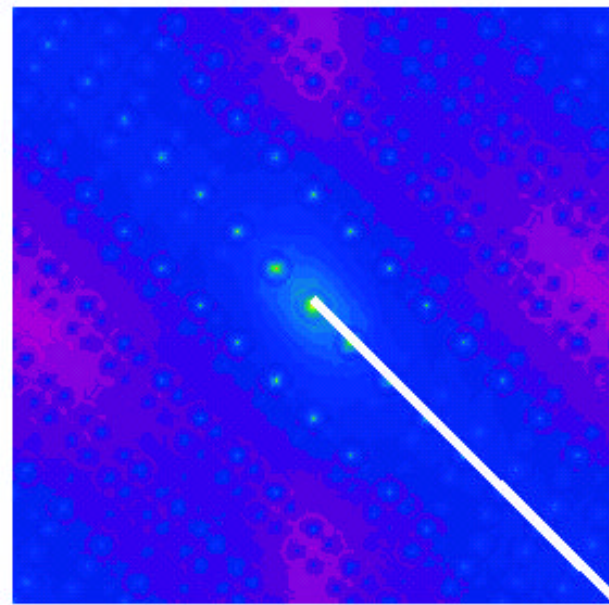
Height of Dominant Feature



# Testing the ACF: Series of Simulated Pits



60  $\mu\text{m}$



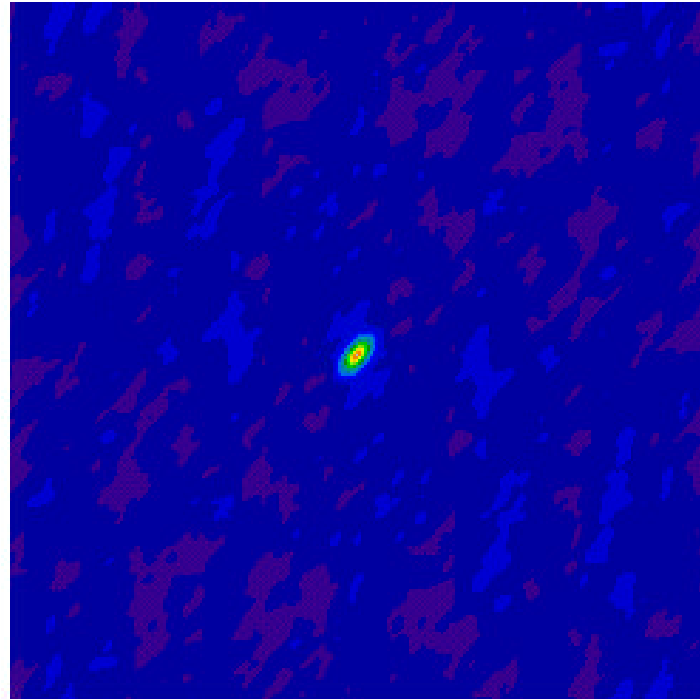
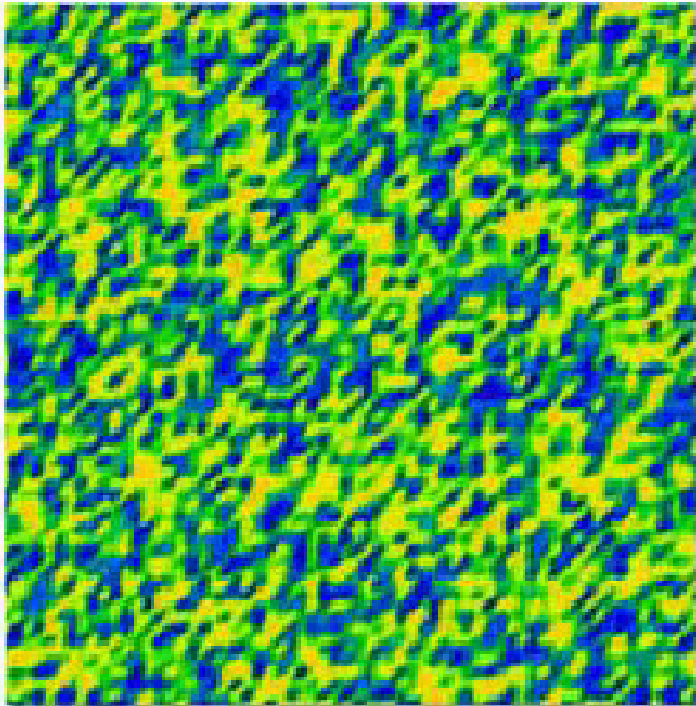
$$A(t) = \exp^{-at} + \cos vt$$

$t^* = 14 \text{ mm} = d$

Spacing = 28 mm

# Random Surface

$$\tau^* = 1 \text{ pixel}$$



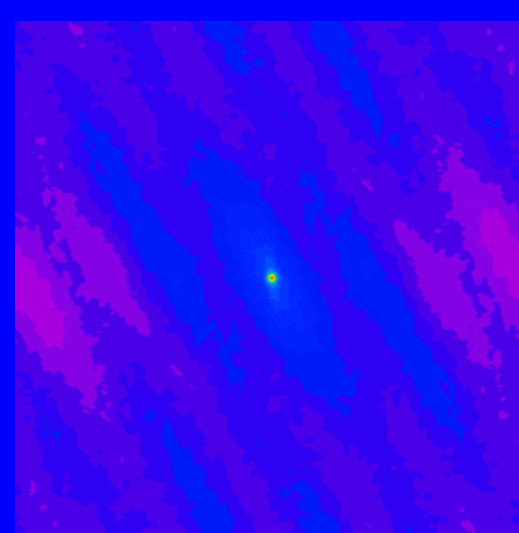
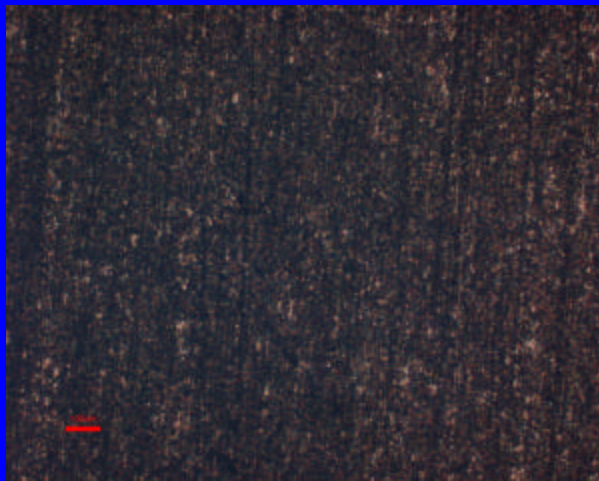
# Texture Aspect Ratio (T)

- Measure of extent of directionality of the periodicity

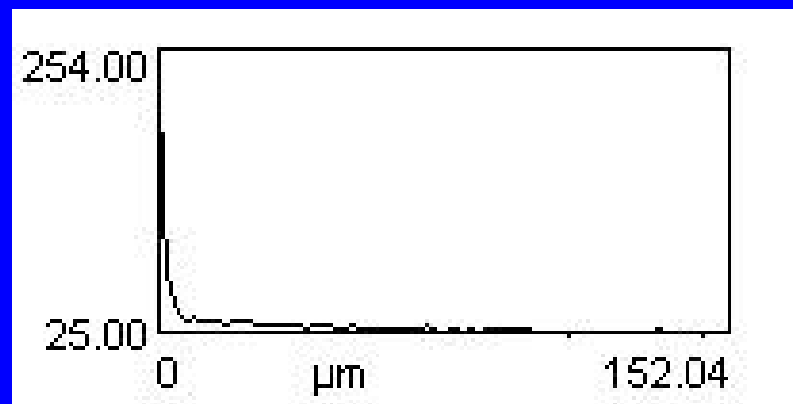
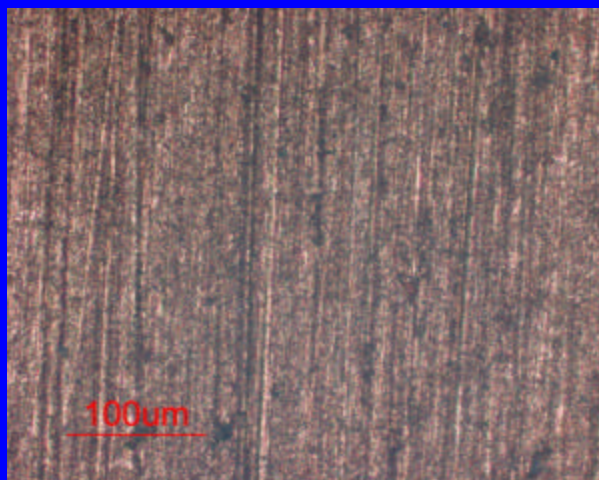
$$T = \frac{t_{\min}^*}{t_{\max}^*}$$

- As directionality of height distribution decreases,  $T \rightarrow 1$

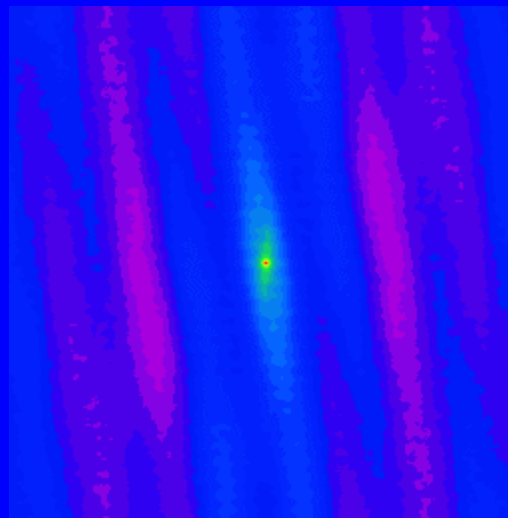
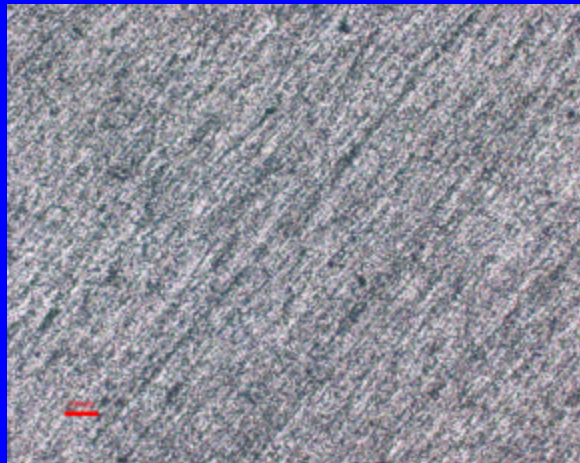
# Cu Electropolished in Phosphoric Acid



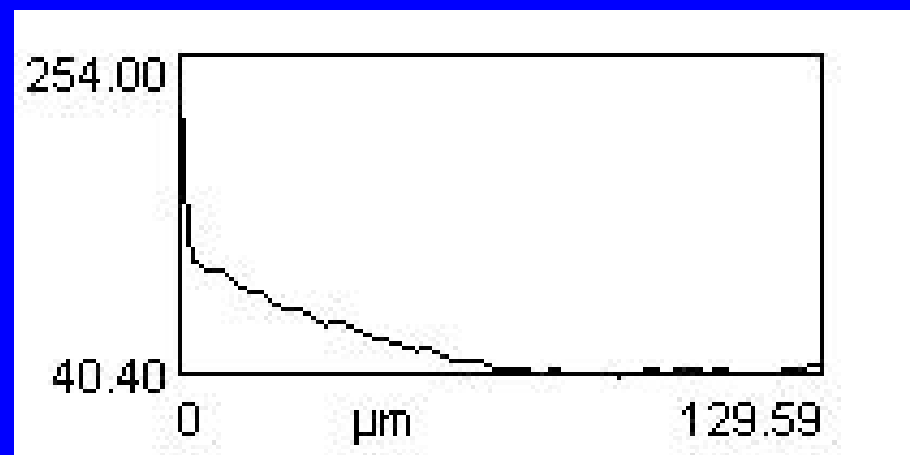
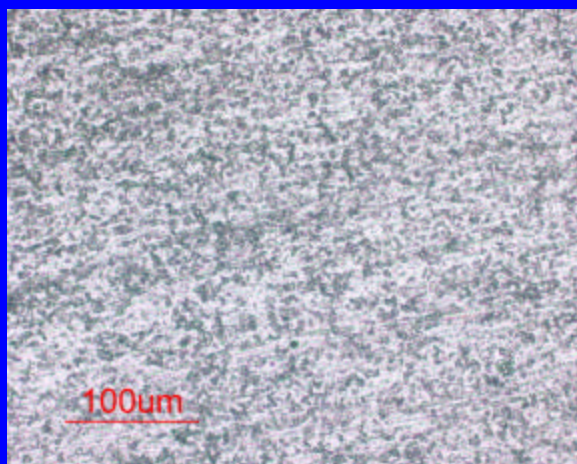
$$\tau^* = 0.91 \mu\text{m}$$
$$T = 0.85$$



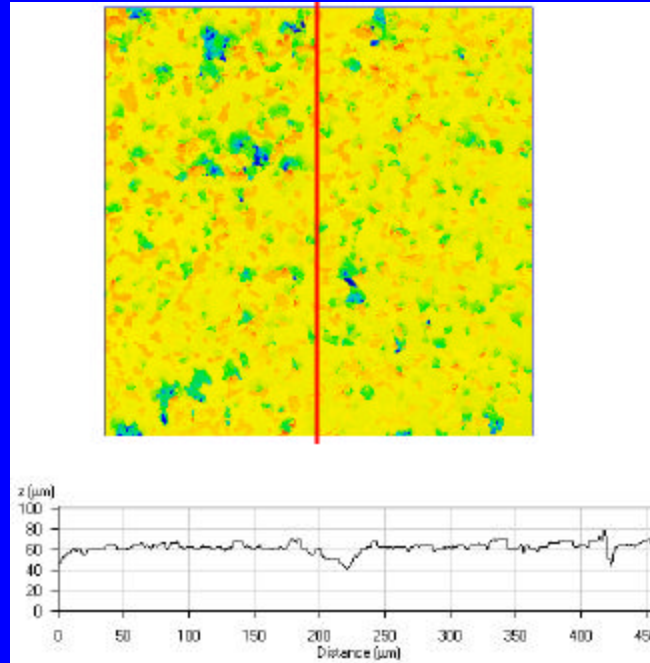
# Al Corroded in NaOH



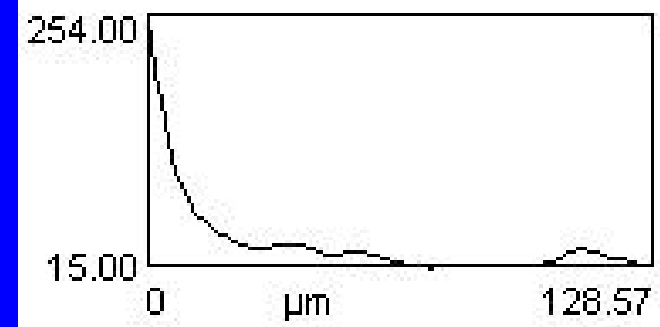
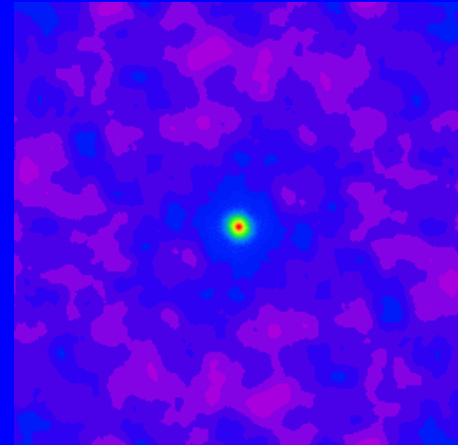
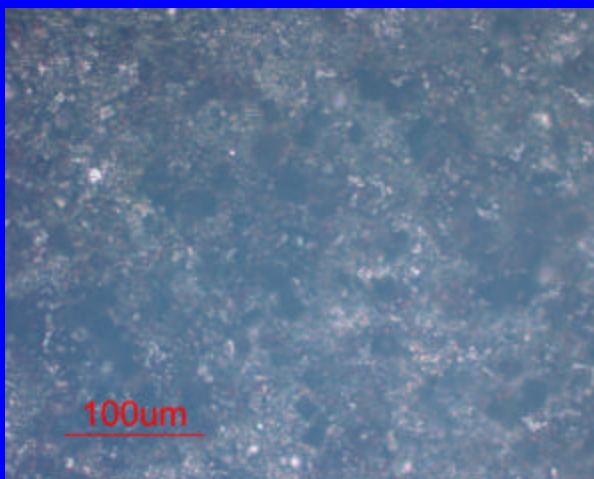
$$\tau^* = 0.92 \mu\text{m}$$
$$T = 0.97$$



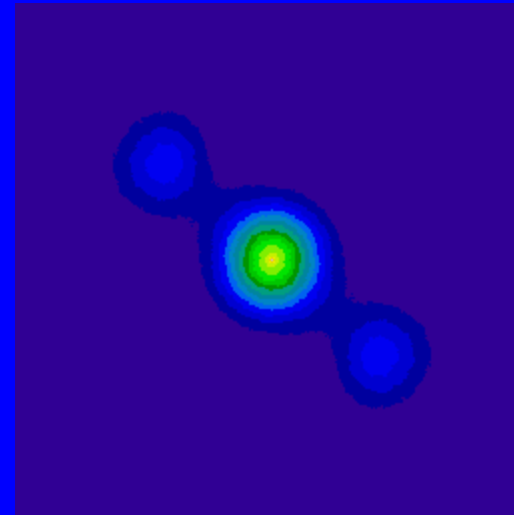
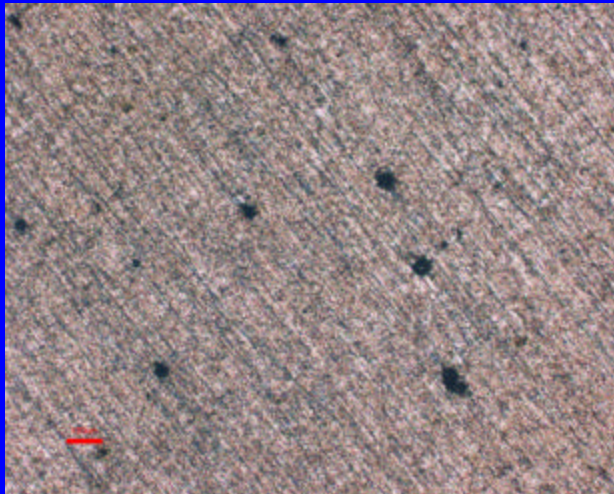
# Carbon Steel in Active Region



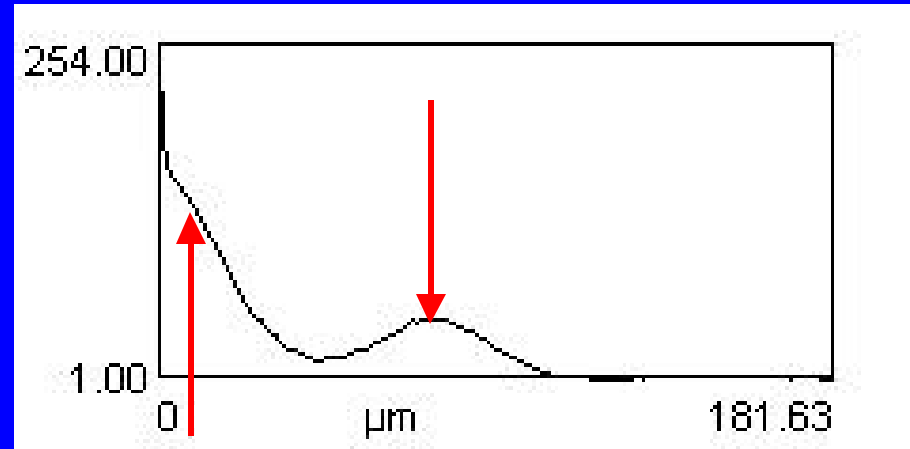
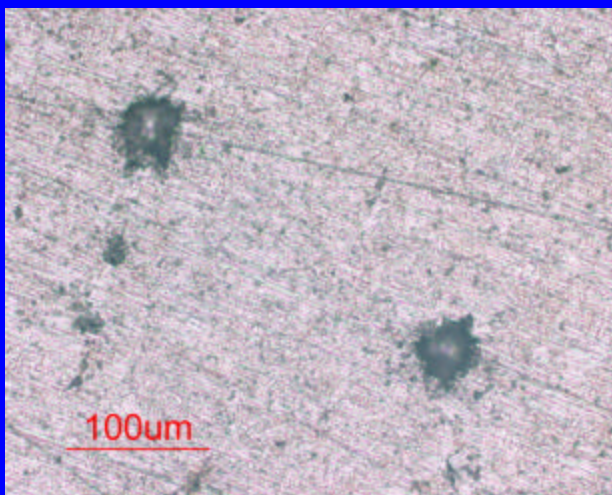
$$\tau^* = 5.04 \mu\text{m}$$
$$T = 0.26$$



# SS304 After Pitting

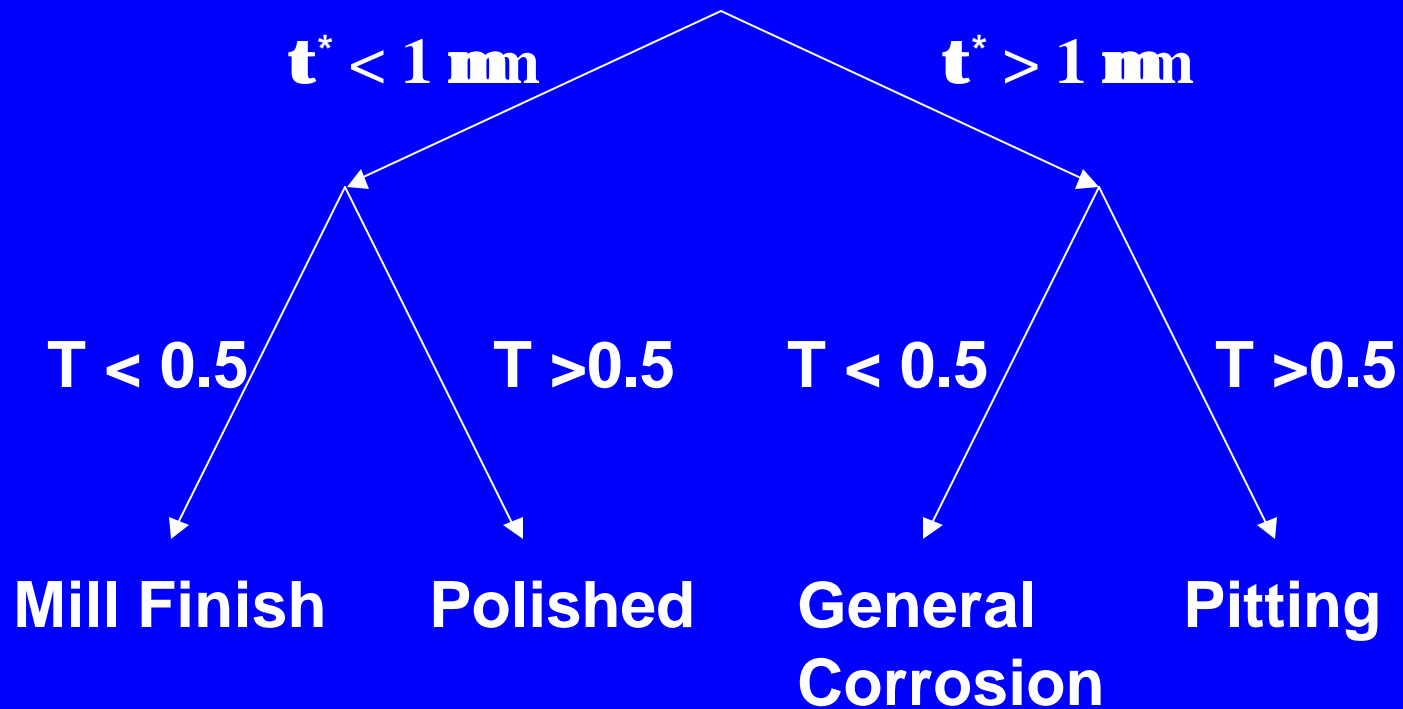


$$\tau^* = 3.76 \mu\text{m}$$
$$T = 0.67$$

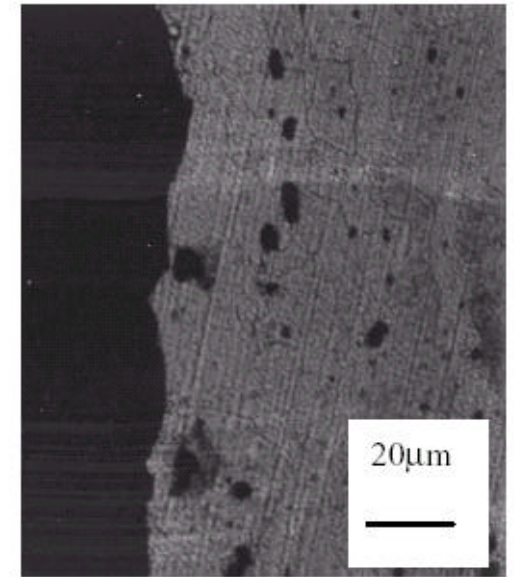
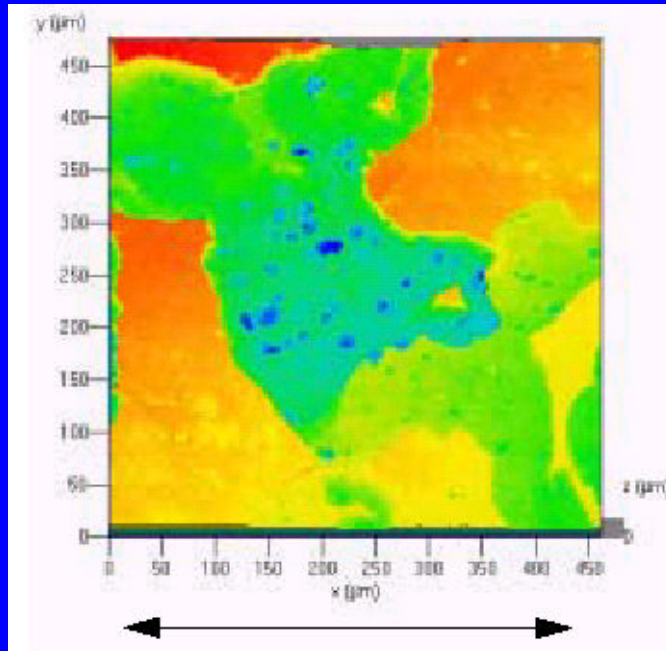


# Decision Tree

Determine  $\tau^*$  and  $T$

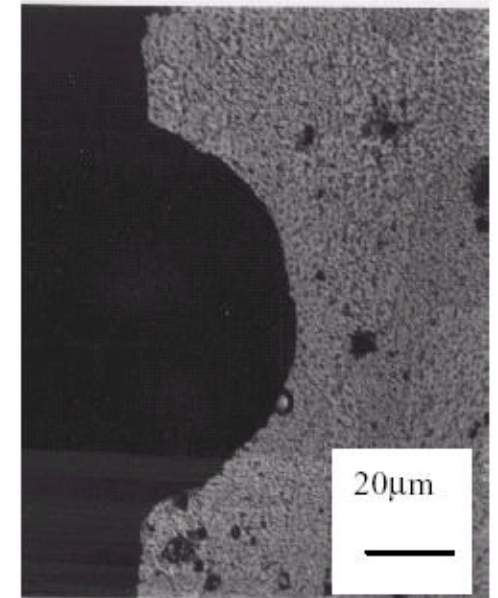
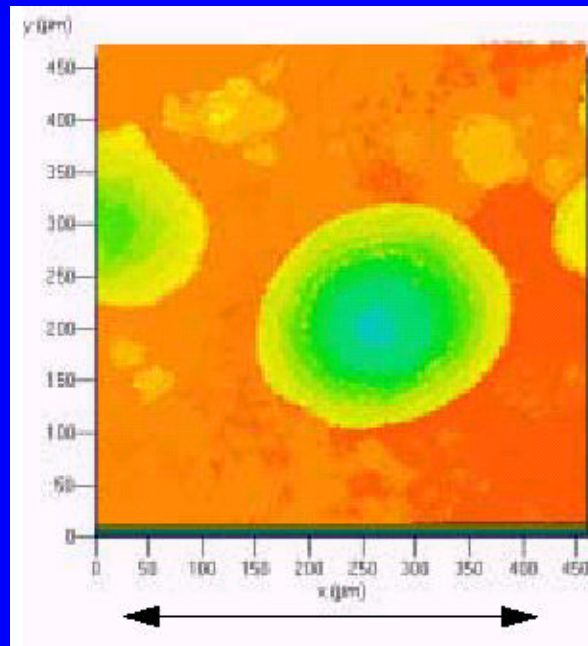


# Application to Lap Joint Corrosion of AA2024- T3



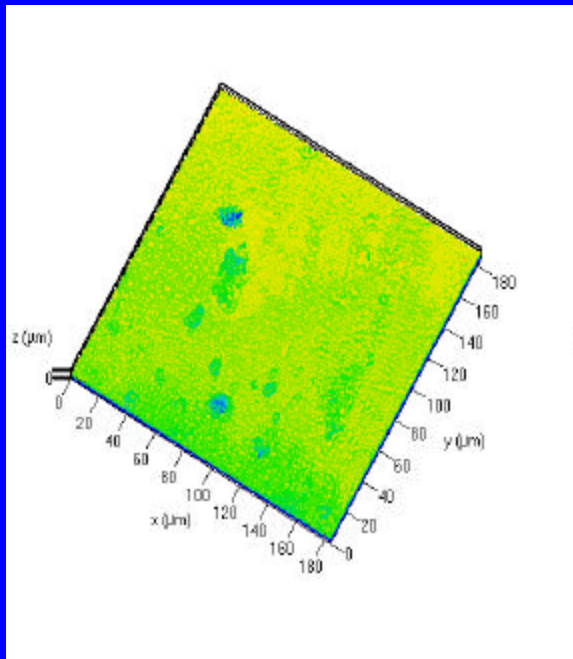
## *Role of CO<sub>2</sub>*

12 wks in LJSS\*  
w/ or w/o CO<sub>x</sub>

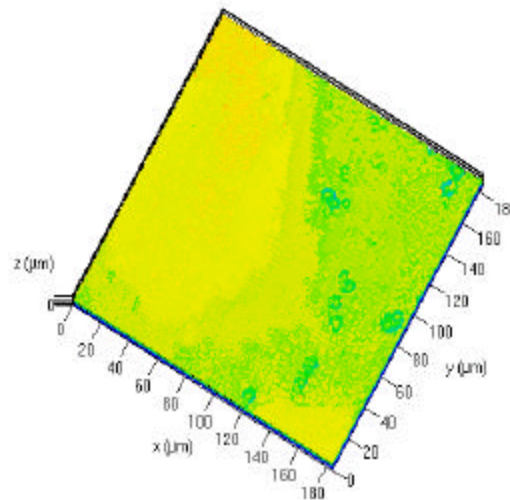


\*20 mM NaCl, 4 mM NaNO<sub>2</sub>, 2 mM NaF, and 4 mM NaHCO<sub>3</sub> at pH 9.0

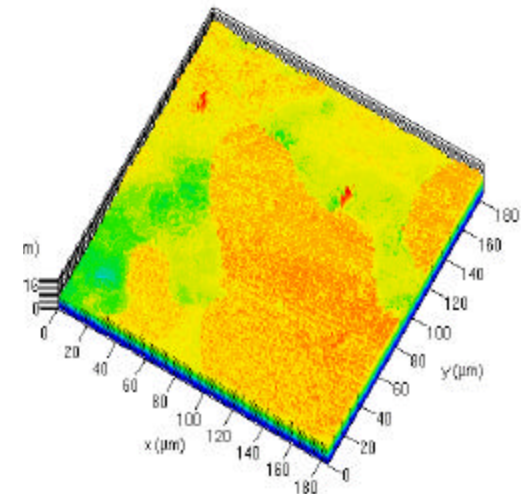
# Evolution of Faying Surface of AA2024-T3 Occluded Region



3 weeks



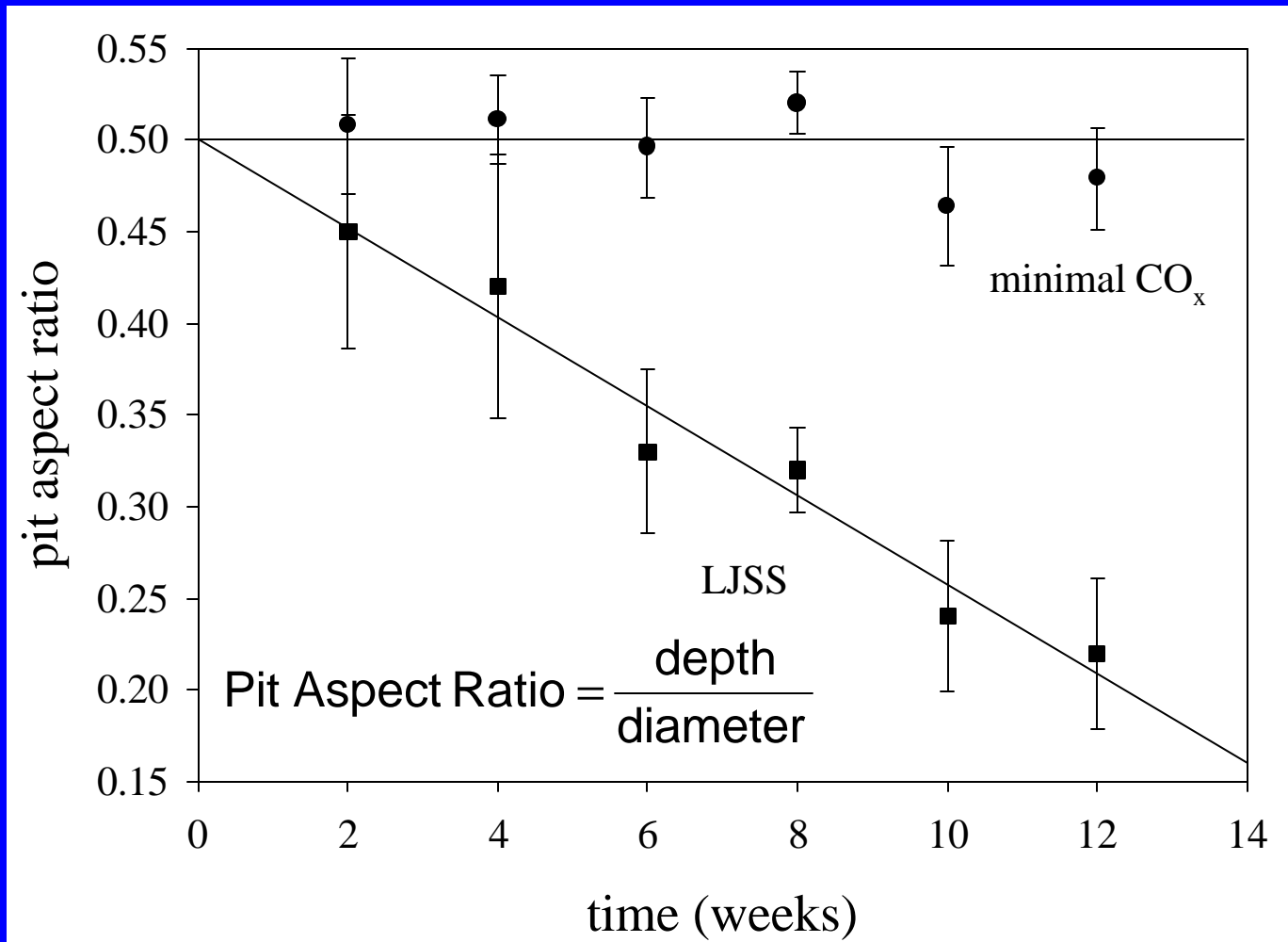
4 weeks



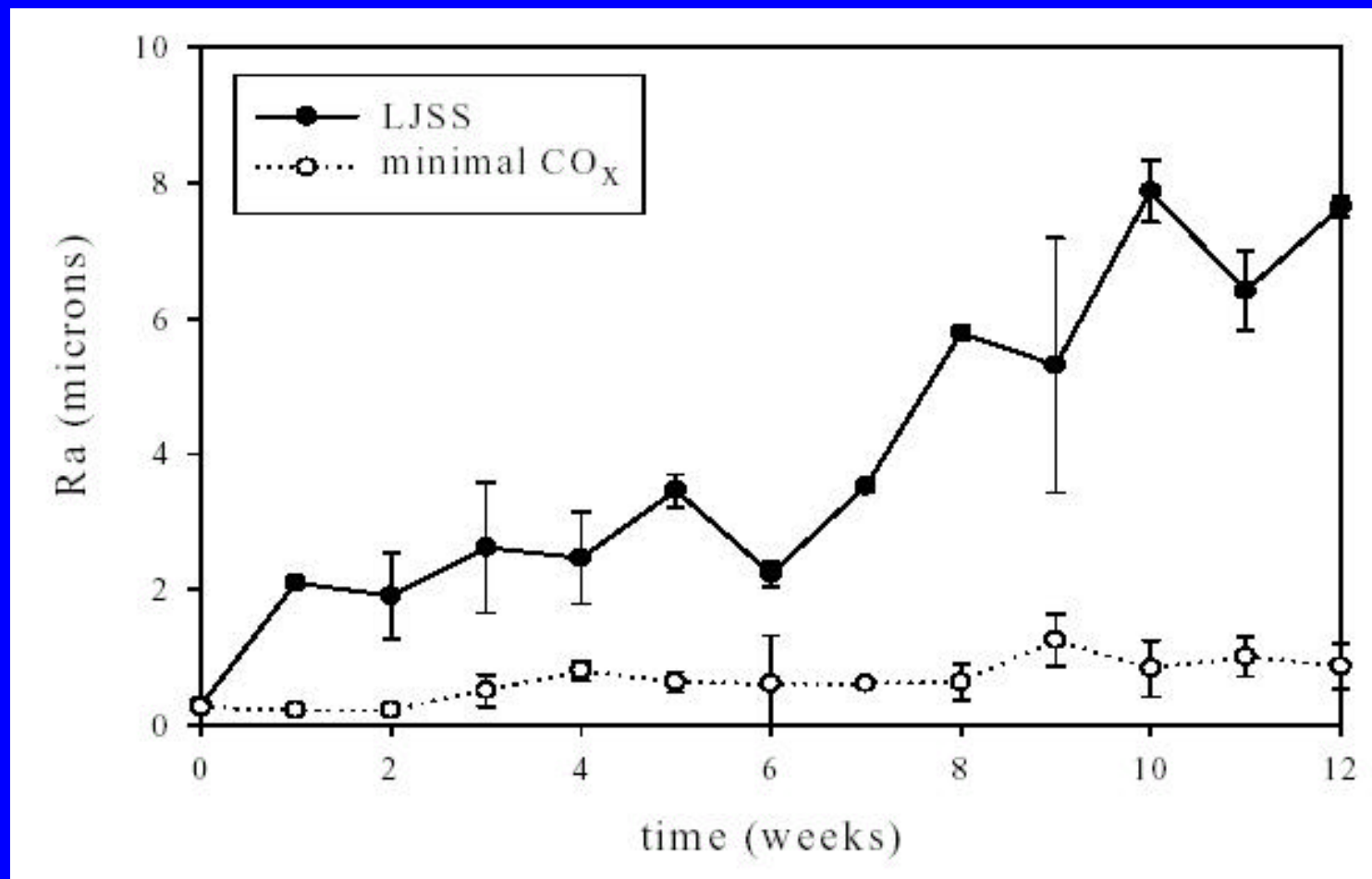
12 weeks

**180 mm in x & y, 28 mm in z**

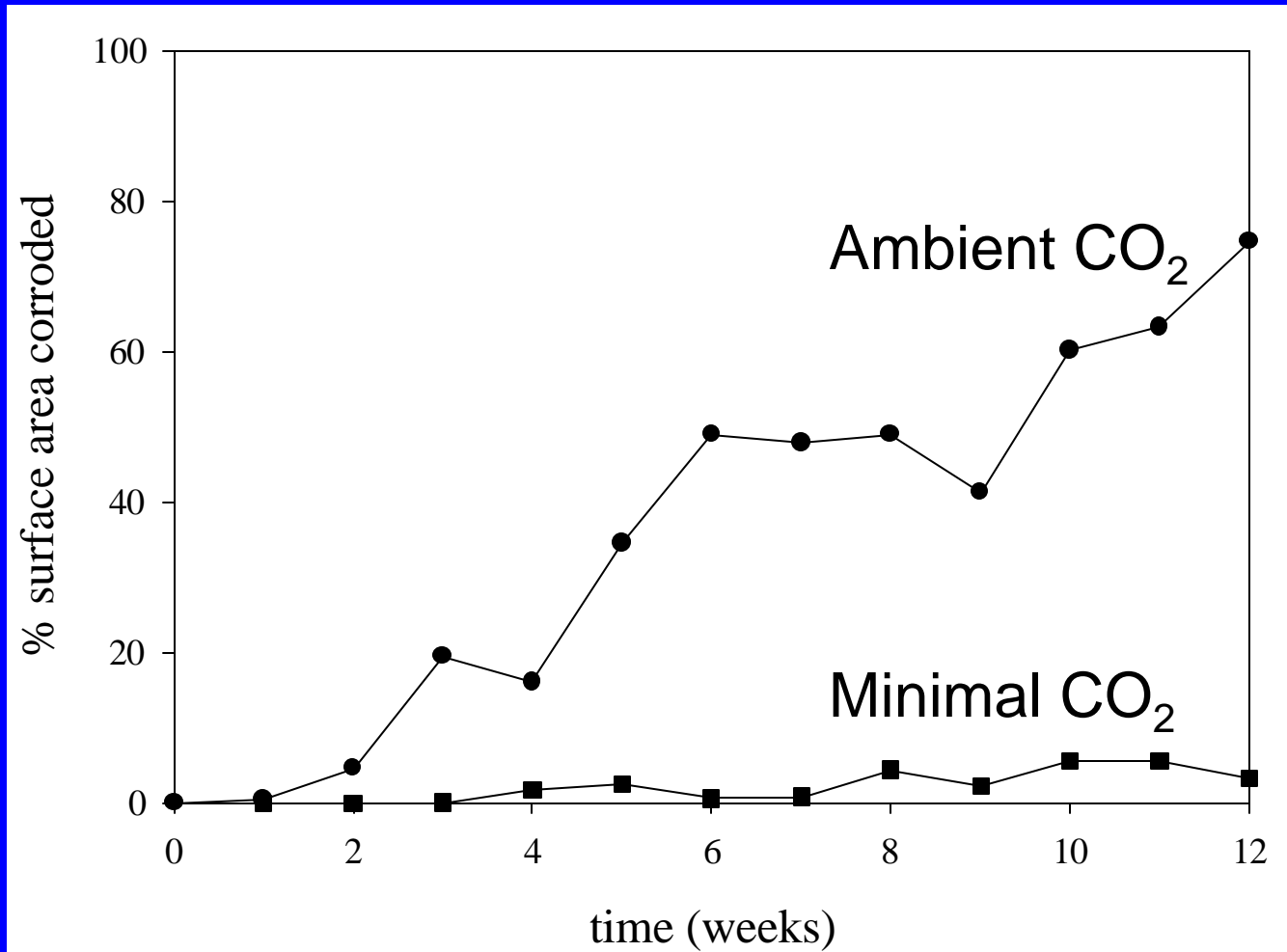
# Pits Form in Both But Die in LJSS



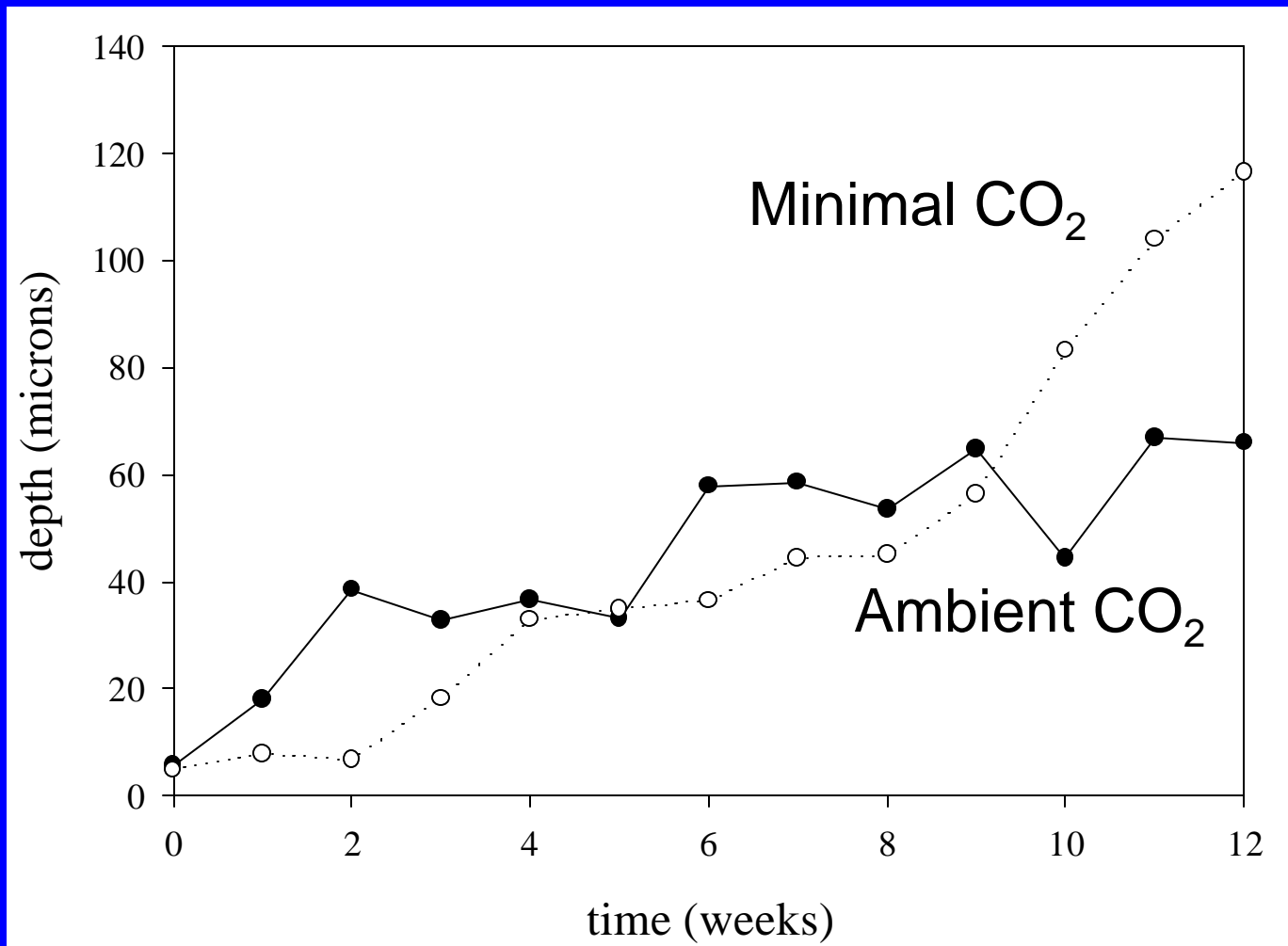
# General Corrosion Leads to Rougher Surface



# % Area Corroded Reflects Differences in Attack

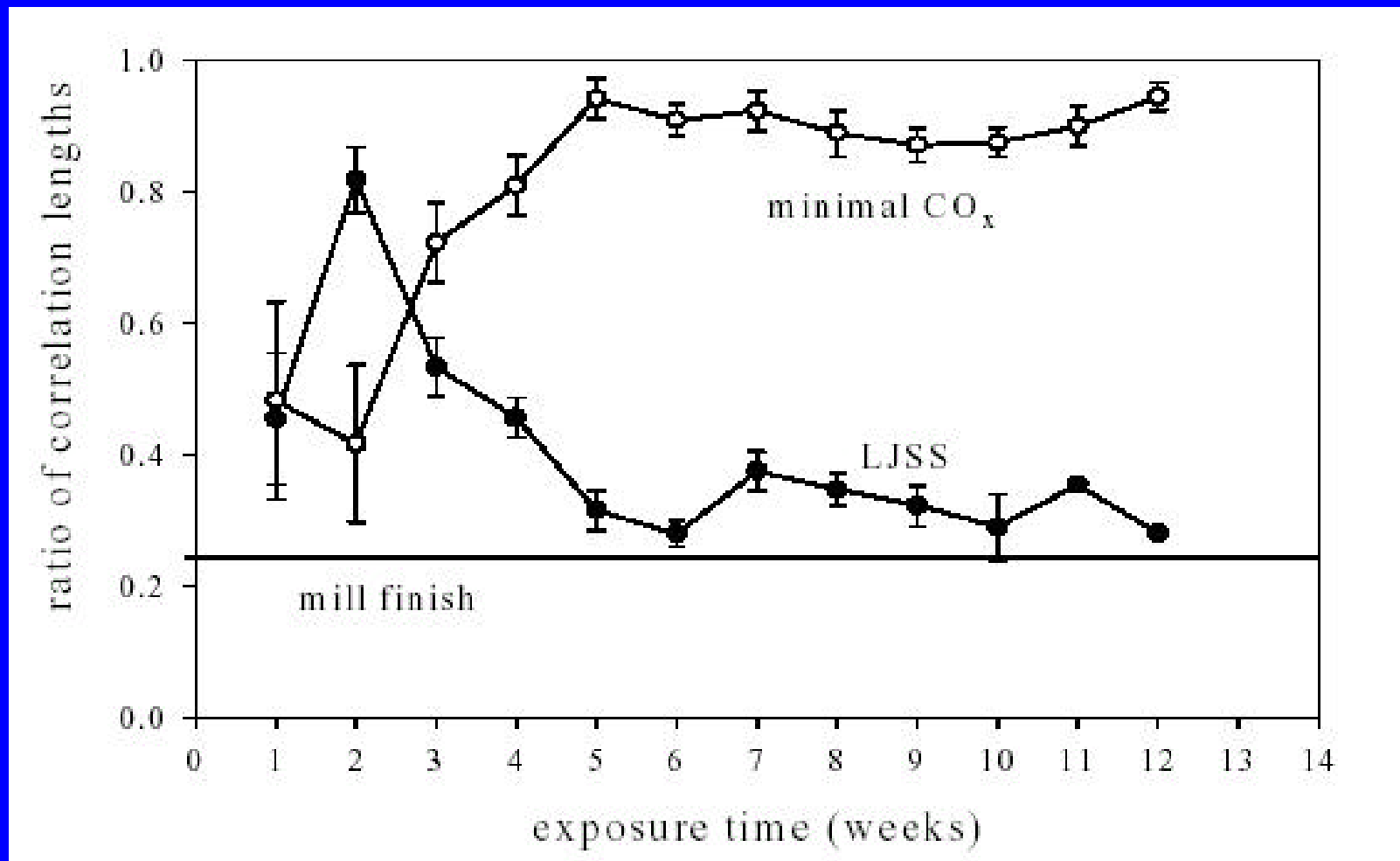


# Max Depth of Damage Does Not Differentiate Well



# CO<sub>x</sub> Inhibits Pit Stability

Leads to More General Corrosion



Note:  $\tau > 1 \mu\text{m}$

# Summary

- ACF allows measure of topography evolution
  - $\tau^*$  is measure of dominant surface feature
  - Combine with T to classify topography
  - Spatial periodicity of pits also determined by ACF( $\tau$ )
- In the LJSS, small pits (<20 micron diameter) formed in the first three weeks of exposure independent of CO<sub>x</sub>
- CO<sub>x</sub> stifles pitting, leading to more general corrosion.

# Acknowledgements

- Dr. Robert Piascik (NASA Langley)
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- Dick Kinzie (AFCPO)