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Impact of Atmospherically Deposited Salts on the Localized Corrosion Performance of Materials Used for the Interim Storage of Used Nuclear Fuel

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Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Is Crevice Corrosion of Interim Storage Components a Legitimate Concern?

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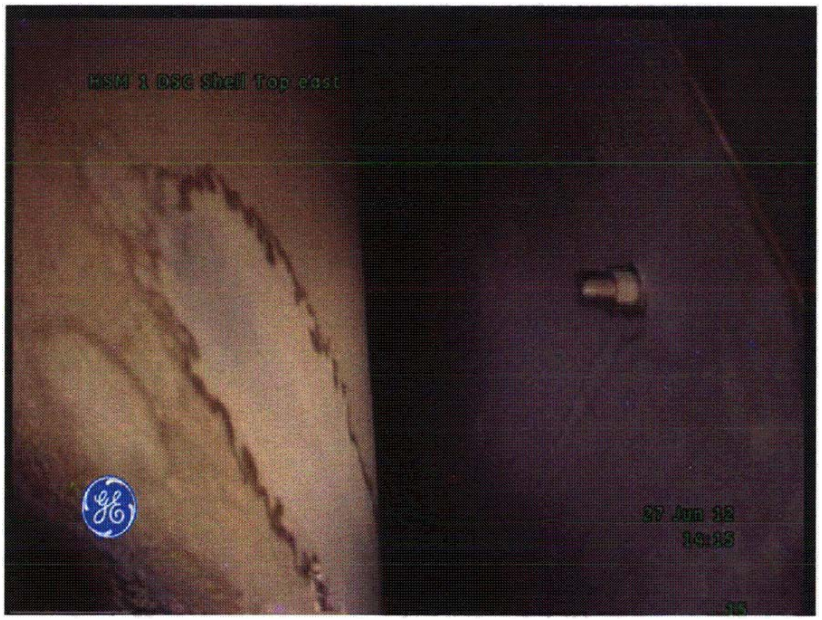
- Requirements for crevice corrosion
- Driven vs. atmospheric
- Implications of a thin electrolyte layer
- Available active surface area outside of a potential crevice limits the ability for crevice corrosion to initiate and/or propagate.

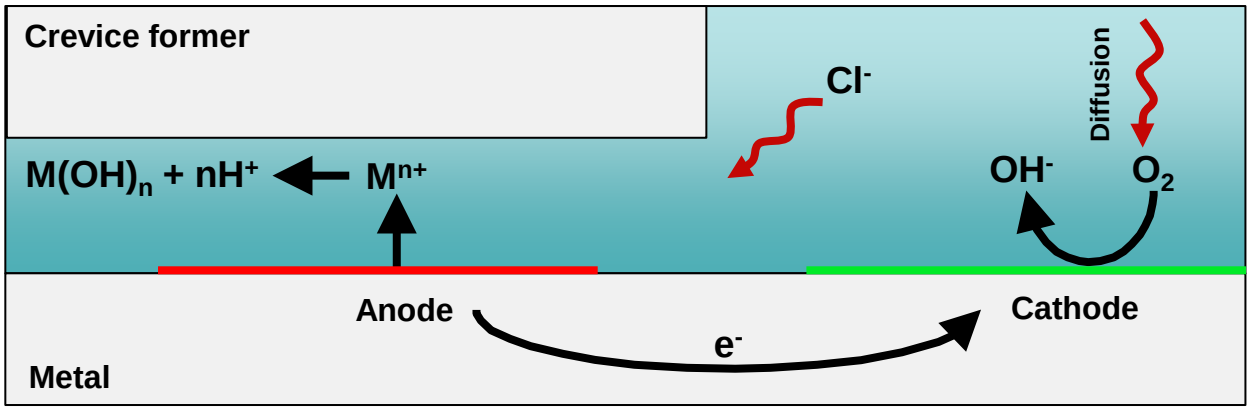
Quantifying the Composition and Quantity of Surface deposits

- Calvert Cliffs inspection
  - SaltSmart device used to acquire surface chloride levels
  - Single measurement made at the 0900 location
  - 543 mg/m^2 (54.3 µg/cm^2) for container which was in service for 19 years
  - Significant particulate visible on the surface of the container



Images from July 27, 2012 supplemental information letter submitted from CENG to the NRC (Adams document no. ML12212A216)

Is Localized Corrosion Possible Under Atmospheric Conditions?

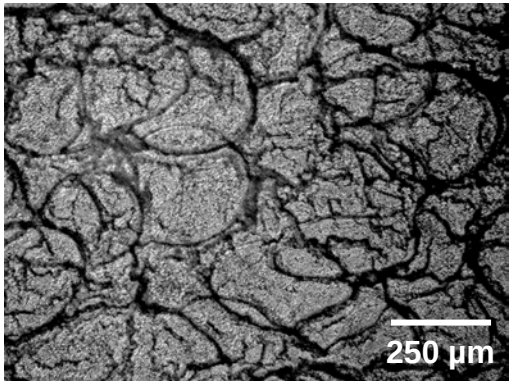


Metal ion content builds and oxygen is depleted within crevice, resulting in local acidification and separation of anode and cathode
Driven conditions – cathode not on sample surface

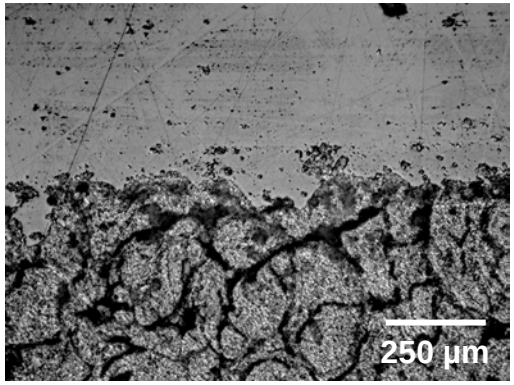
- Available active surface area outside of a potential crevice limits the ability for crevice corrosion to initiate and/or propagate.
  - Relocation of cathode inside crevice does not allow maintenance of the critical crevice solution
    - Turnbull (NPL), Kelly et al. (UVA)
  - Limitation of cathodic capacity outside of the crevice
    - Payer, et al. (CWRU), Kelly et al. (UVA)

Experiments in Chloride-Rich Brines

- PTFE coated ceramic crevice former torqued to 70 in-lbs, Mirror finish on coupon surface
- Salt loadings of 50, 100, and 200 µg/cm^2 (dry) of a NaCl-KCl mixture (~1 µm thick)
- T=105°C, T_d=~94.5°C (pure steam) for 7, 14, 25, 50, or 100 days



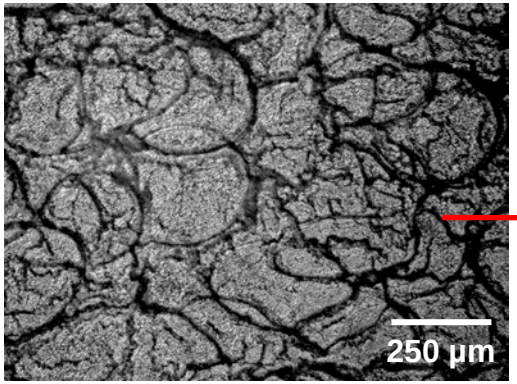
120 µg/cm^2



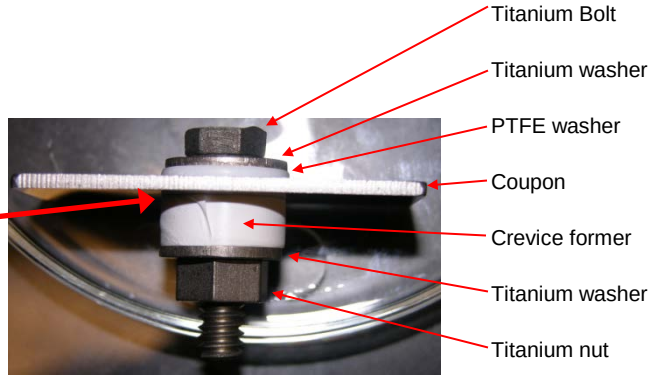
Wiped region

Dust Deliquescence Testing: Initiation Studies

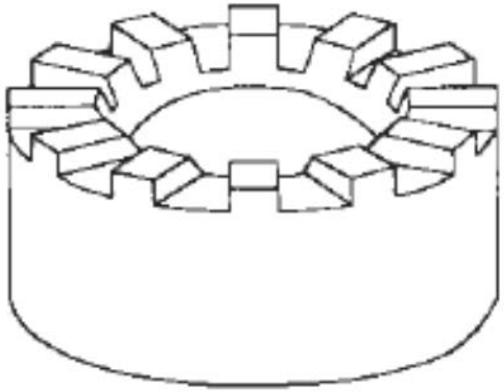
- Crevice former and salt on one side of coupon which was polished to a mirror finish

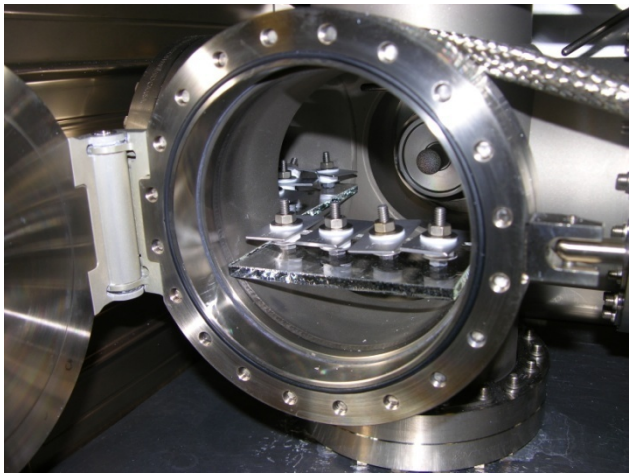


120 µg/cm²



(All titanium hardware electrically isolated from the sample)





Significant Attack observed on 303SS – effectively all crevice regions initiated and underwent extensive propagation

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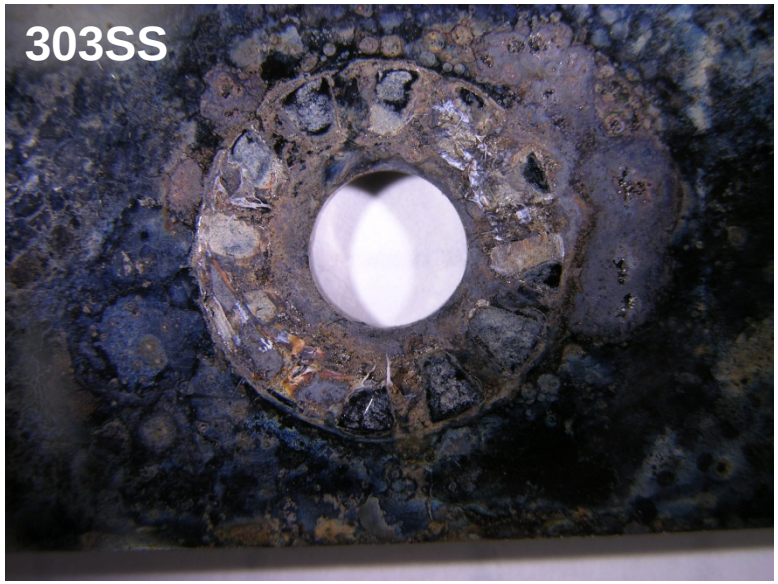
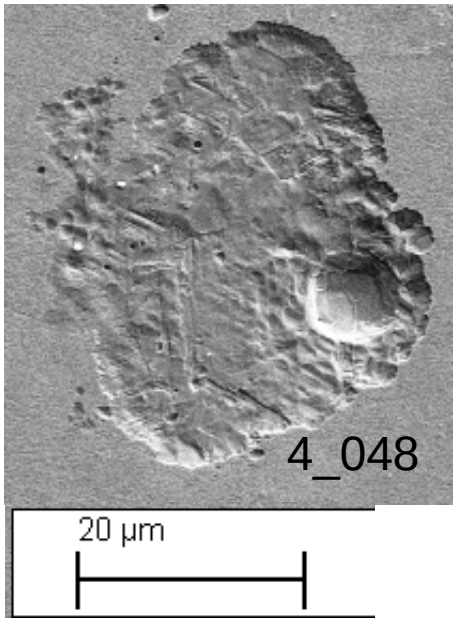
To alleviate concern that technique was not capable of supporting crevice corrosion even on highly susceptible materials, 303SS was introduced into the test matrix

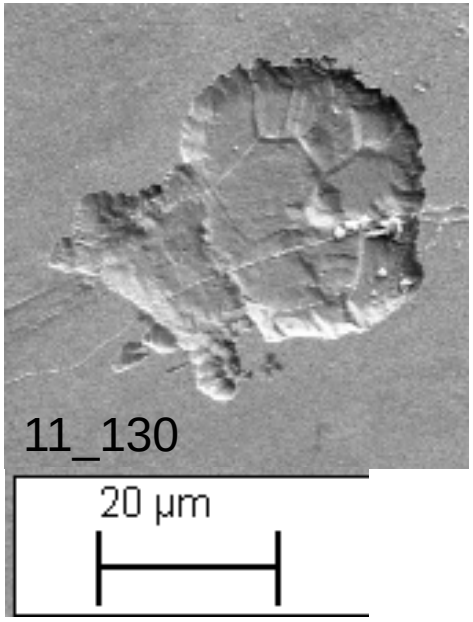


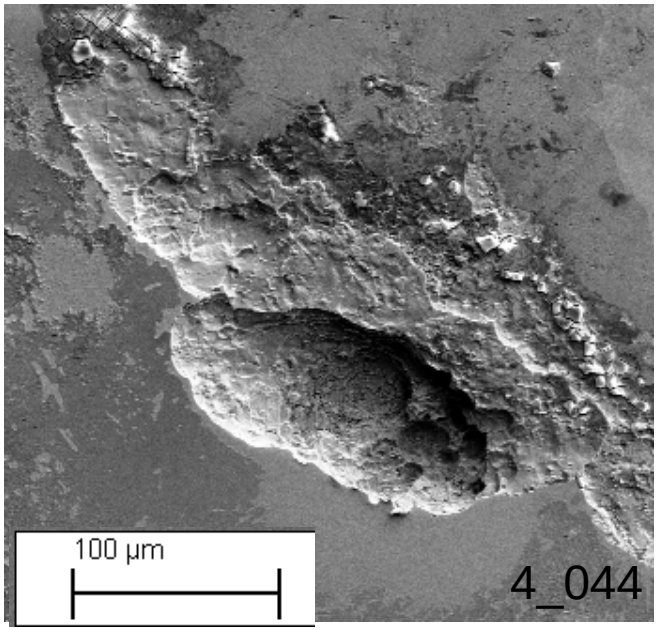
Evaluation of the impact of salt loading was pursued for 304SS (difficult to interpret 303SS results as material was too active) to explore stifling argument

What to do with all that data?

- Data analysis has been difficult
  - Optical – complicated by corrosion product/staining
  - SEM – site identification more straightforward, but time consuming – no depth information
  - Confocal microscopy – best for characterizing sites, but there are a lot of sites…

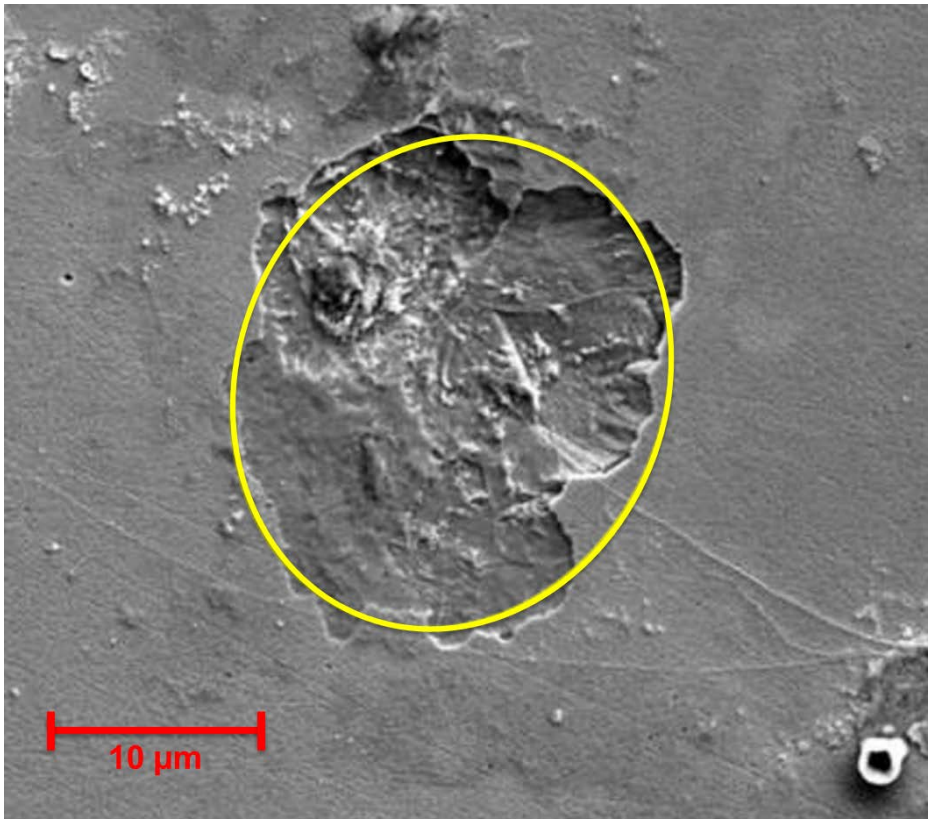




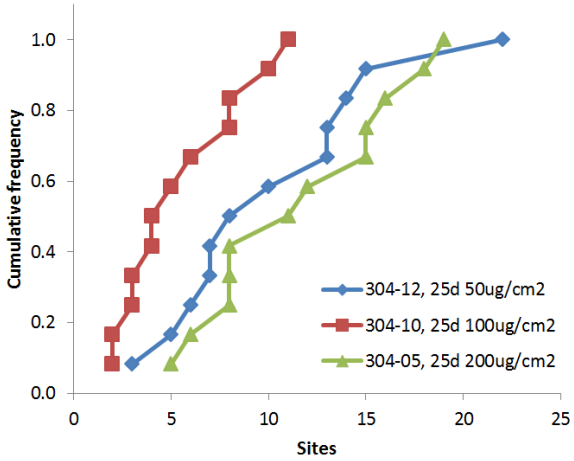


Data Analysis Approach

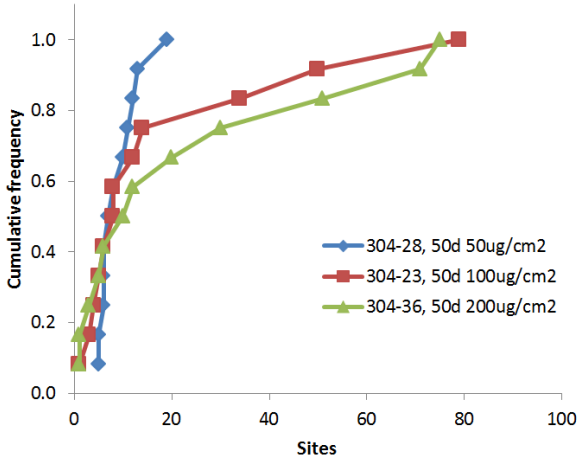
- Identify all corrosion sites, characterizing them as pitting, crevice corrosion, etc.
- Approximate the two dimensional area of each site
- Evaluate trends
  - Mass Loading
  - Time



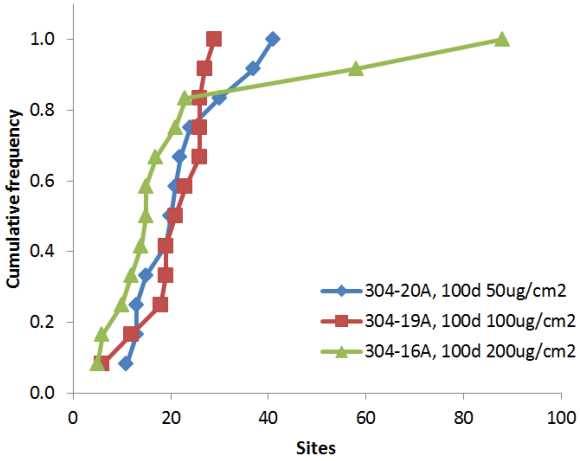
Number density of sites



25d samples no very shallow uniform



50d samples no very shallow uniform

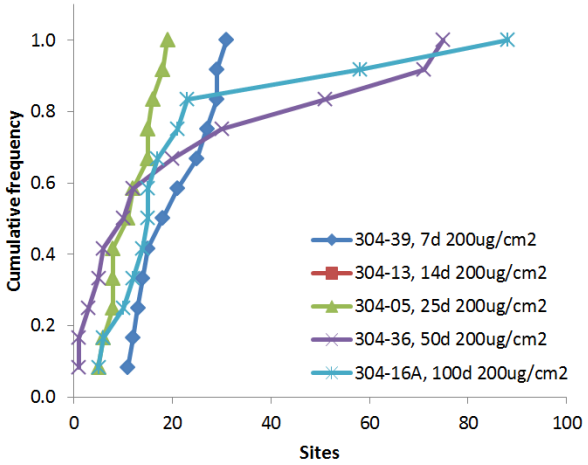


100d samples no very shallow uniform

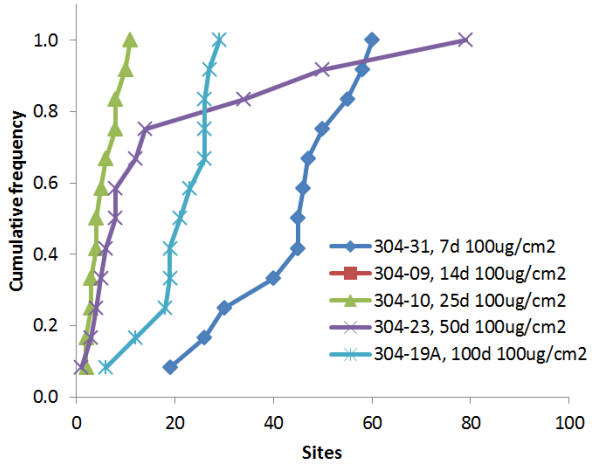
With time, see some regions with very high number of sites for large mass loadings

Each data point corresponds to a single crevice tooth on a single sample

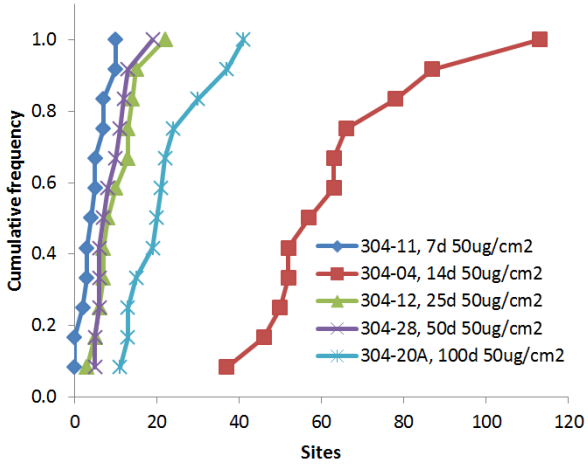
Number density of sites



200ug samples no very shallow uniform



100ug samples no very shallow uniform

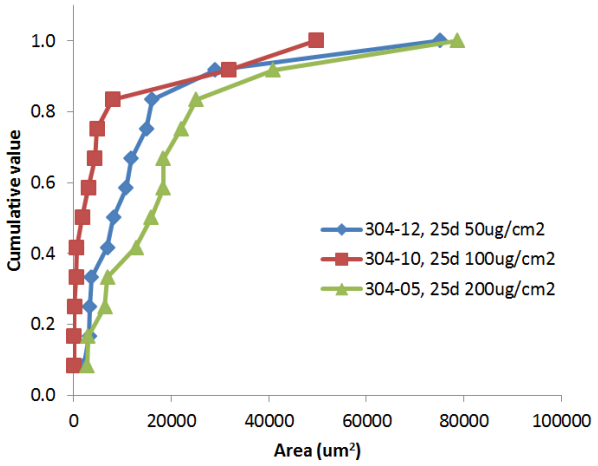


50ug samples no very shallow uniform

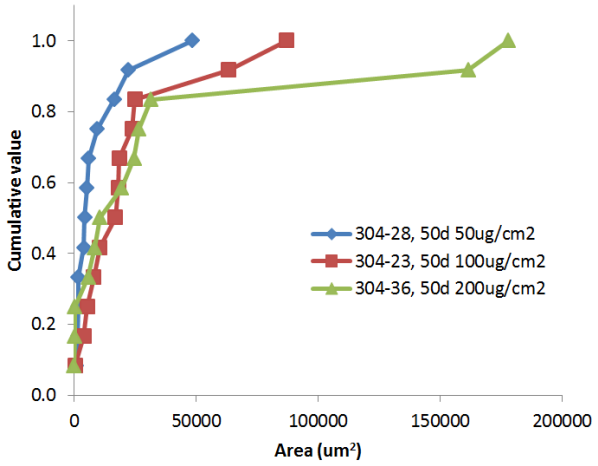
Number of sites does not seem to correlate well with exposure time for a fixed mass loading

Each data point corresponds to a single crevice tooth on a single sample

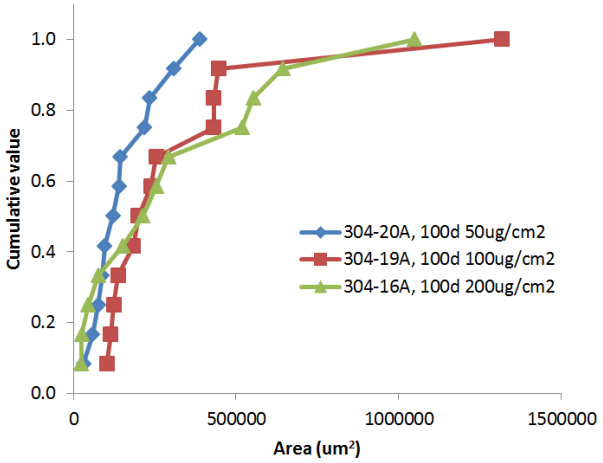
Surface area of sites



25 day samples no very shallow uniform



50 day samples no very shallow uniform.

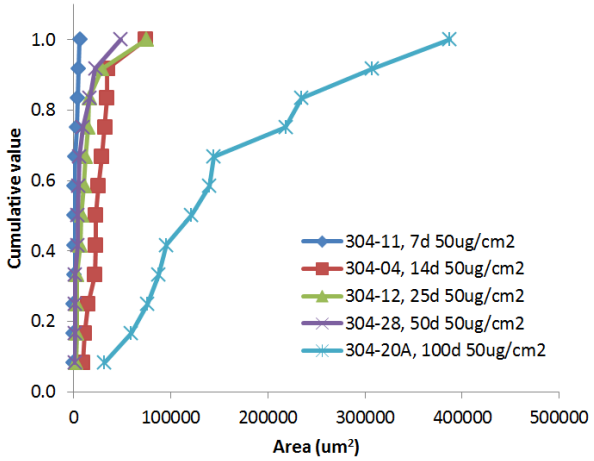


100 day samples no very shallow uniform.

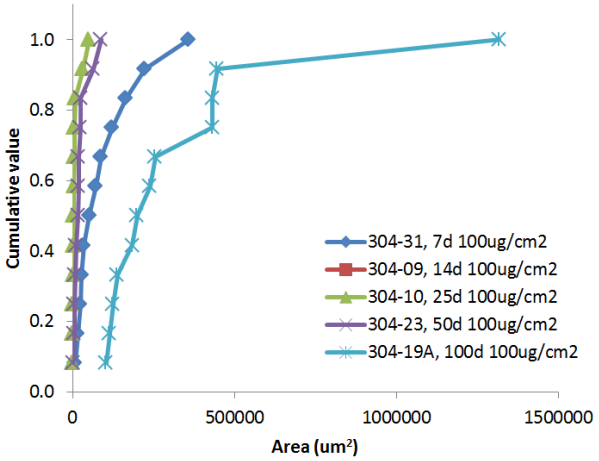
2-D surface area of sites increases with mass loading at a given time

Each data point corresponds to a single crevice tooth on a single sample

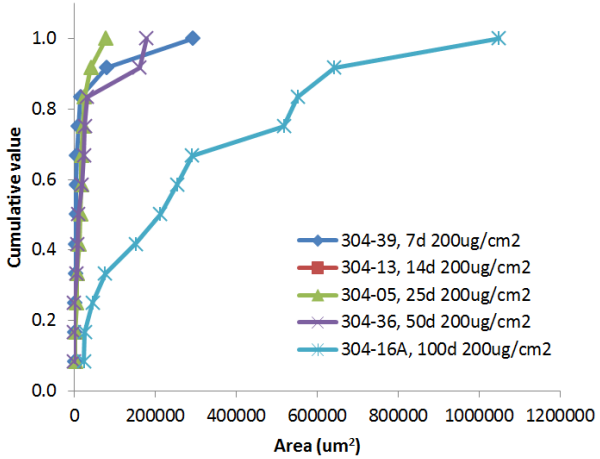
Surface area of sites



50ug samples no very shallow uniform



100ug samples no very shallow uniform



200ug samples no very shallow uniform

For all mass loadings, area of sites continues to grow out to 100 days – has not plateaued

Each data point corresponds to a single crevice tooth on a single sample

Did we observe crevice corrosion stifling?

- Number density of sites suggests that there is continuous nucleation
  - Number of sites per tooth increases with time for all of the mass loadings, but there are exceptions
  - What we are counting is a factor
- Surface area is more indicative of the extent of attack
  - Extent of attack increases with time at a given mass loading
  - Significant increase in area from 50 to 100 days
- The data has limitations…
  - Different samples for each time interval
  - Need more data…

Summary/Conclusions

- Containers for both interim storage and long term disposal will be under environmental conditions where salt particulates will be deposited that are capable of forming a brine at elevated temperature and humidity.
- Information from the literature suggests that localized corrosion under conditions where limited reactant is present should be difficult due to limitations in the cathodic capacity
- Crevice corrosion initiation was observed on both 303 and 304SS under moderate temperature, chloride rich brines
- The extent of attack was characterized for 304SS and was found to correlate with the quantity of salt deposited on the metal surface prior to the experiment.

Acknowledgements

At Sandia National Labs

- Sam Lucero – Salt deposition and experimental setup
- Alice Kilgo – Surface preparation
- Kirsten Norman – Assistance with data analysis
- Bonnie McKenzie – Electron microscopy

NWTRB

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