Laser Ablation and Induction Coating Removal Webinar

AASHTO
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Zoom Meeting Platform User Information

AASHTO
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- Participants are currently muted.
- A Question and Answer Session will follow presentations.
- Use Zoom Q & A button to ask questions at any time during the presentations.
- The webinar is being recorded and will be shared on the AII website at aii.transportation.org.

Agenda

1. Overview of AII Program
2. Speaker Introductions
3. Overview of LACR + ICR Process
4. Adhesion Investigation
5. Environmental and IH Assessment
6. Evaluation of Steel
7. Question and Answer Session with Panel

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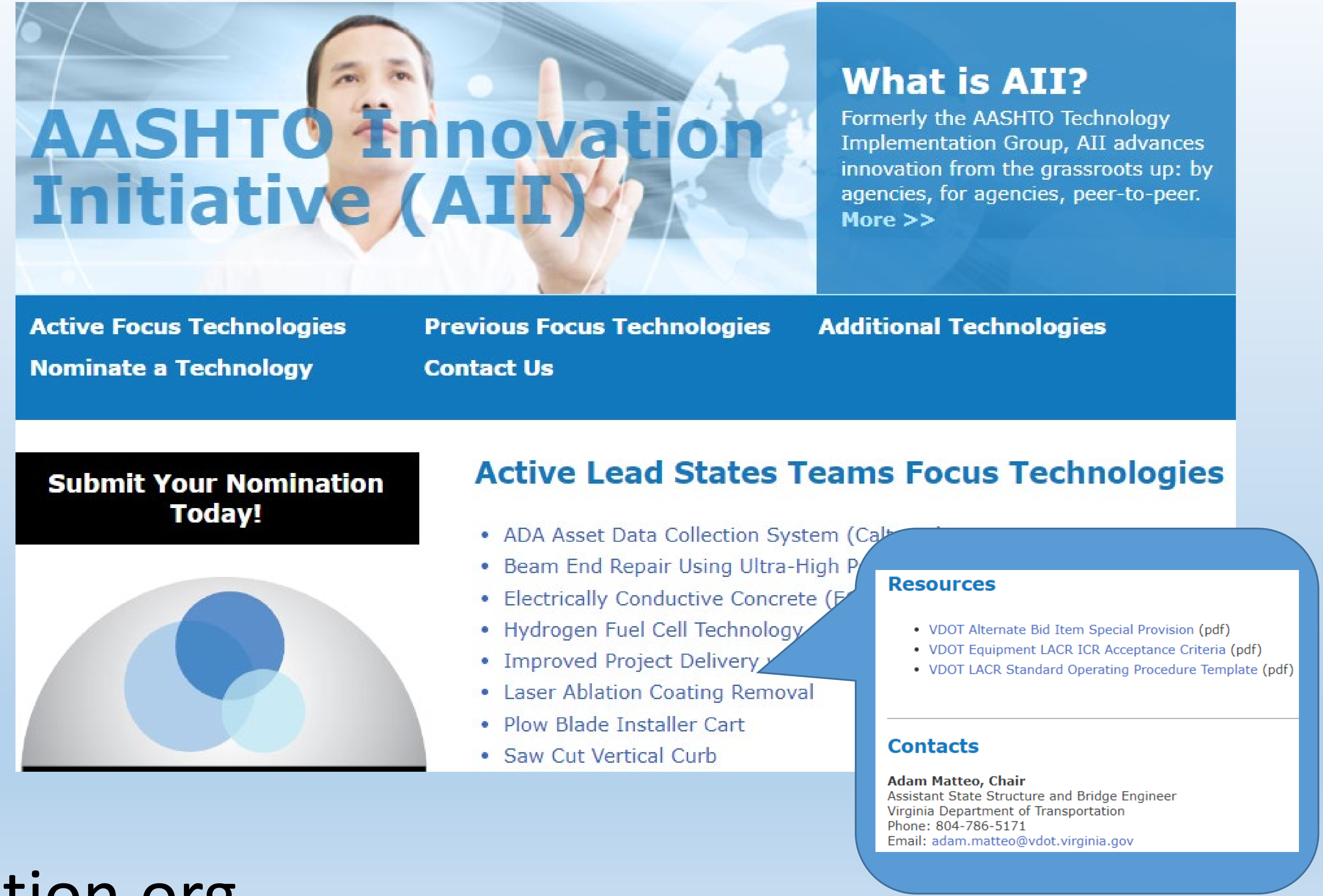
- Established in 1999 and operating since 2000
- Facilitate the implementation of **high-payoff**, **ready-to-use**, **innovative technologies**
- **100+ innovations**



aii.transportation.org

Expert Panel

Stephen Sharp
Laser Ablation and Induction Coating Removal Facilitator

VDOT
Virginia Department of Transportation

University of Virginia
Engineering

Jim Fitz-Gerald

William Moffatt

Raquel Rickard

Jason Provines

Participant Poll #1

LASER ABLATION AND INDUCTION COATING REMOVAL

Stephen R. Sharp, Ph.D., P.E.

August 21st, 2023

Outline

Important Abbreviations

- Induction Coating Removal = ICR
- Laser Ablation Coating Removal = LACR

Outline

- ICR + LACR Project Team
- Conventional Approach
- Motivation for Investigating New Coating Removal Methods
- Questions to Consider
- What is LACR?
- The Integrated 3-Stage Air Emission Control System

Outline, continued

- What is ICR?
- Overview of LACR Evaluation by VDOT/VTRC/UVA
- Overview of ICR plus LACR Evaluation by VDOT/VTRC/UVA
- Resources

My colleagues will provide insight into the adhesion investigation, environmental and IH assessment, and finally the mechanical property evaluation of steel.

ICR + LACR Project Team

Adam Matteo, P.E., VDOT Structure and Bridge Division

Bryan Silvis, P.E., VDOT Structure and Bridge Division

Jeff Milton, VDOT Structure and Bridge Division

C. Wayne Fleming, VDOT Materials Division

David Wilson, VDOT Environmental Division

Raquel Rickard, CIH, VDOT Environmental Division

Dr. Jim Fitz-Gerald, Department of Materials Science and Engineering, University of Virginia

Dr. Sean Agnew, Department of Materials Science and Engineering, University of Virginia

William Moffat, Department of Materials Science and Engineering, University of Virginia

James Gillespie, Virginia Transportation Research Council

Jason Provines , P.E., Virginia Transportation Research Council

Stephen Sharp, Ph.D., P.E., Virginia Transportation Research Council

VDOT Districts, Contractors, Consultants, and Suppliers

Conventional Approach

- Traditionally, abrasive grit blasting used to remove coatings
- Large volume of waste generated
- Abrasive Blasting Fills the Air with Pellets that Contain Lead or Zinc

Conventional Approach, cont.

To do properly, requires containment, extensive PPE, and proper waste disposal

Containment

PPE

Waste Disposal

Motivation for Investigating New Coating Removal Methods

This approach makes sense for large scale bridge recoating work.

Can DOT's simplify containment and PPE, while reducing waste, so they can do smaller repairs, maybe more frequently?

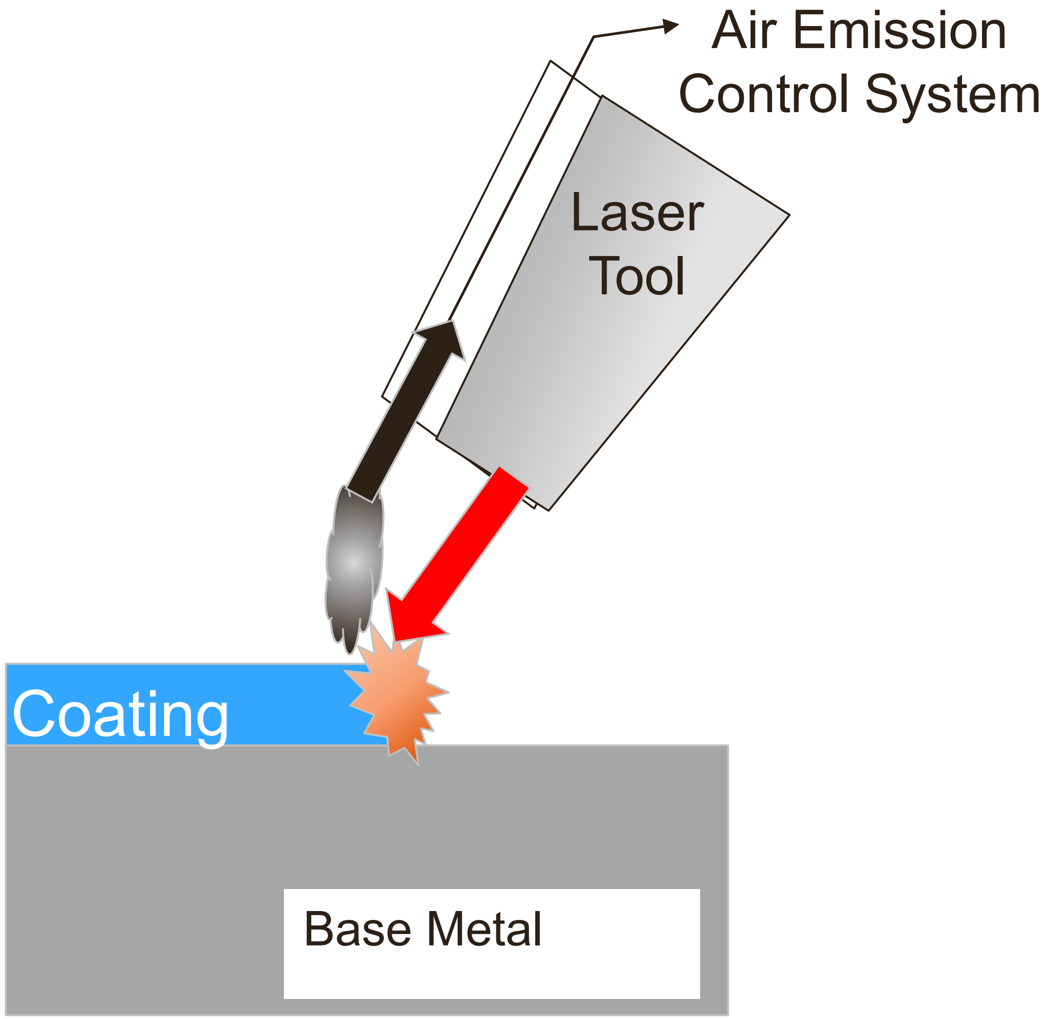
Questions to Consider

- What if we could remove coatings without using costly containments?
  - What would we use?
  - Could we keep workers safe?
  - Could we protect the public and the environment?
  - Can we reduce the amount of waste generated?
- What condition will the steel be in when we are done?
- If successful, how will we go about performing coating removal on local areas?
  - Will this work be done by contractors, or will it be done in-house?

What is LACR

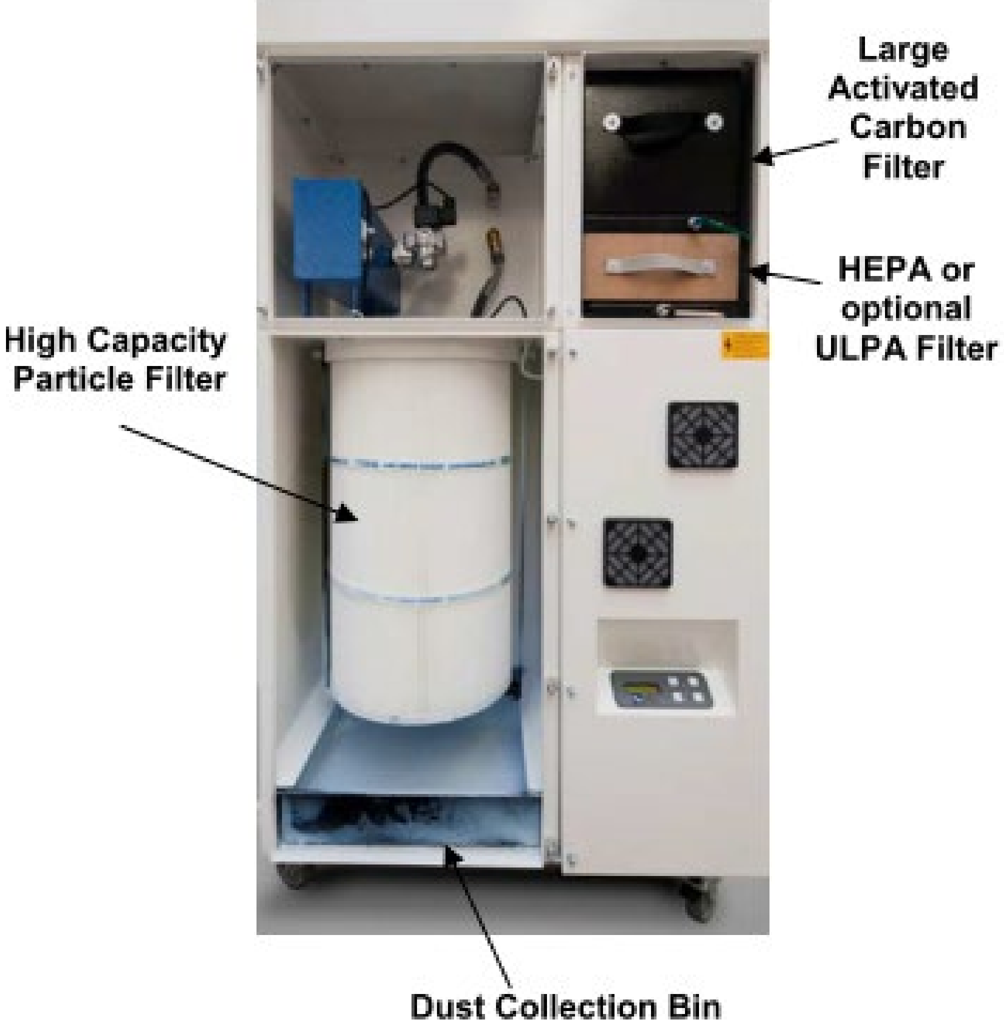
Laser Ablation Coating Removal (LACR)

- In the past, evaluated both continuous and pulsed.
- Focusing on pulsed laser
- Coating absorbs most of the pulsed laser energy and converts into vapor (particles) from thermal energy.
- Integrated 3-stage air emission control system

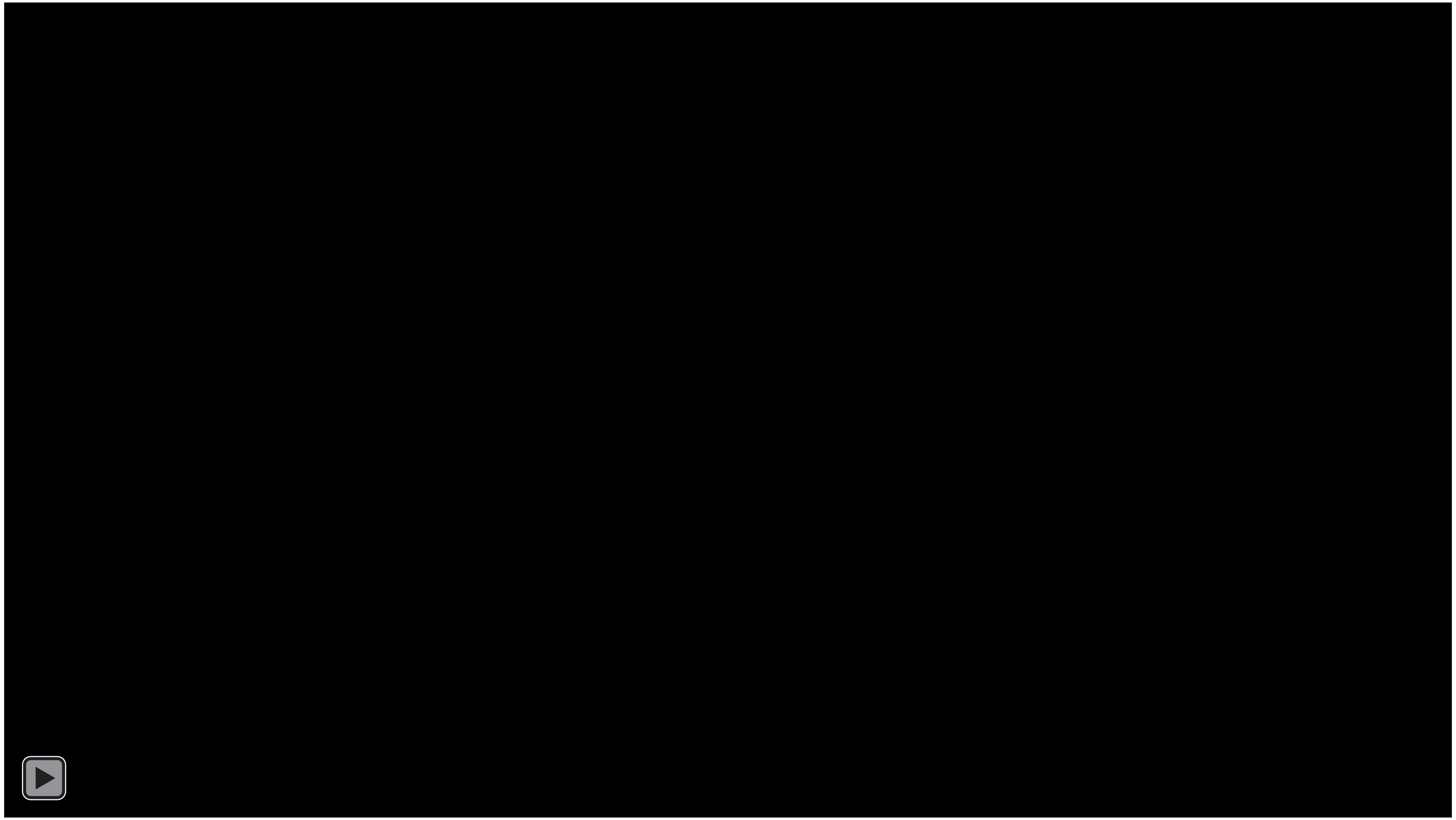


What is an Air Emission Control System

Air emission control system comprised of three filters sealed in a control cabinet



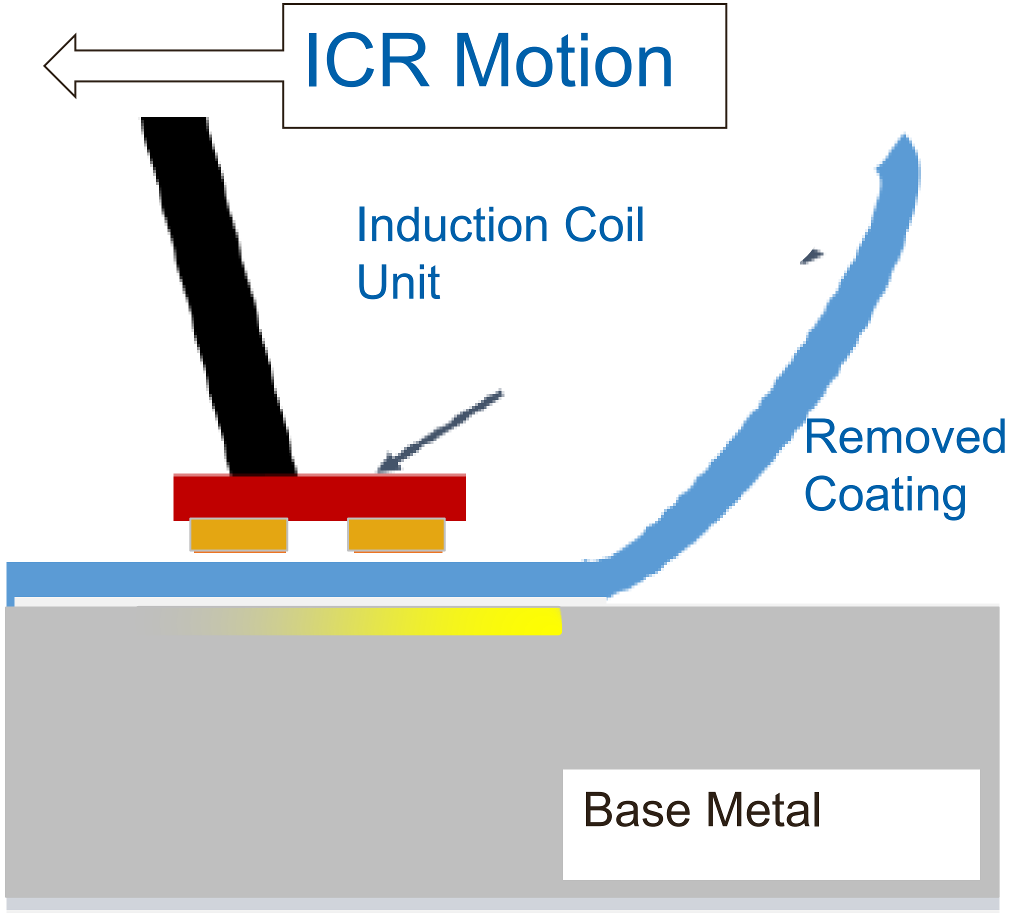
LACR with Air Emission Control System in Action



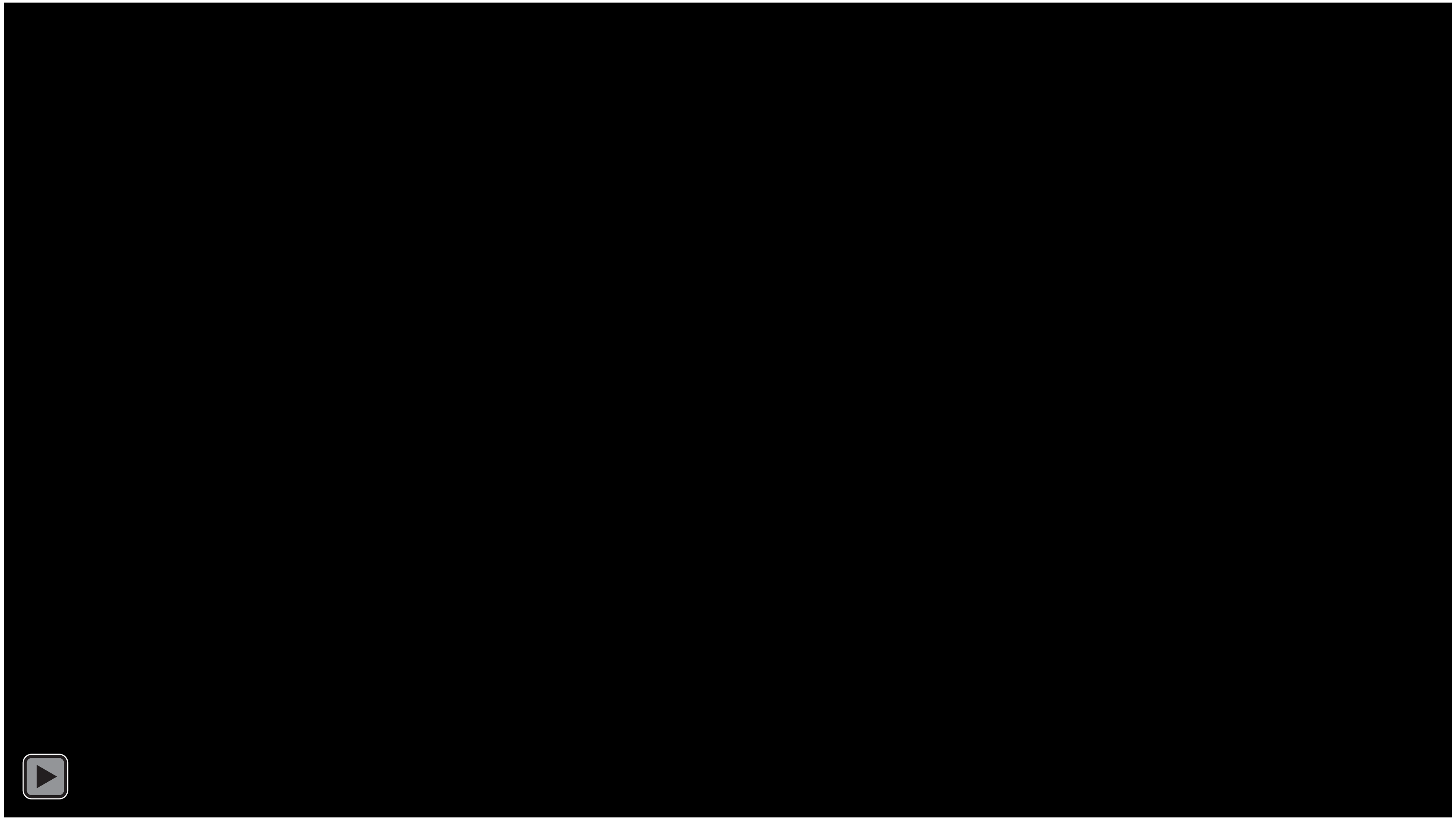
What is ICR

Induction Coating Removal (ICR)

- Initial work was with LACR, but needed to improve removal rate.
- ICR debonds coating, so not sensitive to thickness like LACR
- Localized heating at coating/steel interface disrupts bond
- Integrated 3-stage air emission control system was not used with ICR, but could be adapted if needed

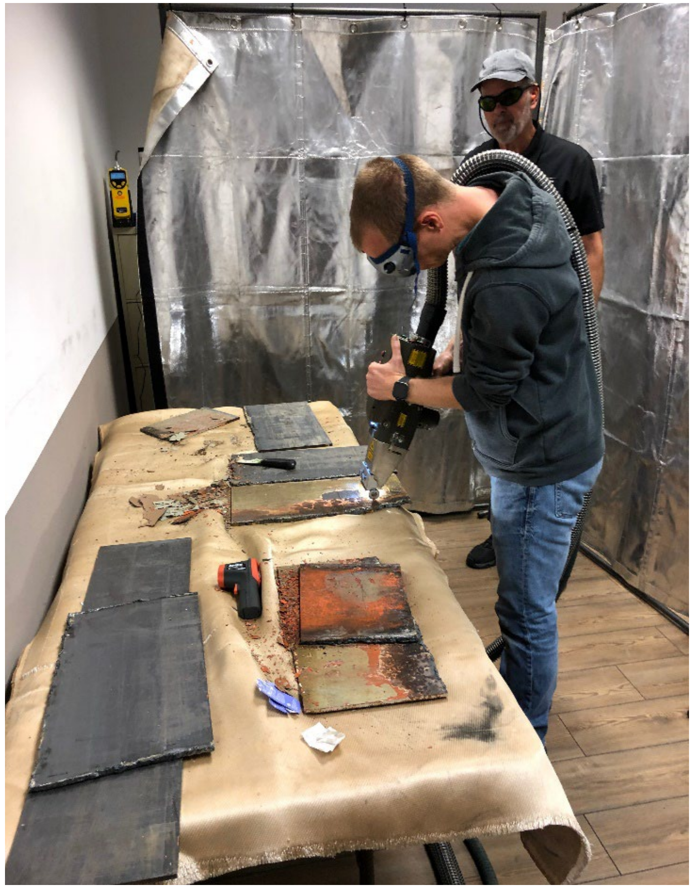


ICR in Action



Overview of LACR Evaluation by VDOT/VTRC

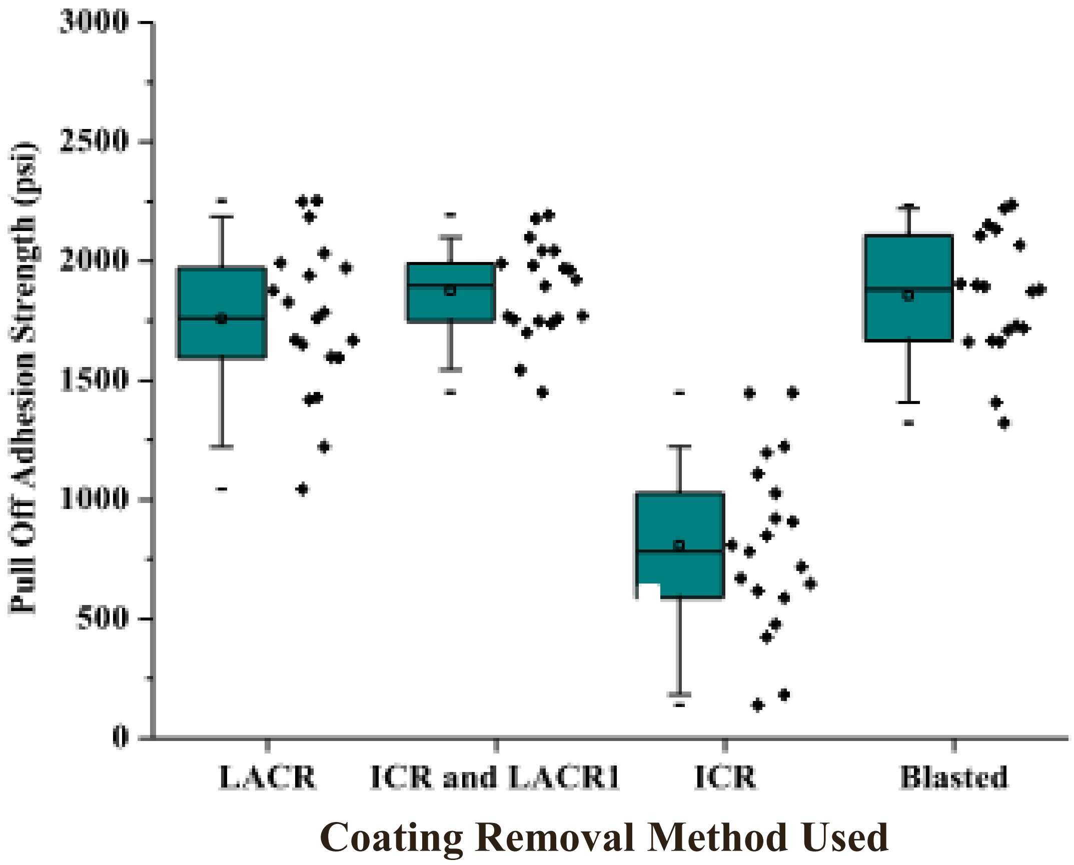
- Initial work done at Norton Sandblasting and Farmville Bridge Site
- In August 2019, VTRC released a final report
  - Innovative Coating Removal Techniques for Coated Bridge Steel, which used a pulse LACR device
- Lessons Learned
  - LACR reduced waste/exposure and provided a relatively clean surface
    - Possible use is hot work
  - LACR was slow, therefore the VTRC report highlights the need to pursue induction coating removal



Overview of ICR plus LACR Evaluation by VDOT/VTRC

- Lessons Learned
  - Combining the two techniques increased speed
  - ICR plus LACR gave favorable adhesion test results
- Next step
  - Publish as part of a university thesis and VTRC report
  - Move to the field again to establish if ICR plus LACR is ready for selective cleaning of steel bridge beams

Organic Zinc Primer on Steel Plate



Resources

VDOT/VTRC

- VDOT Alternate Bid Item Special Provision
- VDOT Equipment LACR ICR Acceptance Criteria
- VDOT LACR Standard Operating Procedure Template
- VTRC Report: Innovative Coating Removal Techniques for Coated Bridge Steel
- TRB Paper: Evaluation of a Continuous Laser Ablation Coating Removal Device for Steel Bridges.

University of Virginia

- Implementation of Laser Ablation Coating Removal Technique for Steel Components on VDOT Bridges
- The Effects of Laser Ablation Coating Removal on the Fatigue Performance of a High Strength Structural Steel

Participant Poll #2

LASER ABLATION AND INDUCTION COATING REMOVAL:

Surface Processing and Adhesion

William Moffat and Prof. James Fitz-Gerald

University of Virginia Department of Material Science and Engineering

August 21, 2023

Outline

- **Testing Regimes: Grit Blasting, ICR, LACR**
- **Surface Chemistry**
- **Recoating**
- **Adhesion Results**
- **Surface Roughness**
- **Adhesion Analysis**

  OZ Grit Blasted Surfaces

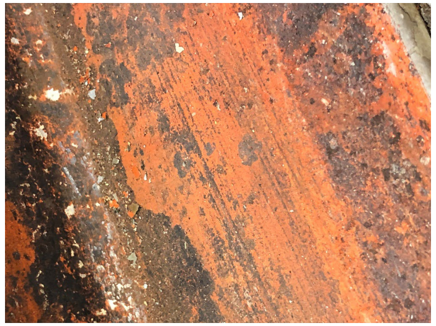
  OZ ICR + LACR Surfaces

Testing Regimes

Base Metal

ICR

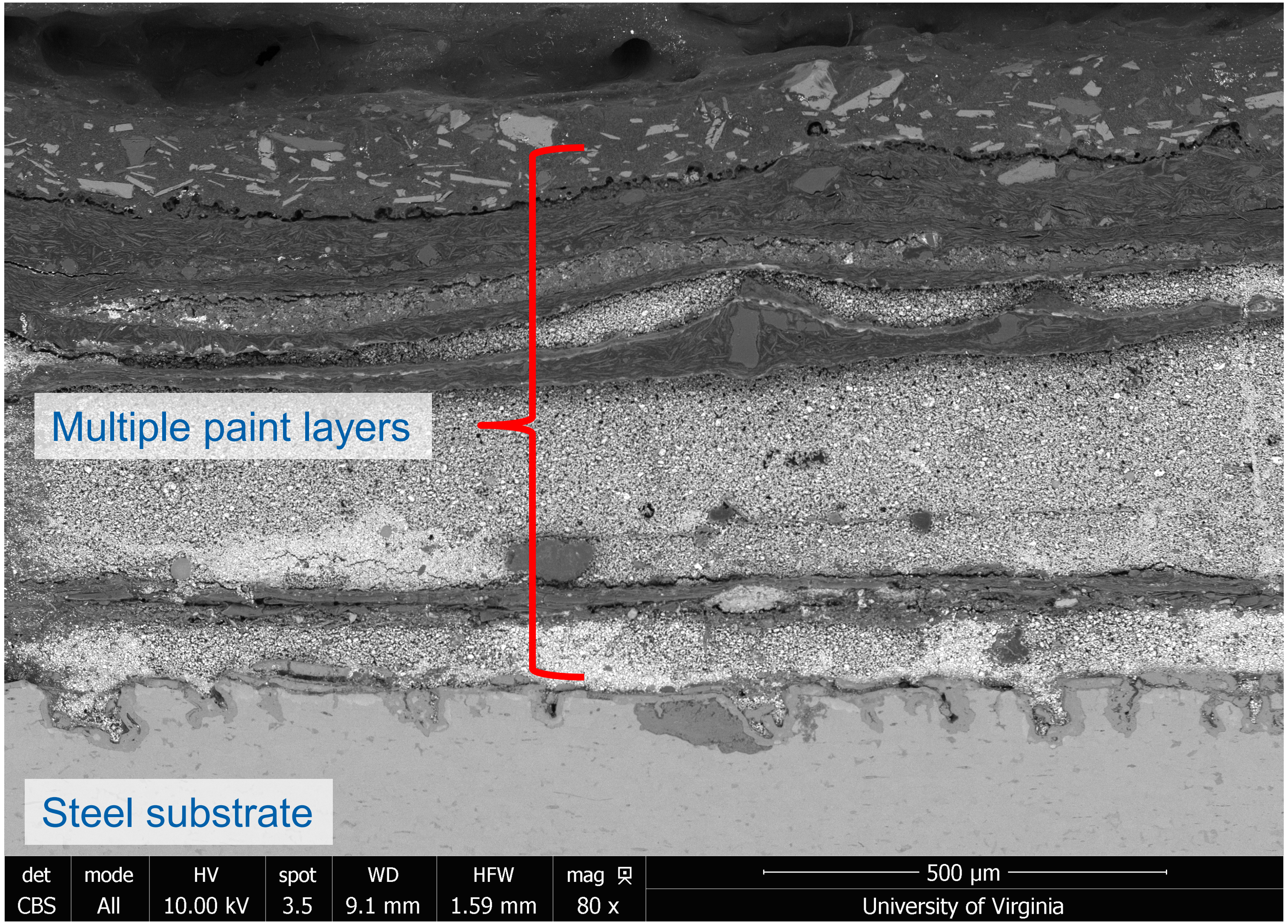
LACR



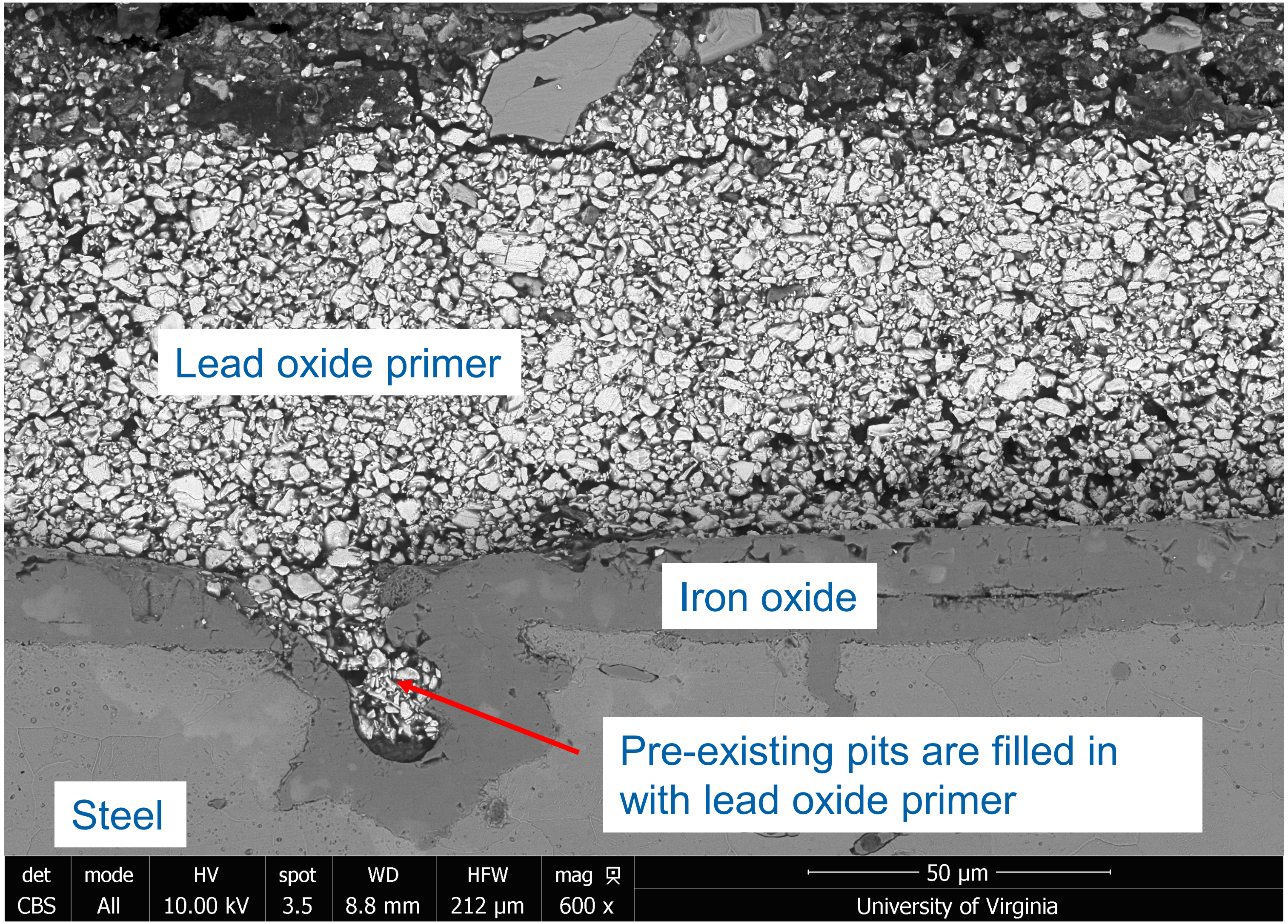
ICR Surface

ICR + LACR Surface

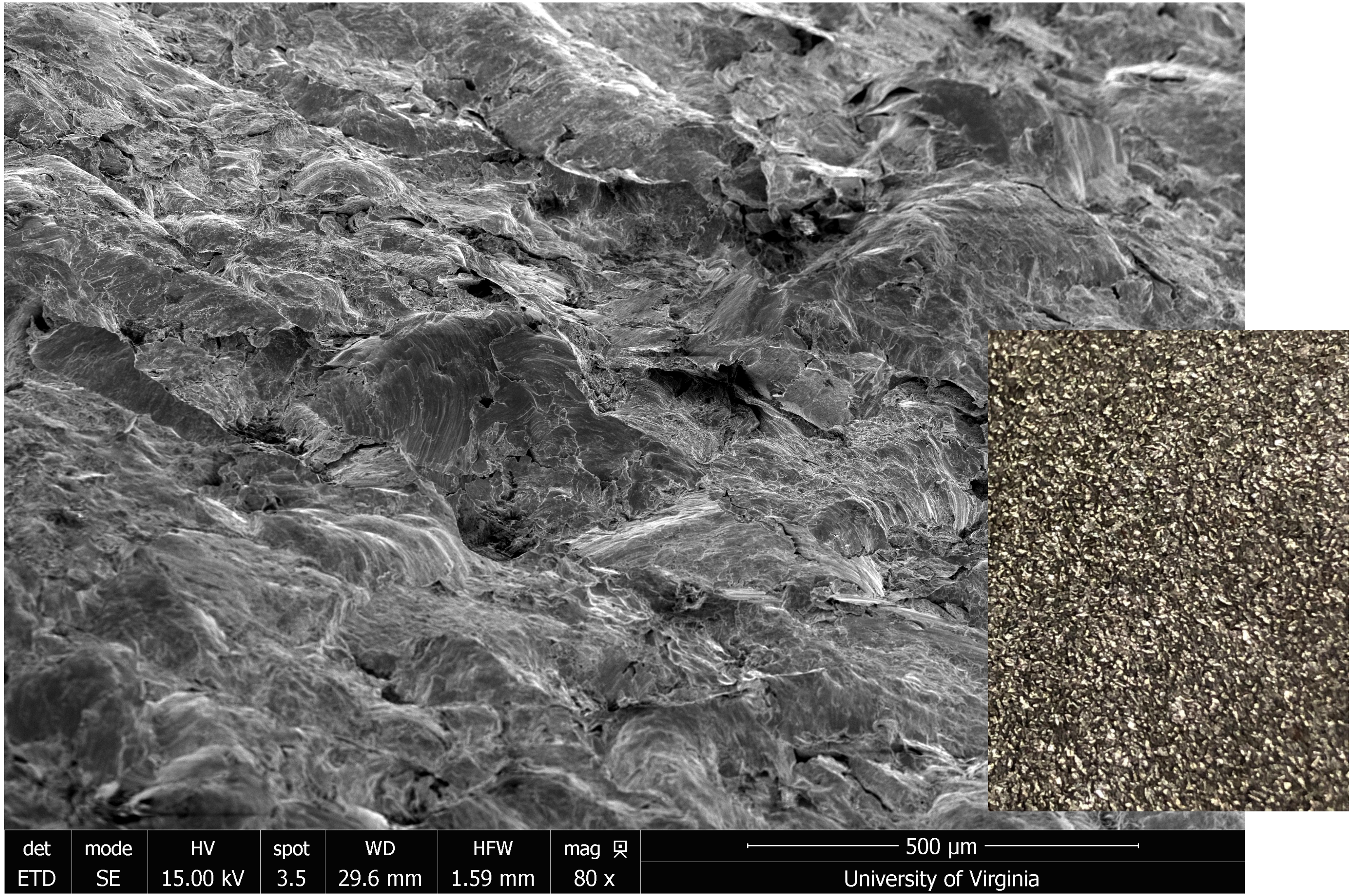
Base Metal Cross Section



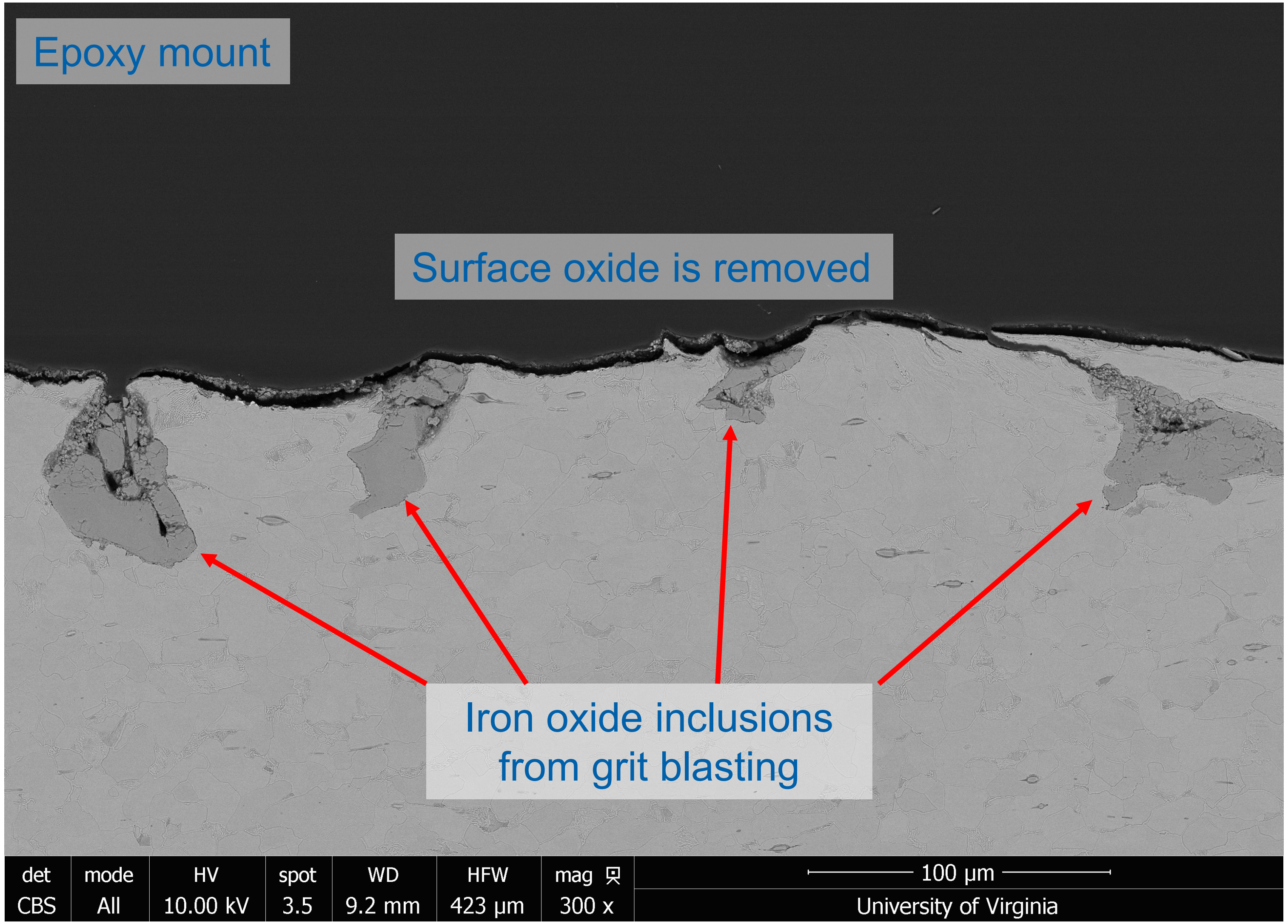
Base Metal Cross Section



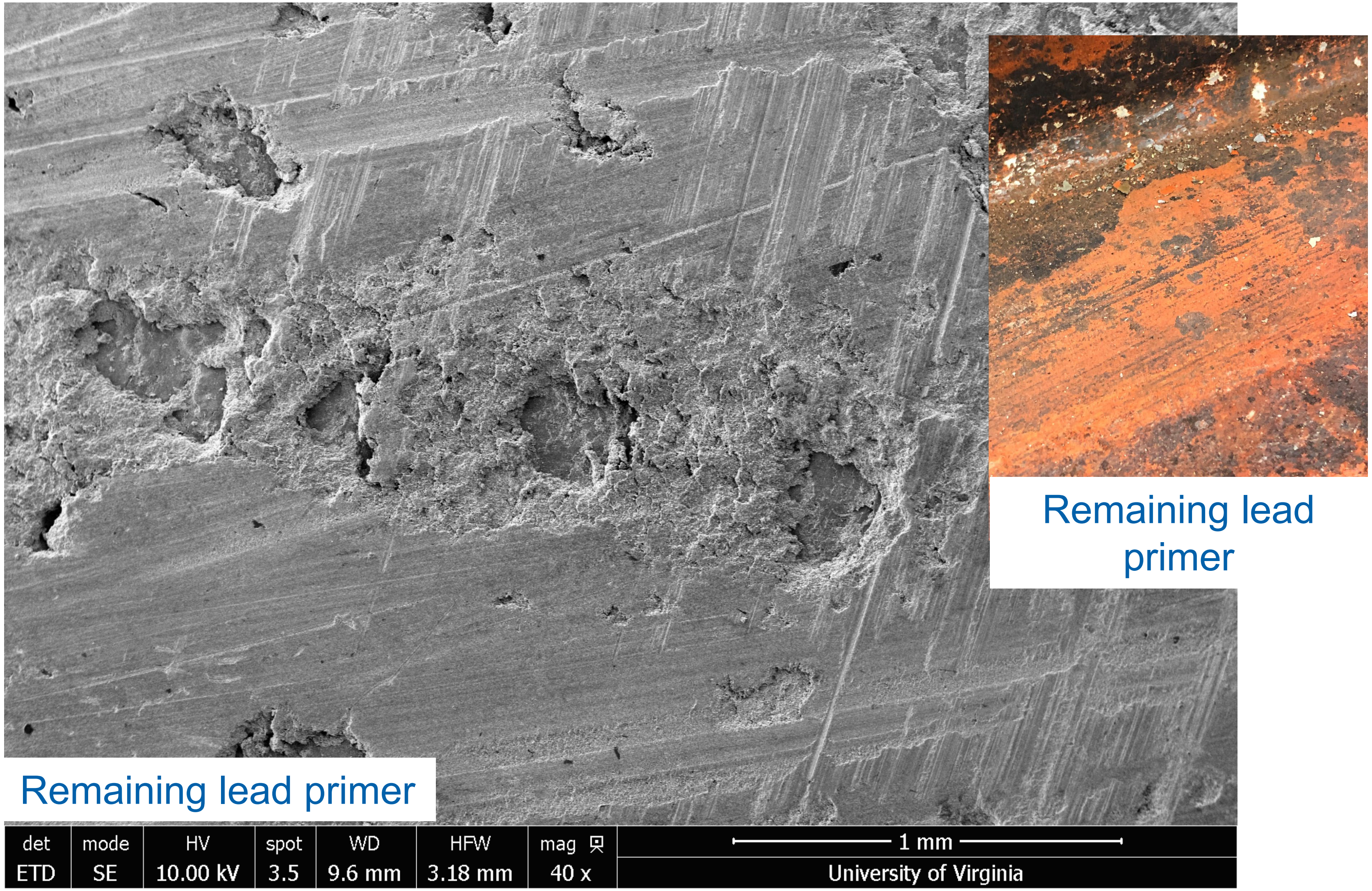
Grit Blasted Surface



Grit Blasted Cross Section

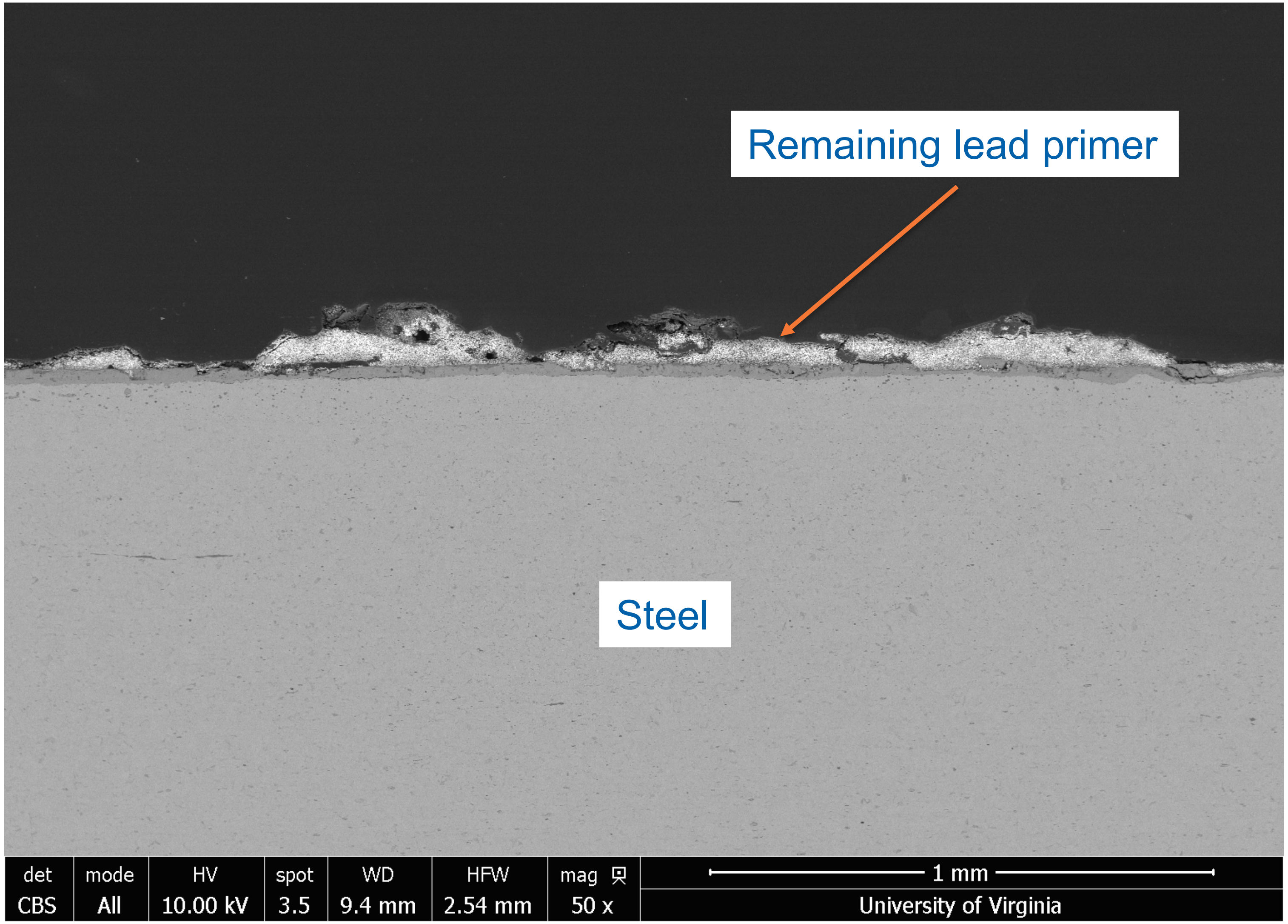


ICR Surface

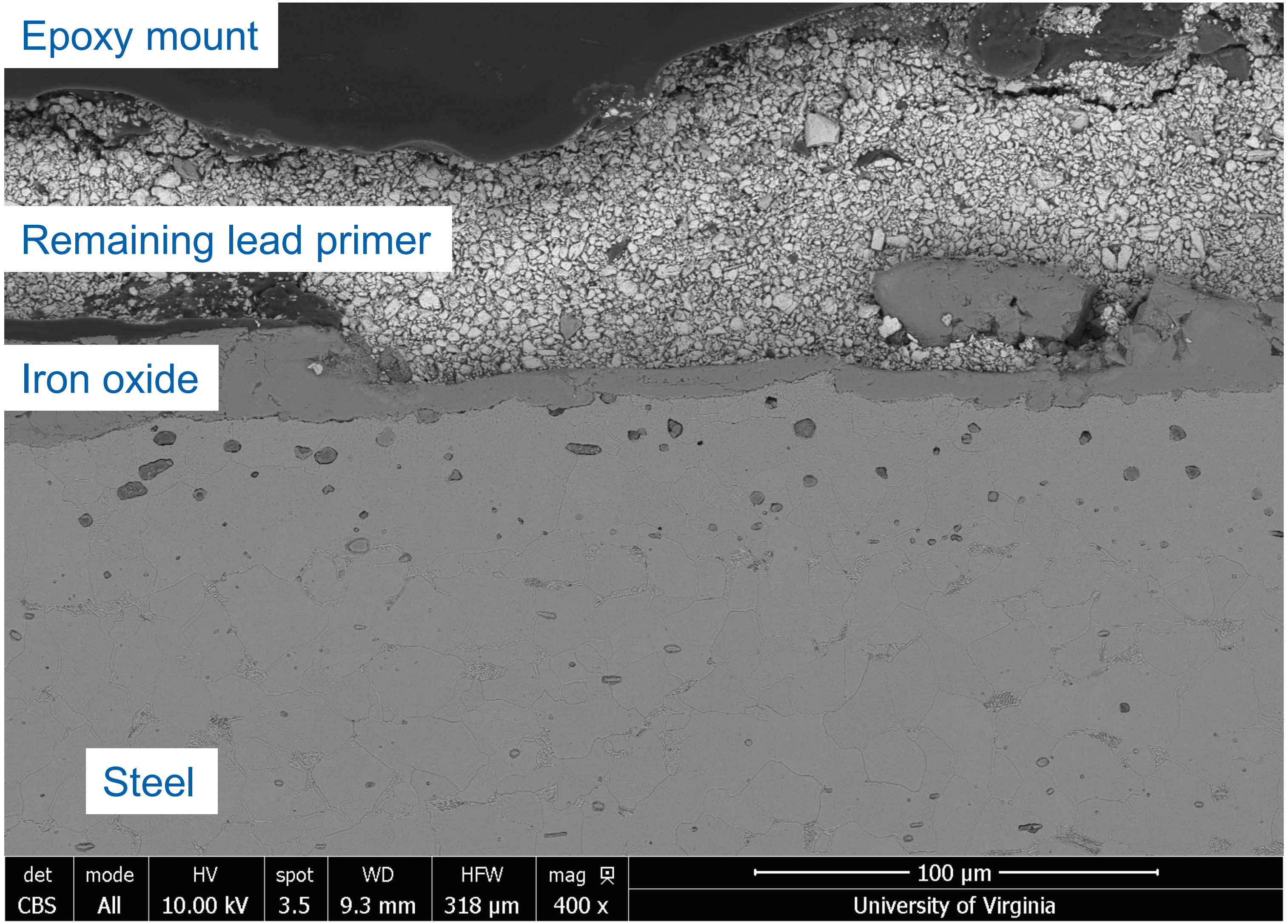


Remaining lead primer

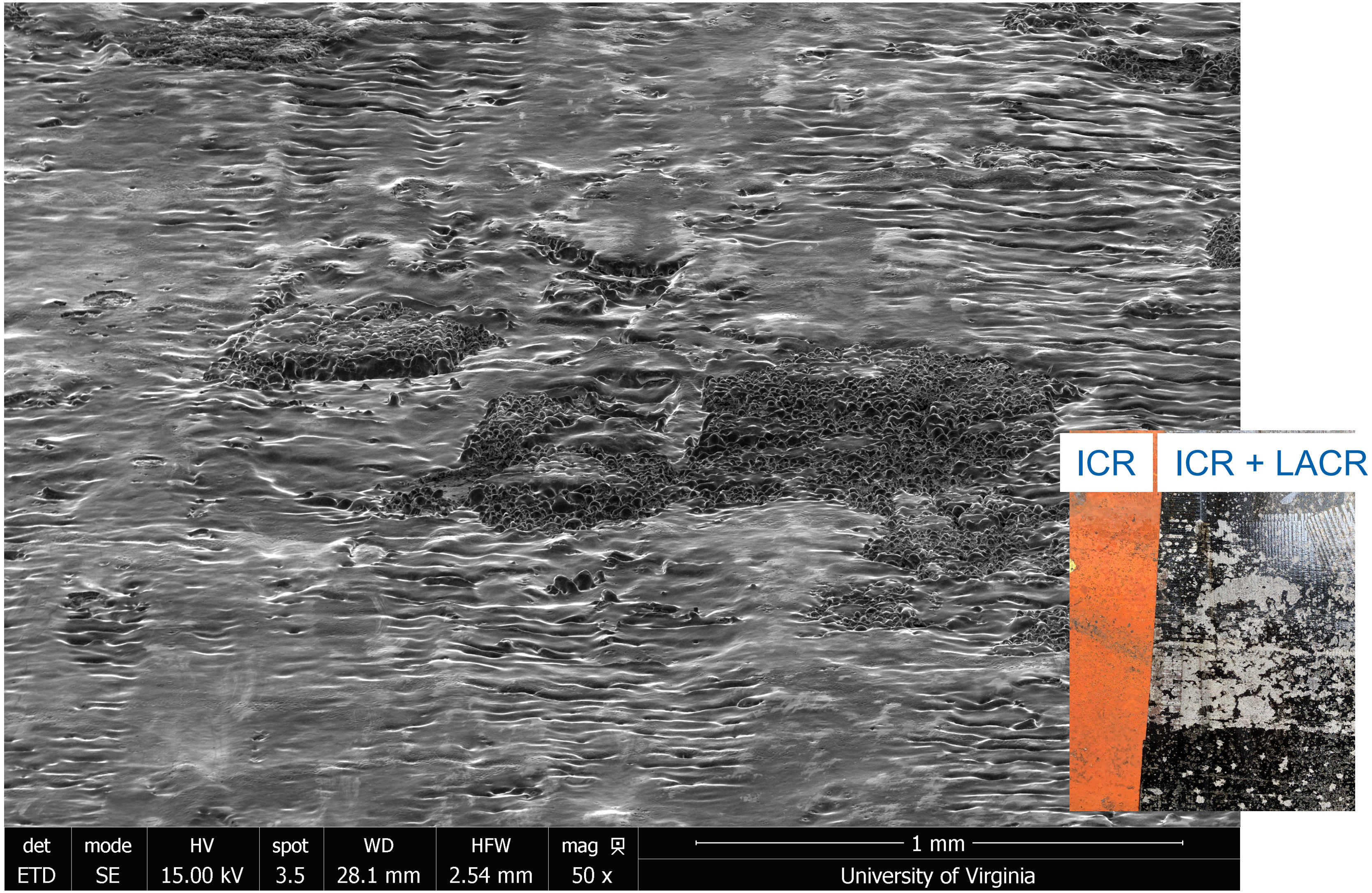
ICR Cross Section



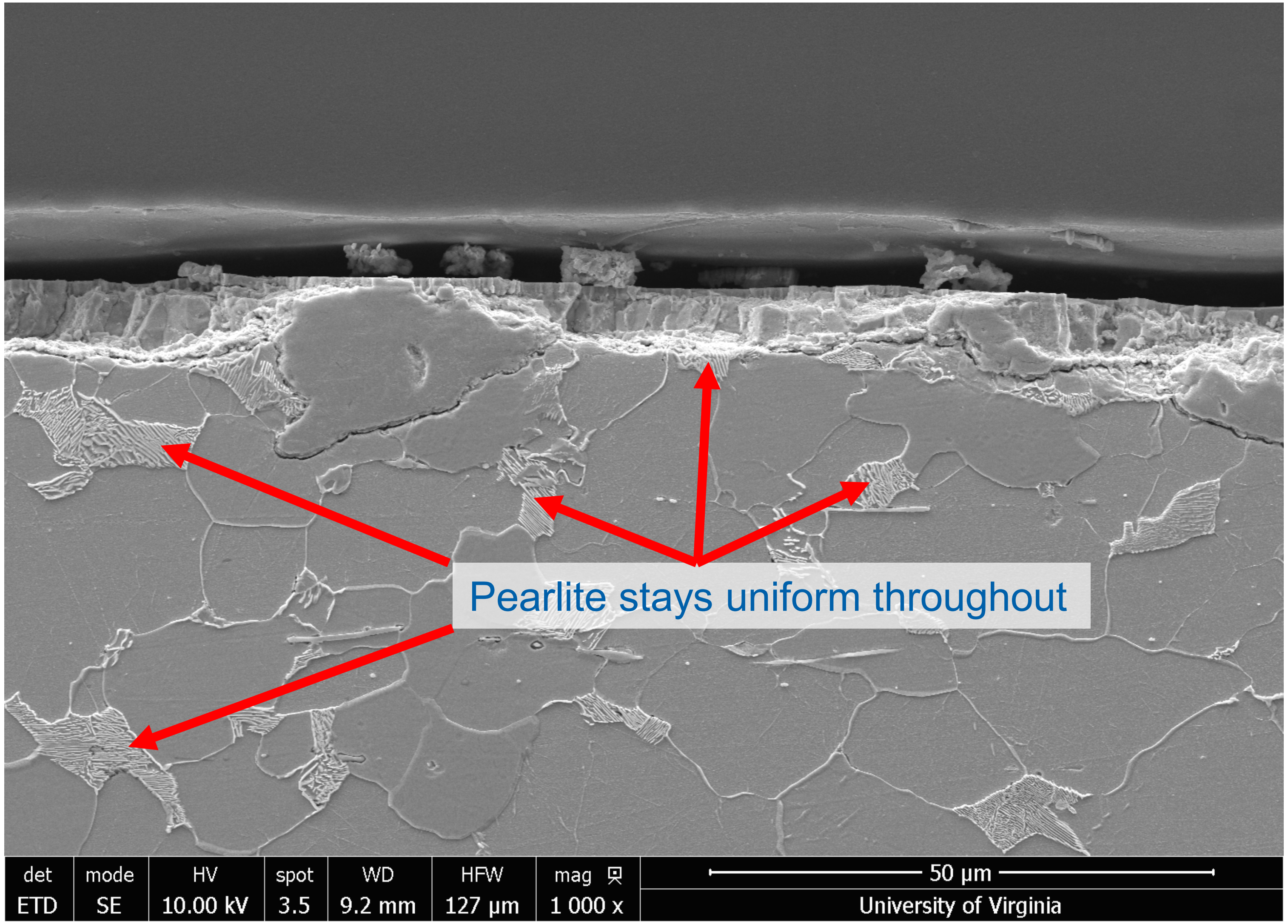
ICR Cross Section



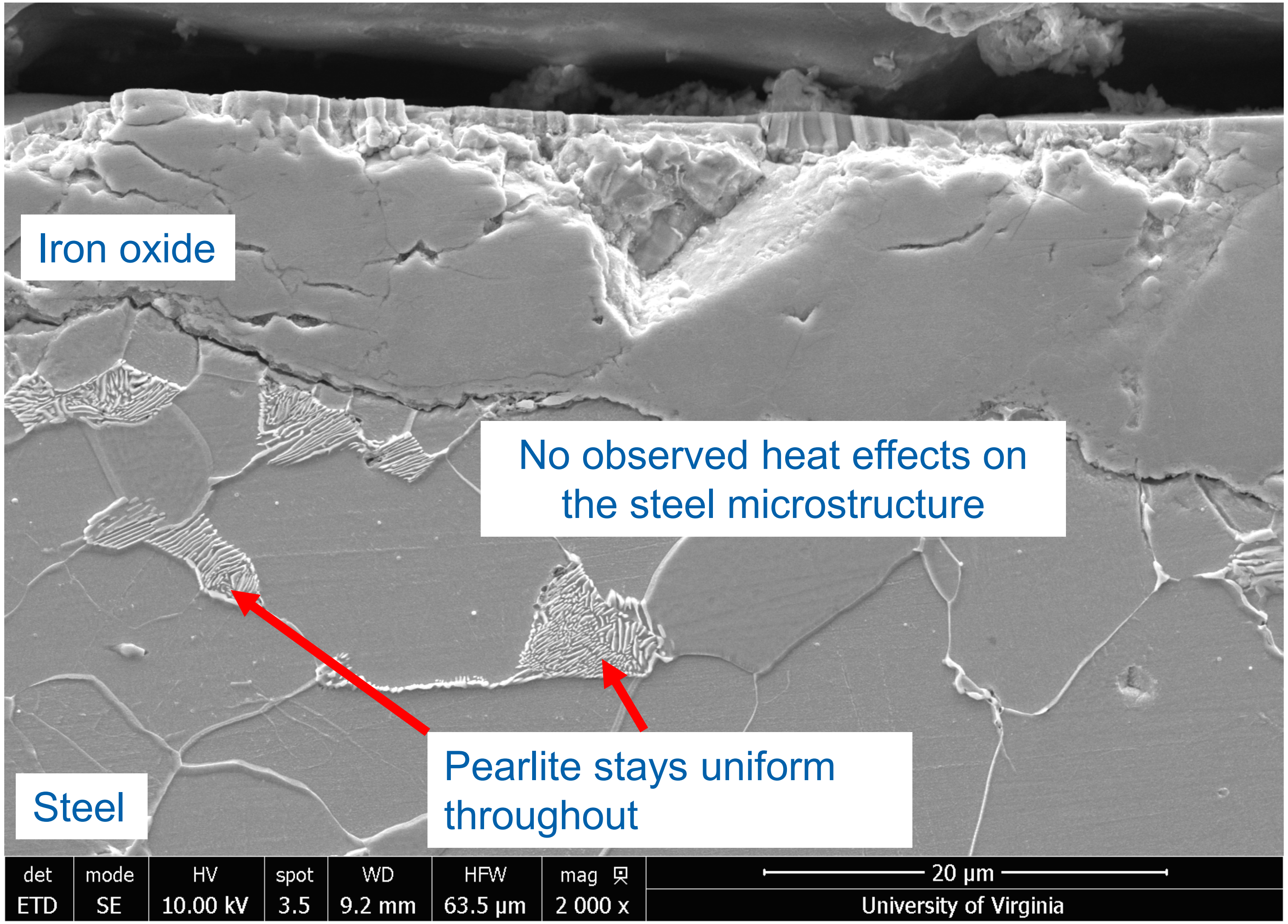
ICR + LACR Surface



ICR + LACR Cross Section

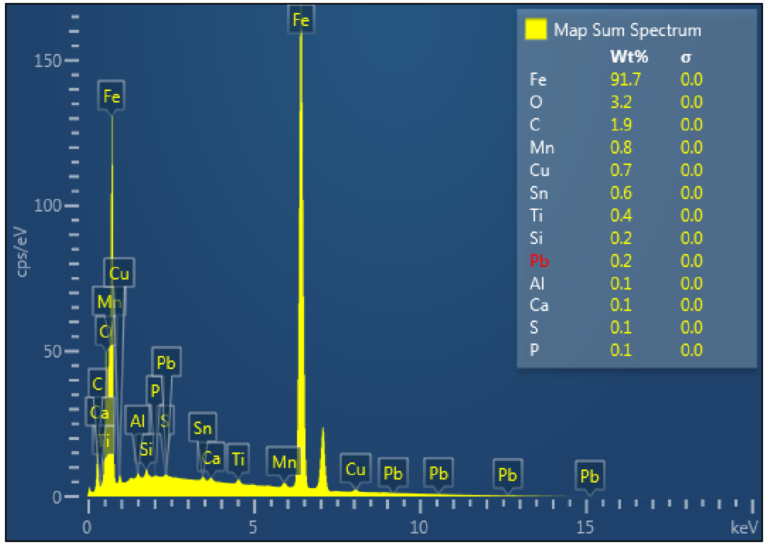


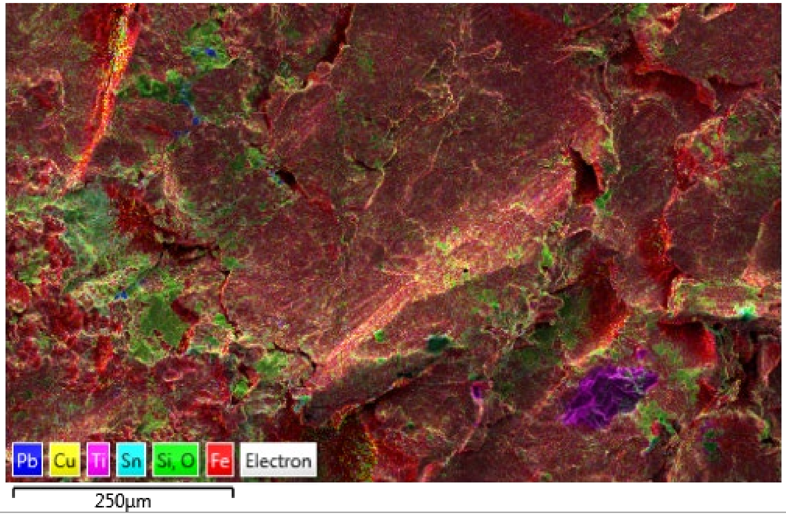
ICR + LACR Cross Section



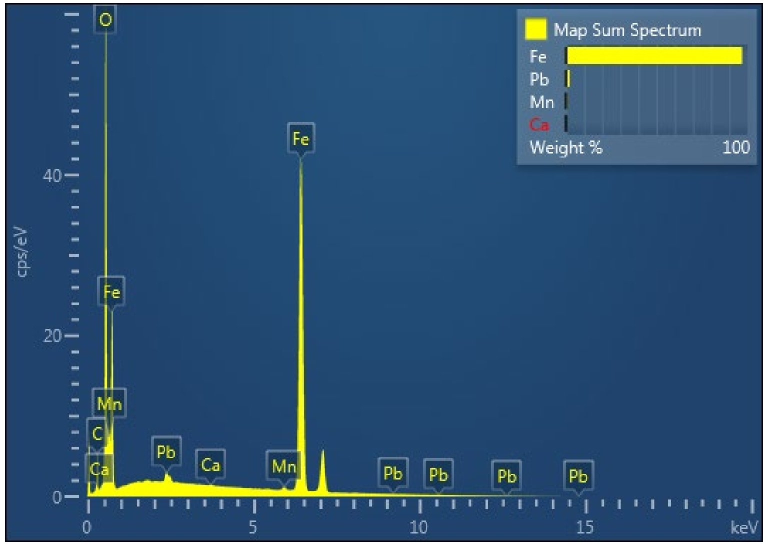
Surface Chemistry

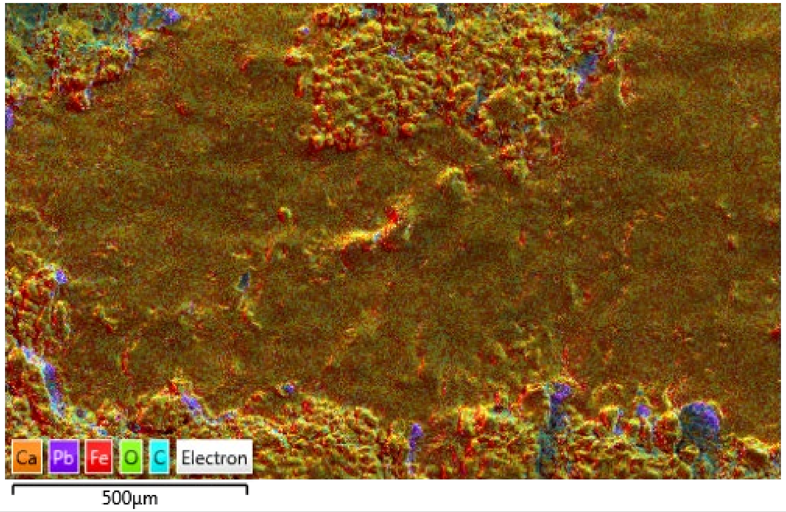
Grit Blasted





ICR+LACR





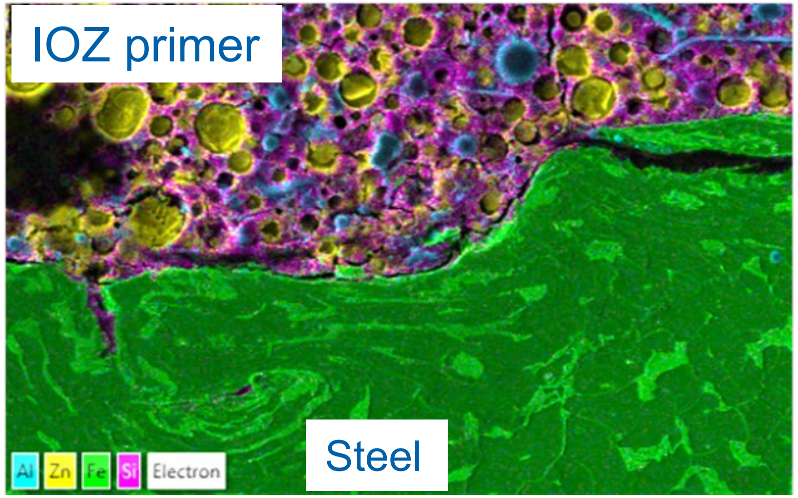
Coating Systems Applied

- Coating removed using ICR, LACR, ICR + LACR, and grit blasting
- Samples recoated:
  - Conventional 3 coating system
  - Different primer on each side of the plates

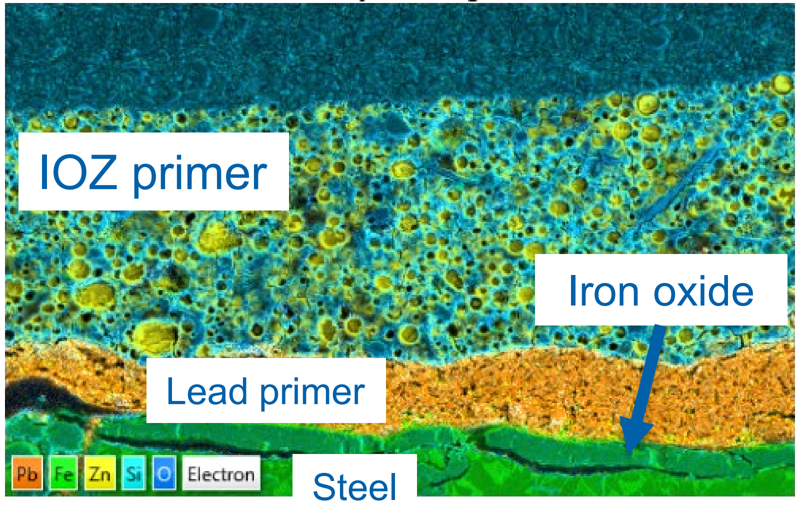
Side Designation	Primer Material	Midcoat Material	Topcoat Material
Side 1	Inorganic Zinc (Green) Carbozinc® 11 HS	Epoxy (White) Carboguard® 893	Polyurethane (Gray) Carbothane® 133 LV
Side 2	Organic Zinc (Gray) Carbozinc® 859	Epoxy (White) Carboguard® 893	Polyurethane (Gray) Carbothane® 133 LV

Recoating with Zn Rich Primers

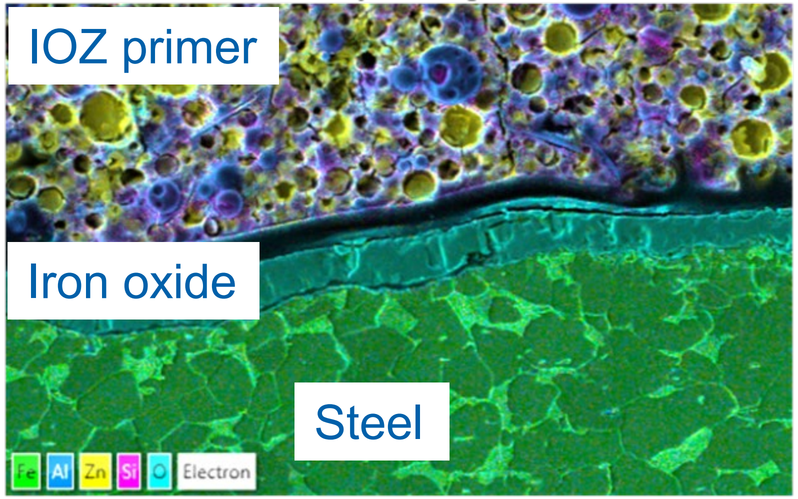
Grit Blasted



ICR

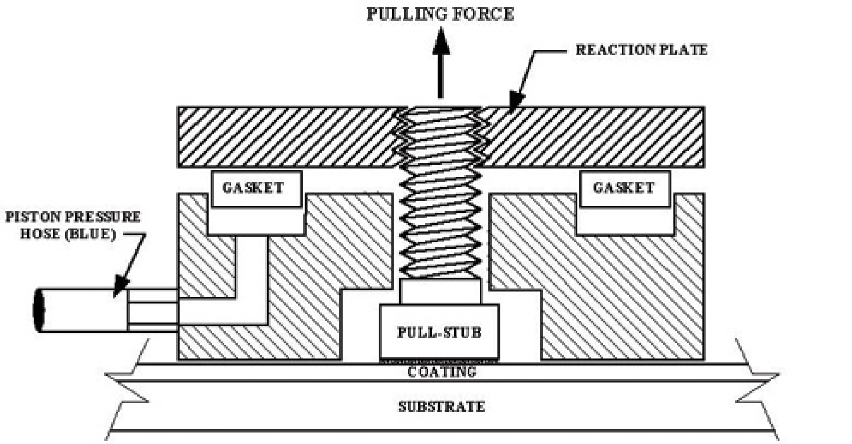


ICR + LACR



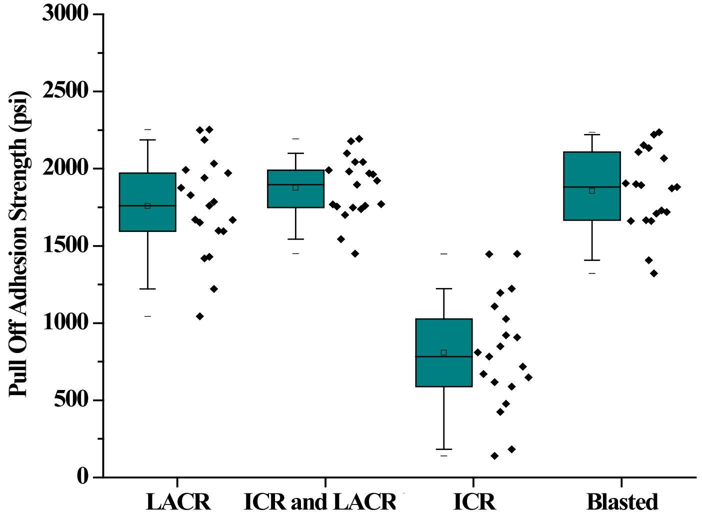
- Reapplied coatings show full coverage of the substrate
  - Indicative of good wetting, needed for adhesion

PATTI Adhesion Data

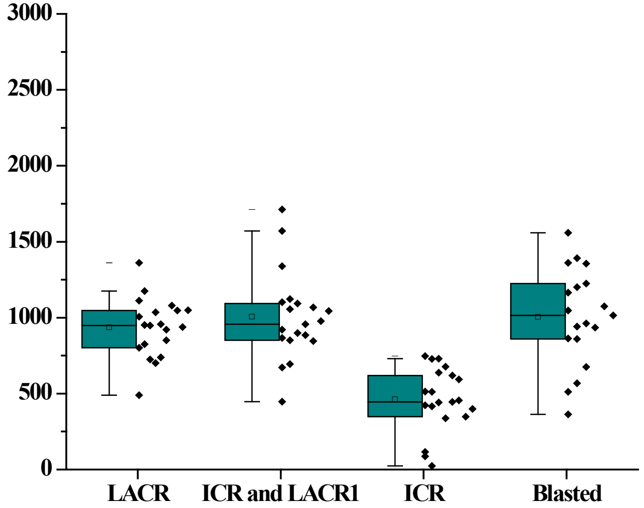


CROSS-SECTIONAL SCHEMATIC OF SELF-ALIGNING PISTON WITH PULL-STUB

Organic Zinc Primer



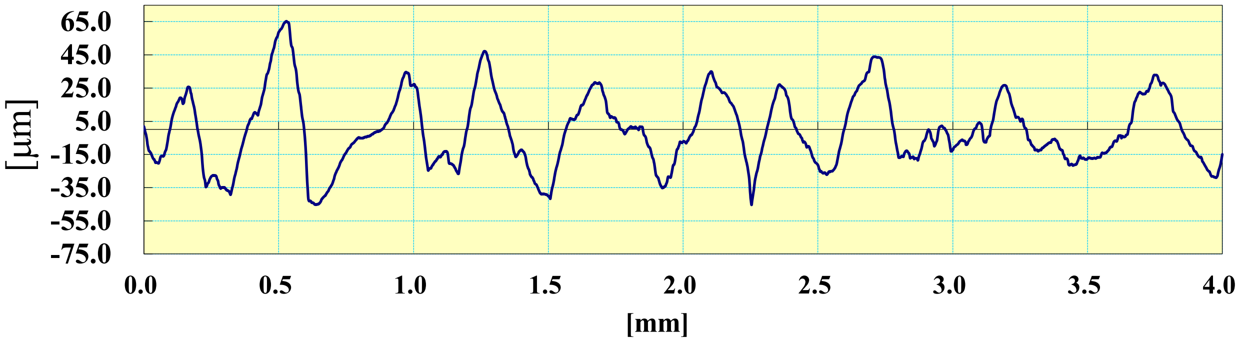
Inorganic Zinc Primer

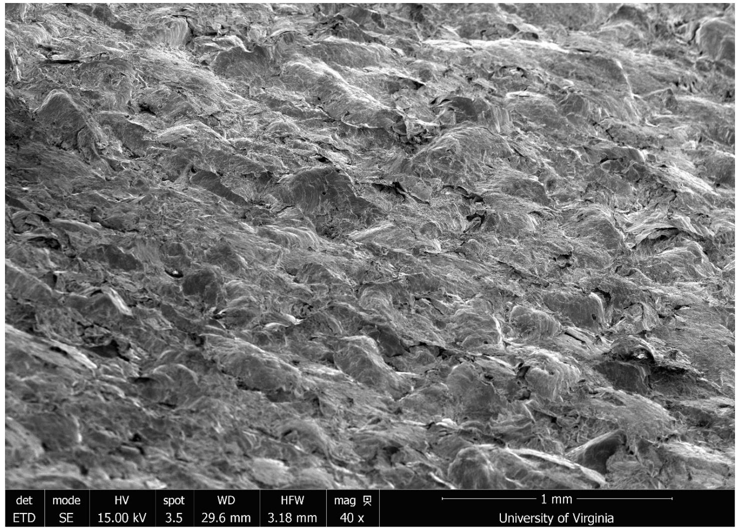


Roughness Comparison

Grit Blasted Surface Profile

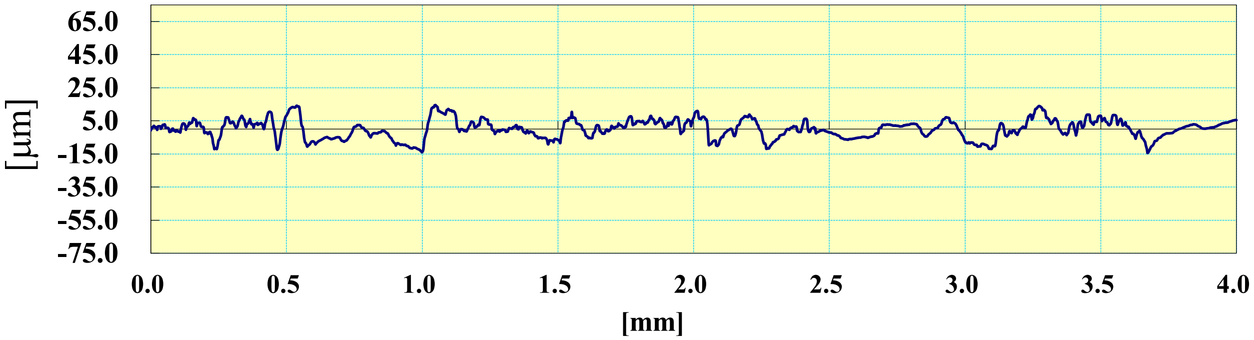
- **Average Roughness (Ra): 12.252** (10 measurements)





ICR + LACR Surface Profile

- **Average Roughness (Ra): 4.015** (10 measurements)

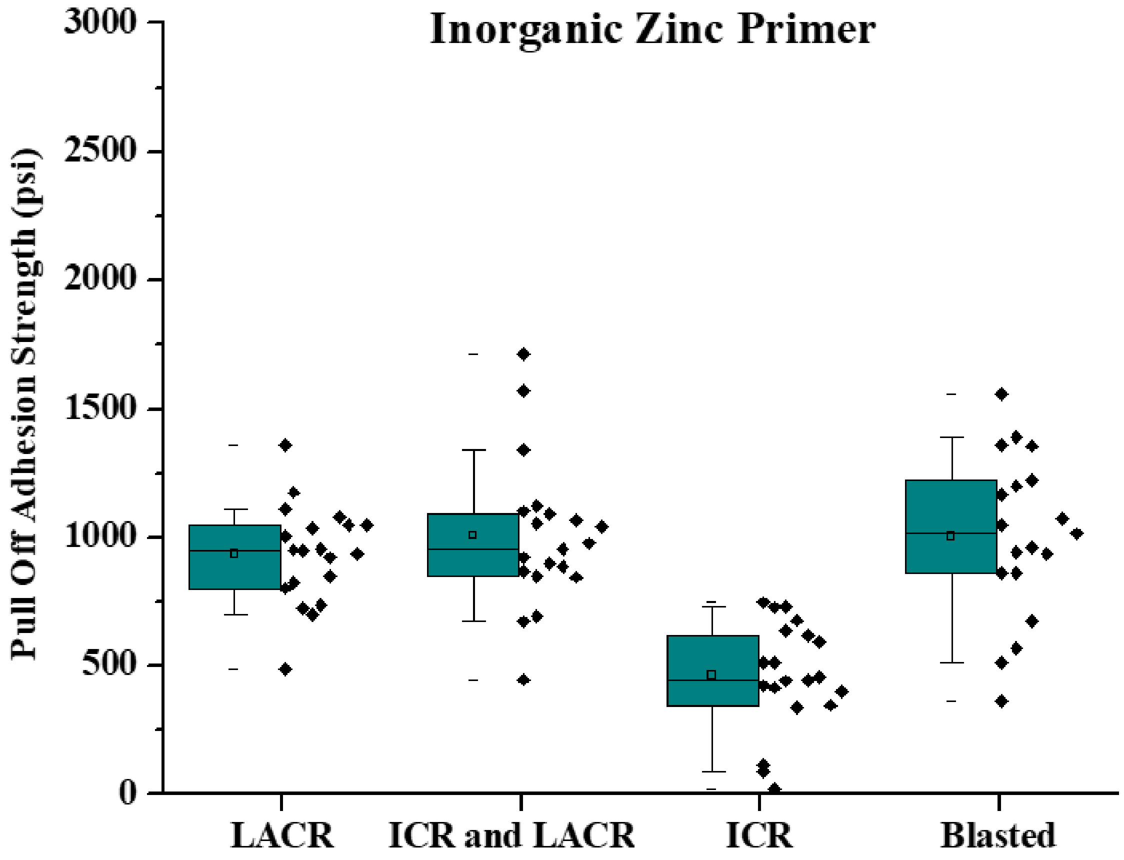


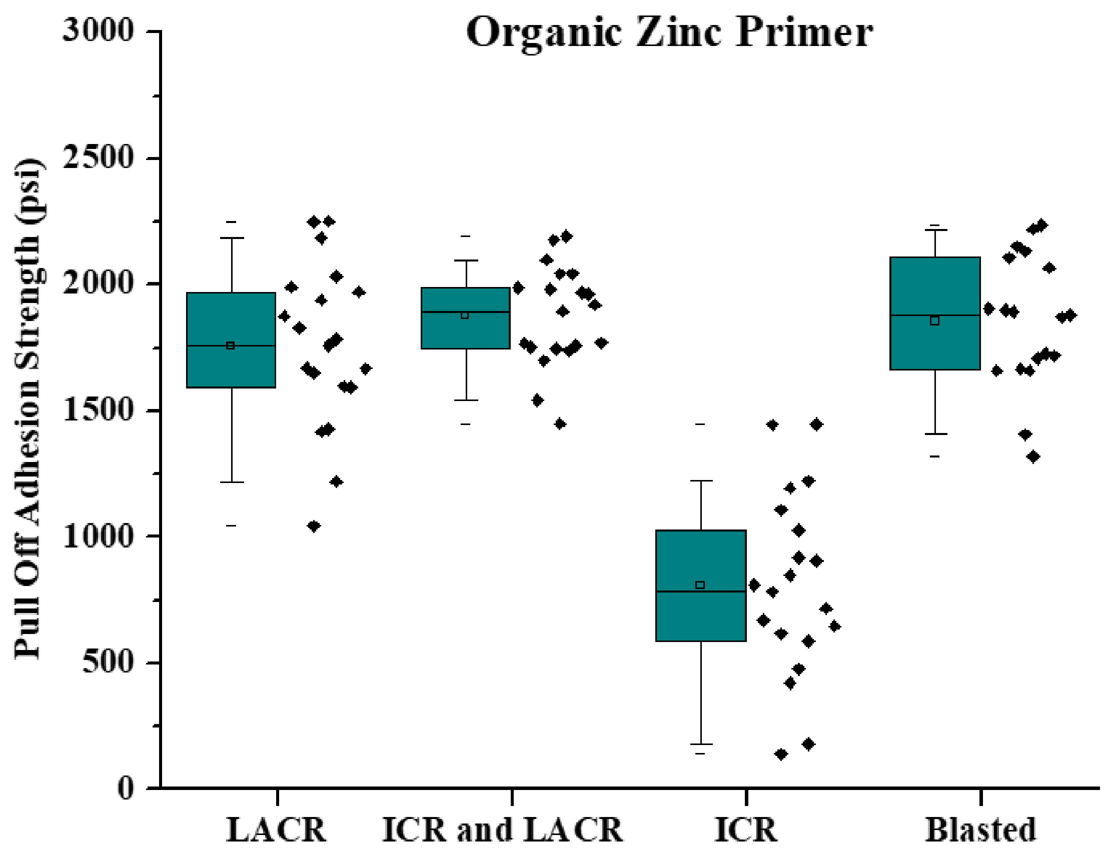
Coating Applicator Measured Surface Profiles

Surface Profile Measurements

Client ID	Testex® Coarse Measurement (*mils*)	Testex® X-Coarse Measurement (*mils*)	Average Profile Depth Measurement (*mils*)
Blasted	—	5.4	5.4
ICR + LACR	1.7	2.4	2.1
LACR	1.7	2.1	1.9

PATTI Data: IOZ and OZ Primers



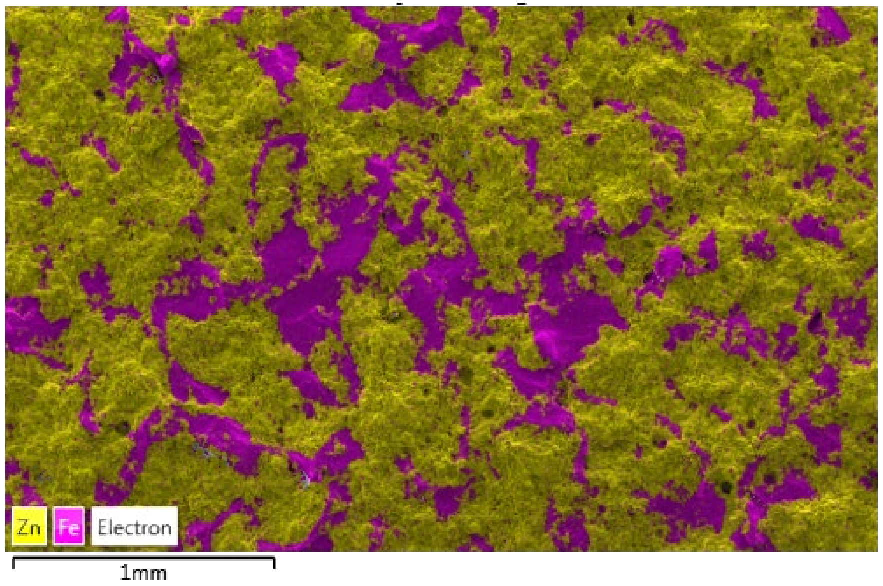


Three Main Adhesive Failure Modes

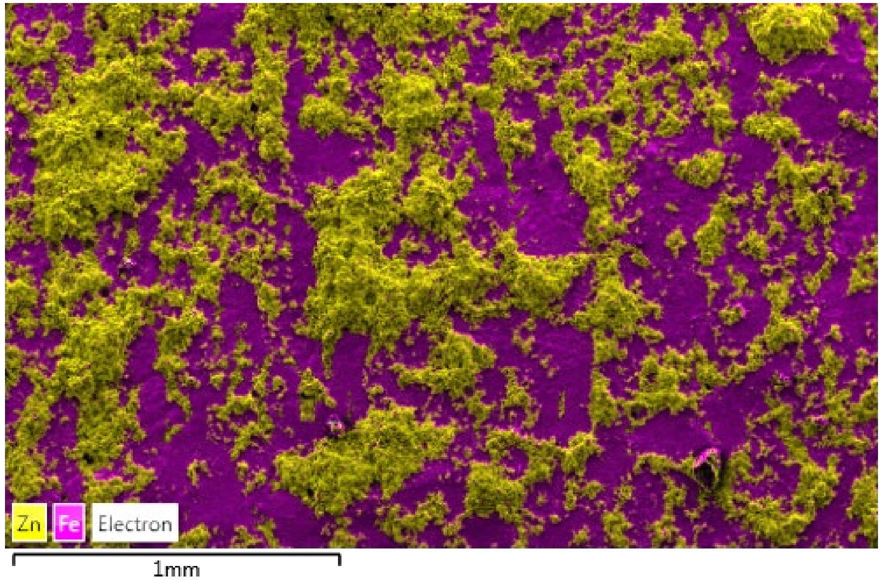
Cohesive Failure | Adhesive Failure | Mixed Mode

<u>Top-down</u> view of PATTI test sites using SEM/EDS:

Grit Blasted



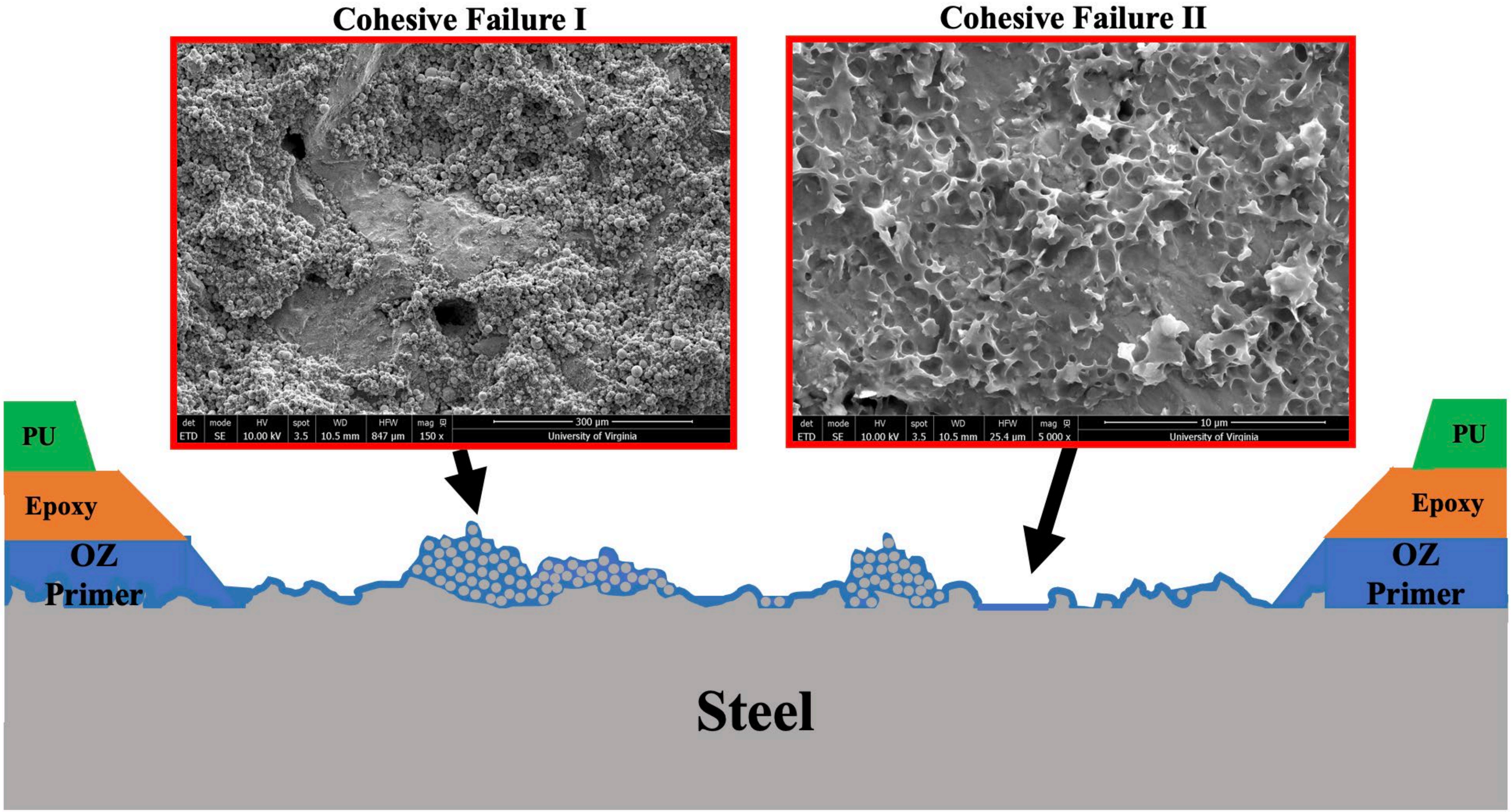
LACR



Zn

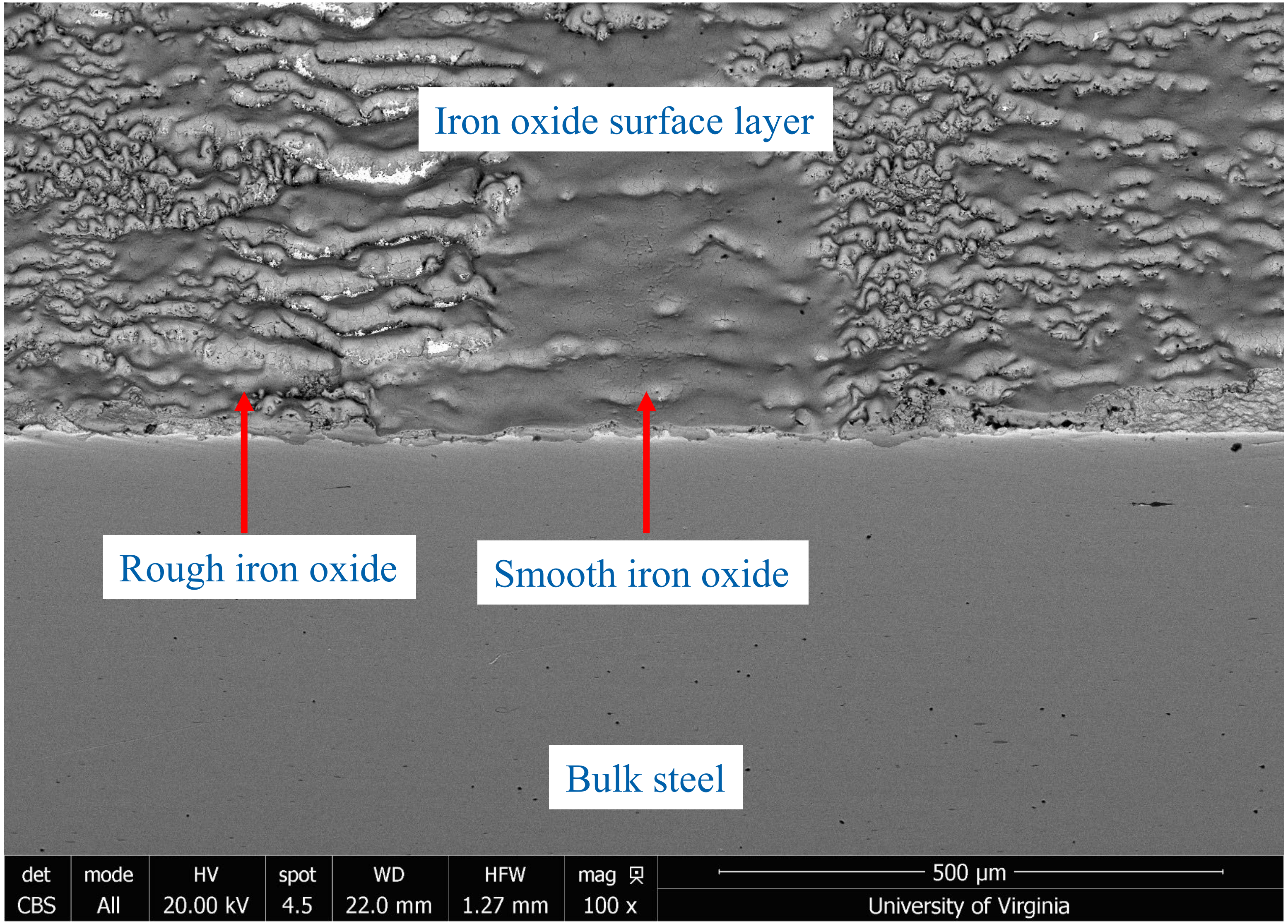
Fe

Grit Blasted Organic Zinc Model Diagram

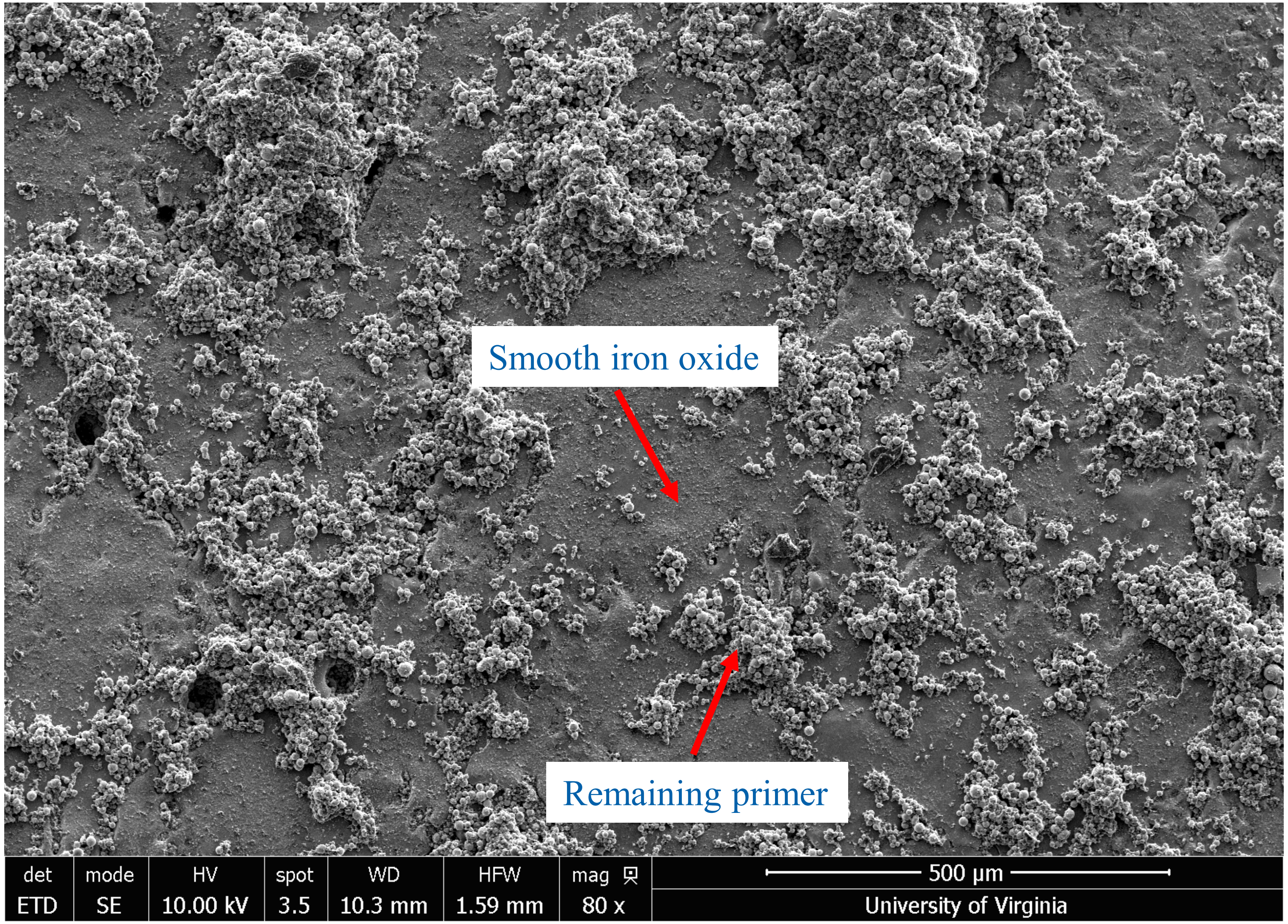


Uncoated ICR + LACR Surface

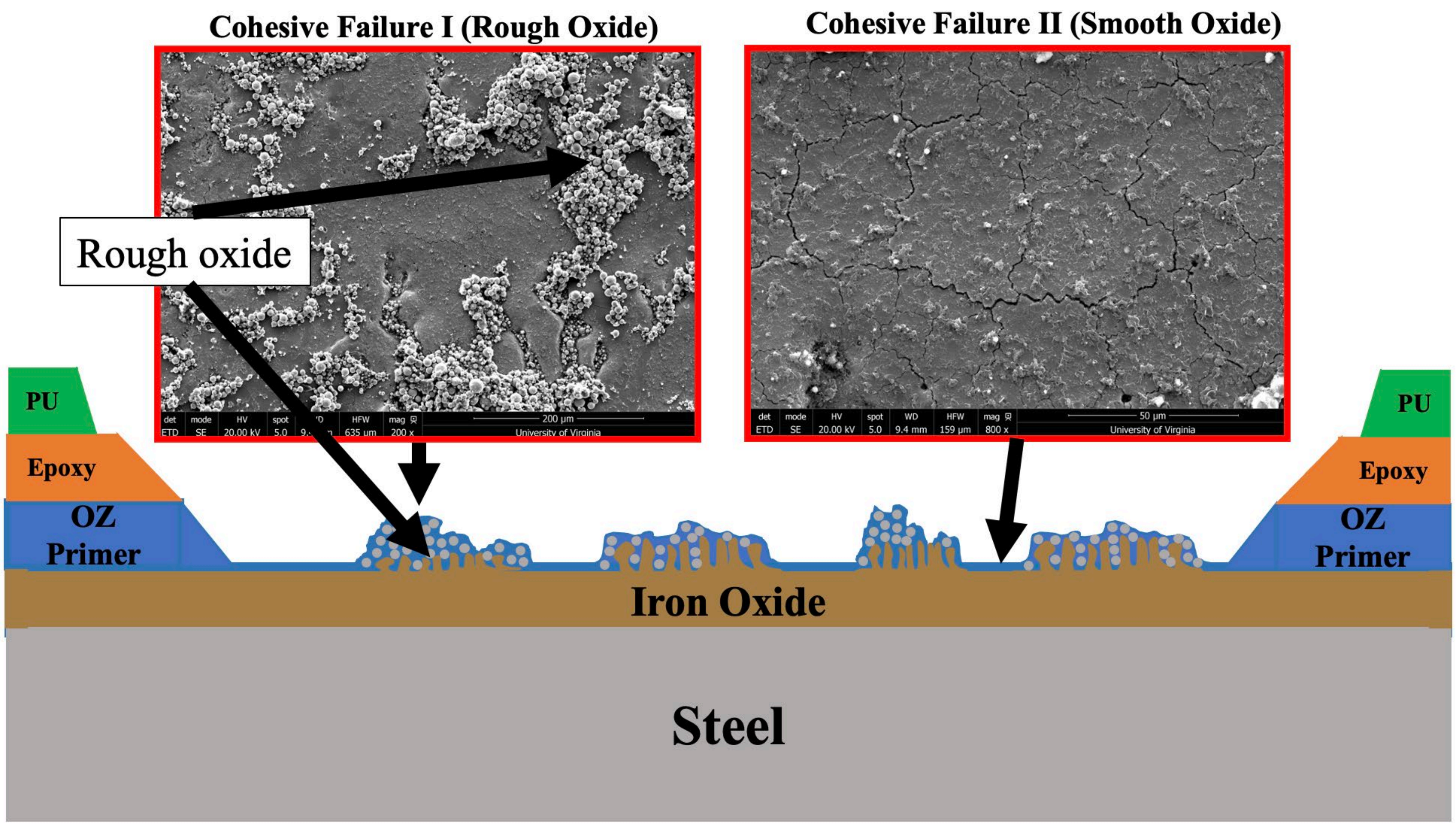
Titled 45 degrees



ICR + LACR PATTI Surface



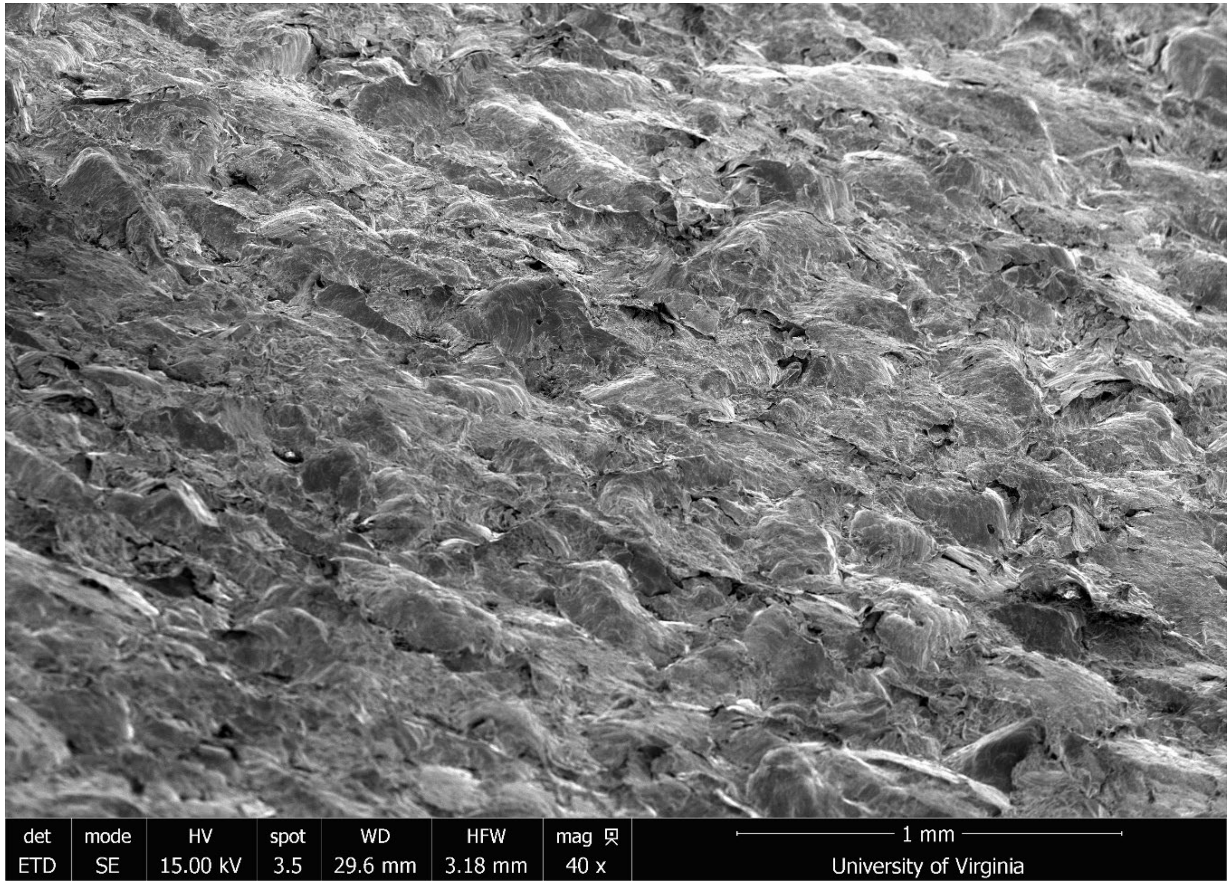
ICR + LACR Organic Zinc Model Diagram



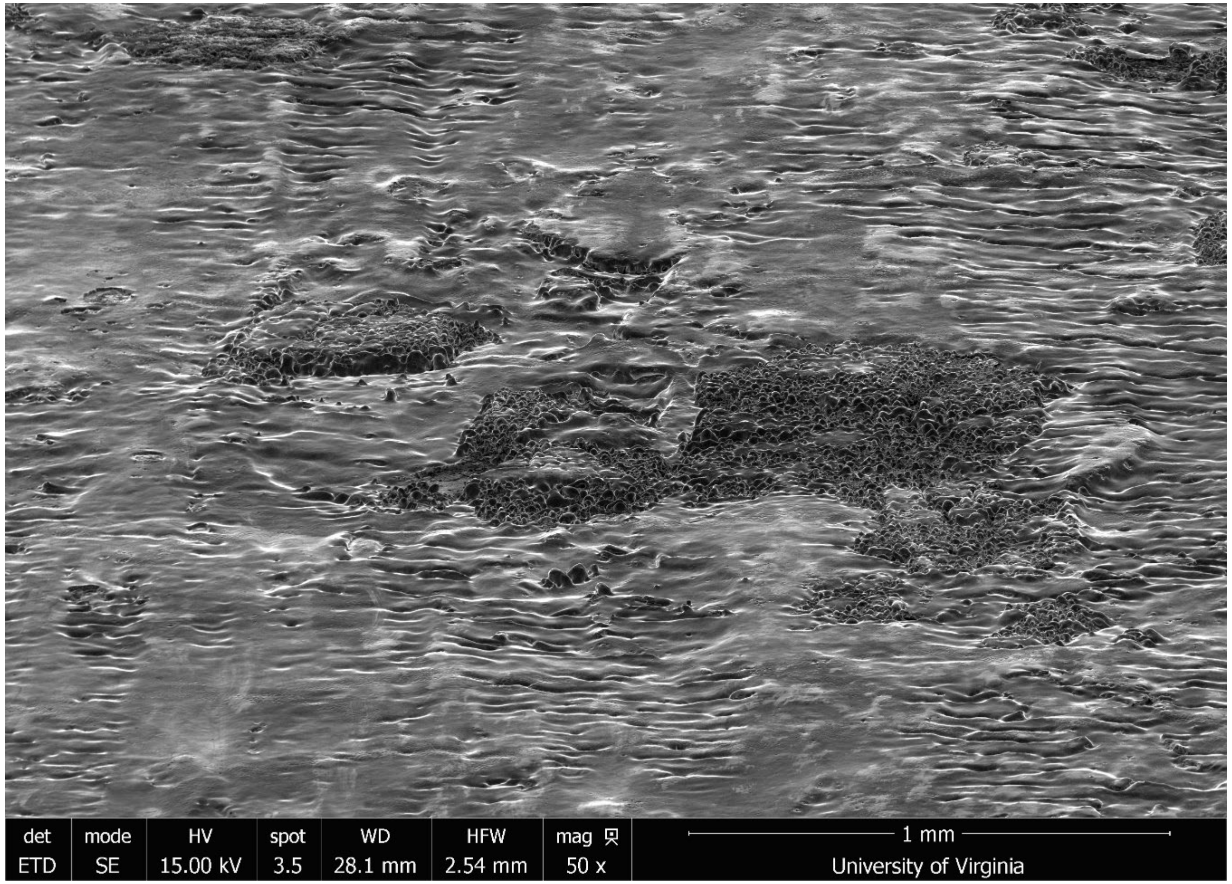
Surface Roughness Does not Affect Adhesion

- 3x decrease in surface roughness does not affect adhesion

Grit Blasted Surface



ICR + LACR Surface



Conclusions

Coating Removal Methods:

- Grit blasting removes all previous coatings and oxides, however it does not provide a very clean surface
- ICR Removes all coating layers except the lead primer
- LACR effectively removes and cleans the surface leaving behind a clean well adhered oxide layer
- No heat effects are observed on the steel microstructure

Roughness and Adhesion:

- ICR + LACR adhesion is equivalent to grit blasting adhesion despite a 3-fold decrease in surface roughness

Conclusions

Adhesion Analysis:

- **OZ coated grit blasted and ICR + LACR surfaces display cohesive failure**
- **Cohesive failure occurs in one of two ways:**
  - Cohesive I: Bulk Zn primer remains on the surface
  - Cohesive II: A thin epoxy layer covers the surface

Participant Poll #3

LASER ABLATION AND INDUCTION COATING REMOVAL

Raquel Rickard

August 21st, 2023

Industrial Hygiene Exposure Assessment Goals

- Identify potential air and environmental contaminants
- Evaluate in-place work process
- Measure worker and environmental exposures
- Recommend engineering, administrative, and PPE requirements based on findings

Abbreviations

PEL: “Permissible Exposure Limit” OSHA, the legally enforceable limit for a chemical, typically calculated as an 8-hour time weighted average

AL: “Action Level” OSHA, Usually about ½ the Permissible Exposure Limit, starting level for implementing a written chemical specific program, implementing controls, and instituting medical surveillance

NIOSH: “National Institute for Occupational Safety and Health”

Industrial Hygiene Studies

- 2016 Lab and Field Testing with VTRC and UVA, Conducted by EI Group- Laser with Fume Extraction
- 2018- Lab Testing in Newport News, VA, VDOT IH- Laser with Fume Extraction
- 2018- Task-Based Field Testing, VDOT IH, Hot Work Following Ablation on Welded C-Beams and Rolled I-Beam
- 2019/20- Lab Testing in Michigan, VDOT IH- Laser without Fume Extraction
- 2022- ICR and LACR- Lab Testing in Newport News, VA, VDOT IH- Laser with Fume Extraction, Rolling ICR and ICR Plates
- 2022- Field Testing in Salem, VA- Laser without Fume Extraction

Coating System Metals Characterization

South Quay, VA 2021

Samples from the South Quay Bridge Over Blackwater River					
Analyte	21M-062-1	21M-062-2	21M-062-3	21M-062-4	21M-075-1
Aluminum	-	-	-	-	7.9%
Antimony	0.03%	0.01%	<0.0006%	0.02%	0.002%
Arsenic	0.003%	< 0.0006%	<0.0006%	0.002%	-
Cadmium	0.001%	0.001%	<0.0006%	0.001%	0.003%
Chromium	2.04%	0.4%	0.002%	0.8%	0.3%
Copper	0.01%	0.002%	0.002%	0.004%	-
Lead	10.3%	16.5%	0.3%	21.5%	16.6%
Mercury	<0.00001%	<0.00001%	<0.00001%	<0.00001%	-
Zinc	4.5%	0.6%	0.2%	0.6%	1.8%

Newport News, VA 2018

Sample Number	Composition
18M-044-1	Lead: 62.023%
Beam A, 4"x4" Grid	Cadmium: <0.005%
	Chromium: <0.01%
18M-044-2	Lead: 64.472%
Beam A, 4"x4" Grid	Cadmium: <0.005%
	Chromium: <0.01%
18M-044-3	Lead: 54.722%
Beam B, 4"x4" Grid	Cadmium: <0.005%
	Chromium: <0.01%

Figure 13: Photomicrograph of Paint Chip 21M-075-2, Cross-Section 500x Magnification

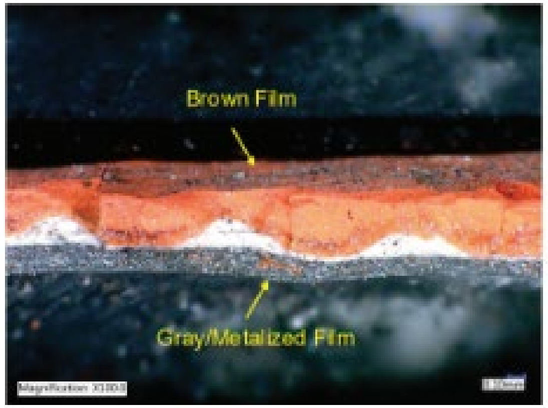


Figure 1: Photomicrograph of Paint Chip 21M-069-2, Cross-Section 100x Magnification

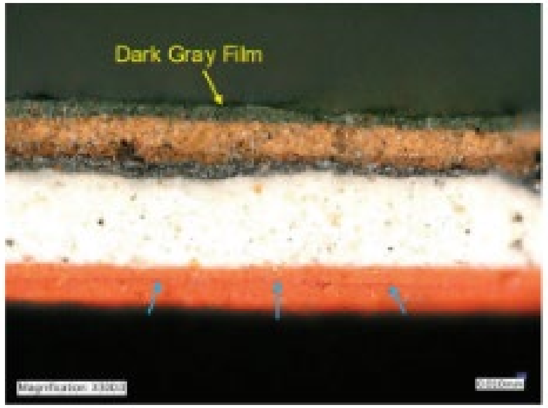
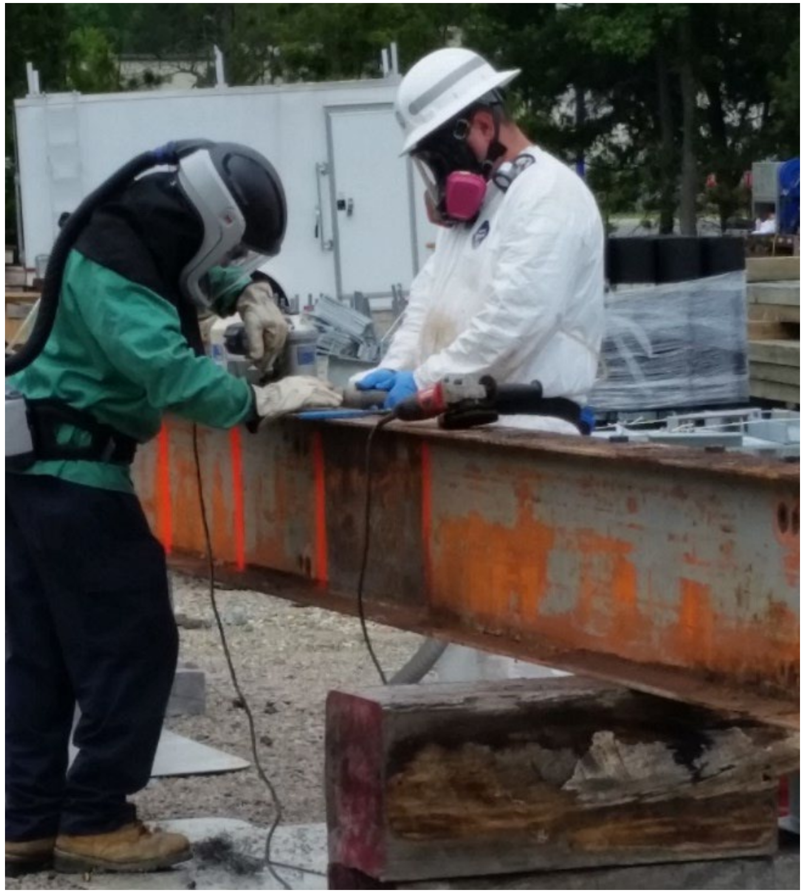


Figure 8: Photomicrograph of Paint Chip 21M-074-2, Cross-Section 300x Magnification

Potential Employee Exposure Hazards

- Organic Hazards/products of thermal decomposition
- Inorganic Hazards- metals
- Heat and light liberate other chemicals vs. blasting
- Class IV Laser – eye damage / skin burn
- ICR – electromagnetic fields
- Waste - bulk samples 10%-60%, lead
- Waste Characterization
- Noise



Metal Panel Sampling

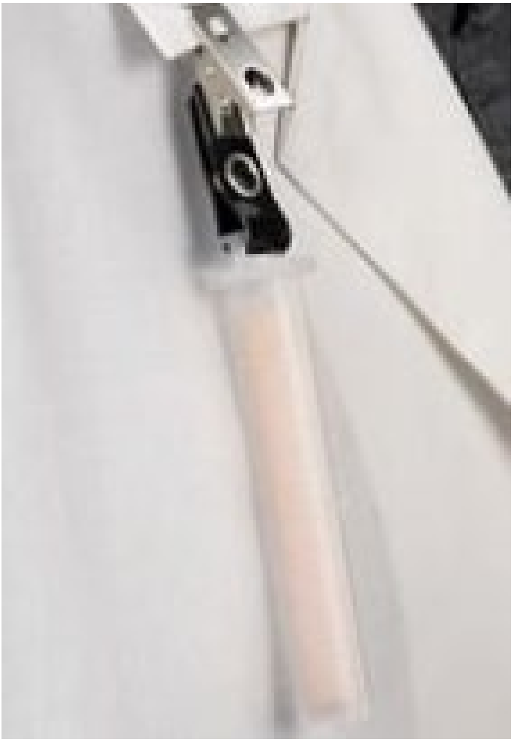
- TCLP for bulk waste
- Lead wipe sampling, analyzed by Flame AAS
- Personal and area samples collected as full shift
- NIOSH 7300 Method for Metals
  - MCEF filter with Inductively Coupled Argon Plasma, Atomic Emission Spectroscopy (ICP-AES) Analysis
  - Samples collected at about 2.0 lpm with GilAir Pumps
  - Panel analysis for a variety of metals, including lead and zinc
- Area Sampling for Hexavalent Chromium, NIOSH 7600 Method
  - Tared 5.0 um PVC membrane, 2 lpm
  - Visible absorption spectrophotometry

Organic Vapor Profiles

- **Personal and Area Samples using 3M 3500 OV Badge or Assay 566**
- **NIOSH Methods:**
  - **NIOSH 1003M**: 1,1,1-Trichloroethane, 1,1,2- Trichloroethane, 1,2- Dichloroethane, Acetone, Carbon Tetrachloride, Chlorobenzene, Ethylbenzene, Tetrachloroethylene
  - **NIOSH 1005:** Methylene Chloride
  - **NIOSH 1022M:** Trichloroethylene
  - **NIOSH 1300:** Methyl isobutyl ketone
  - **NIOSH 1501M:** Benzene, m,p-Xylene, o-Xylene, Styrene, Toluene
  - **NIOSH 1500M**: Heptane, Hexane, Octane,
  - **NIOSH 2500M**: Methyl ethyl ketone
- **Area Samples Using Galson TO-15 with Library Search and TICs, Suma Canister, 8hr Regulator**
- **Real-time PID**

Aldehyde Panel Monitoring

- **Personal and Area aldehyde panel samples collected via badge method**
- **NIOSH Method 2016**
  - Assay Badge 581
  - High Performance Liquid Chromatography with Ultraviolet Detection



Respirable Dust and Crystalline Silica

- Area dust sampling was collected via an SKC Aluminum Cyclone at 2.5lpm
- NIOSH Method 600, gravimetric, respirable dust
- NIOSH Method 7500 silica by x-ray diffraction

Sampling Results: LACR with Fume Extraction

- Lead fumes did not exceed the action level during any VDOT sampling in open air as an 8-hr TWA and did not exceed the PEL as a concentration
- Currently recommend adding general mechanical ventilation or local exhaust ventilation (LEV) in enclosed spaces (more data needed)
- Organics observed included low levels (ppbv) of n-Butane, Acetone, Isopropyl Alcohol, Methyl Ethyl Ketone, Ethyl Acetate, and Trichloroethylene
- Respirable dust and RCS <LOD

Type of Sample	Analyte	10/26/2021	10/27/2022	
		ICR Operator	LACR Operator 1	LACR Operator 2
Organic Personal Breathing Zone Samples (as concentration)	Acetaldehyde	< 0.03 ppm (Avdot-1)	< 0.04 ppm (Avdot2-1)	Not Sampled
	Benzaldehyde	<0.02 ppm (Avdot-1)	< 0.03 ppm (Avdot2-1)	
	Butyraldehyde	< 0.03 ppm (Avdot-1)	< 0.04 ppm (Avdot2-1)	
	Crotonaldehyde	< 0.03 ppm (Avdot-1)	< 0.04 ppm (Avdot2-1)	
	Formaldehyde	<0.02 ppm (Avdot-1)	< 0.02 ppm (Avdot2-1)	
	Isovaleraldehyde	< 0.03 ppm (Avdot-1)	< 0.04 ppm (Avdot2-1)	
	Propionaldehyde	< 0.03 ppm (Avdot-1)	< 0.04 ppm (Avdot2-1)	
	Valeraldehyde	< 0.03 ppm (Avdot-1)	< 0.04 ppm (Avdot2-1)	
Inorganic Personal Breathing Zone Samples (as concentration)	Antimony	< 1.8 µg/m³ (Mpvdot-1)	<1.9 µg/m³ (Mpvdot2-1)	<3.9 µg/m³ (Mpvdot2-2
	Beryllium	<0.015 µg/m³ (Mpvdot-1)	<0.016 (Mpvdot2-1)	<0.033 (Mpvdot2-2)
	Cadmium	<0.30 µg/m³ (Mpvdot-1)	<0.32 (Mpvdot2-1)	<0.66 (Mpvdot2-2)
	Chromium	<15 µg/m³ (Mpvdot-1)	<16 (Mpvdot2-1)	<33 (Mpvdot2-2)
	Cobalt	<0.91 µg/m³ (Mpvdot-1)	<0.96 (Mpvdot2-1)	<2.0 (Mpvdot2-2)
	Copper	<0.61 µg/m³ (Mpvdot-1)	<0.64 (Mpvdot2-1)	<1.3 (Mpvdot2-2)
	Iron Oxide	<22 µg/m³ (Mpvdot-1)	<23 (Mpvdot2-1)	<47 (Mpvdot2-2)
	Lead	12 µg/m³ (Mpvdot-1)	6.2 (Mpvdot2-1)	2.9 (Mpvdot2-2)
	Manganese	<0.30 µg/m³ (Mpvdot-1)	<0.32 (Mpvdot2-1)	<0.66 (Mpvdot2-2)
	Molybdenum	<0.30 µg/m³ (Mpvdot-1)	<0.32 (Mpvdot2-1)	<0.66 (Mpvdot2-2)
	Nickel	<0.61 µg/m³ (Mpvdot-1)	<0.64 (Mpvdot2-1)	<1.3 (Mpvdot2-2)
	Vanadium	<0.91 µg/m³ (Mpvdot-1)	<0.96 (Mpvdot2-1)	<2.0 (Mpvdot2-2)
	Zinc Oxide	<9.5 µg/m³ (Mpvdot-1)	<10 (Mpvdot2-1)	<20 (Mpvdot2-2)
	Hexavalent Chromium	Not Sampled		

Findings from Other Entities

- Dependent upon coating type- concentrations of lead, chromium, and hexavalent chromium vary by coating type
- The primary constituents of concern for VDOT coating systems are lead, chromium, and zinc
- Some sampling data from outside sources showed regulatory limit exceedances for lead and hexavalent chromium
- Reports and interviews indicate issues with fume extraction, the dust collector, and laser focus for high results

Sampling Results- LACR Without Fume Extraction

- No filtration unit built into laser device
- Lead fume measured between 150 and 1,500 µg/m³ as a concentration in Michigan & Salem, VA
- Formaldehyde and Crotonaldehyde observed in the enclosed space
- Laser was poorly focused leading to products of thermal decomposition (burning vs ablation)

Sampling Results- ICR

- **Lead levels less than OSHA AL of 30 µg/m³ as an 8-hr TWA, no sample exceeded 50 µg/m³ as a concentration**
- **Hex chrome observed in one area sample at 0.0363 µg/m³ as a concentration (2.5 AL)**
- **Organics observed included low levels (ppbv) of n-Butane, Acetone, Isopropyl Alcohol, Ethyl Acetate, and Trichloroethylene**

Photograph 16: RPR ICR

Hot-Work on Steel Beams After Removal

Operation:

- Grinding
- Oxyacetylene Torch Cutting
- Plasma Torch Cutting

Results

- Torch cutting of beams < AL as 8-hr shift* where coating fully removed
- Torch cutting of beam with coating left intact/hidden likely to exceed PEL

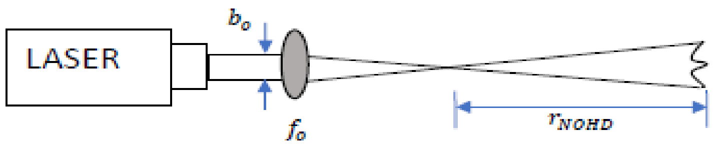
Ergonomic Observations

- Weight, configuration, and vibration of units caused worker fatigue
- Laser caused trigger fatigue for VDOT workers
- Bridge beam ends often have uncomfortable work configurations
- Estimated that a single worker will not be able to comfortably complete > 4 hours of use per day

Other Observations

- Noise levels below 85 dBa SLM and Dosimetry
- LACR and ICR exposed the employee to some amount of lead dust and fume with and without fume extraction
- LACR and ICR operations left behind leaded dust
- LACR and ICR created waste that was characterized as hazardous by TCLP. Paint chips, carbon-materials, filters, etc. should go with the waste stream.
- The LACR is capable of causing injury due to laser light/laser exposure.
- The ICR is capable of causing injury to those with pacemakers due to EMF exposure.
- Both the Laser and EMF hazards are manageable through work practices such as engineering and administrative controls.

$$r_{NOHD} = \left(\frac{f_o}{b_o}\right)\left(\frac{4\Phi}{\pi MPE}\right)^{1/2}$$



Parameters

- fo = 160mm
- bo = 14.5 mm
- Φ = 850 W (laser power at beam aperture after power loss at fiber optic in/out couplings)
- $MPE_{Eye} = 0.005\ W/cm^2$
- $MPE_{Skin} = 1\ W/cm^2$

Skin: $r_{NHD} = 3.6\ m$

Eye: $r_{NOHD} = 51.3\ m$

$$OD = log_{10}\left(\frac{Hp}{MPE}\right)$$

$$OD = log_{10}\left(\frac{\frac{850\ W}{\left(\pi\frac{(0.7cm)^2}{4}\right)}}{0.005\ W/cm^2}\right)$$

7 mm is used for normal aperture diameter. This is the standard for the eye if the beam diameter is smaller than 7 mm

$$OD = 5.645$$

$$OD\ 6 + is\ Specified\ for\ Laser\ Safety\ EyeWear$$

Findings and Conclusions

- Exposures to lead from blasting is several orders of magnitude greater than from LACR or ICR
- With a working fume extractor, LACR exposures are below regulatory limits for VDOT coatings for analytes sampled
- Exposures to lead during LACR without fume extractor exceeded the PEL by 300%
- ICR lead exposures below AL but ICR was not able to remove leaded coating
- Where LACR fully removed coating, exposures to subsequent hot work were < PEL as a concentration
- Difficult to focus laser on angles and bolts, which can cause increased fume

Recommended Controls

Engineering Controls:

- **Built-in Fume Extraction- Choose units with built-in fume extraction.**
- **Additional Ventilation- In additional to fume extraction, use positionable local exhaust ventilation (preferred) or dilution ventilation spaces with restricted air flow**

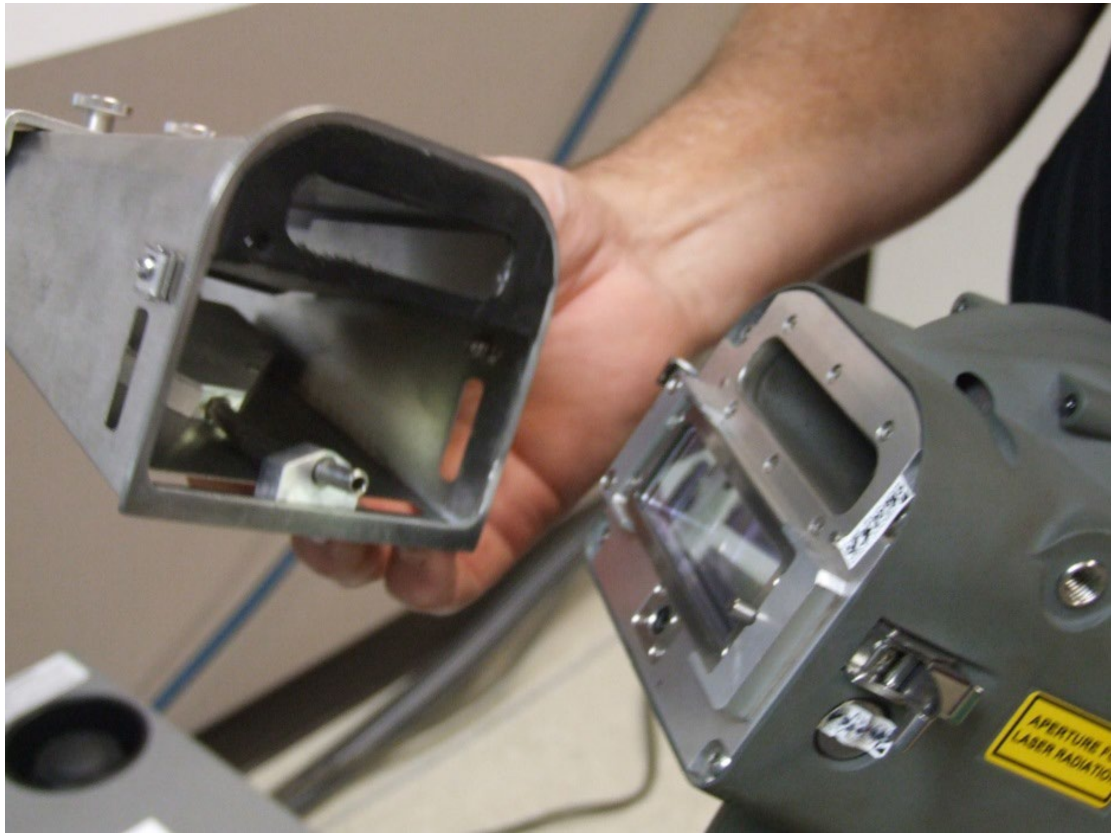
Administrative Controls:

- **Controlled Work Area- Operators using the laser must work within a laser-controlled area, delineated with signage and laser curtains or protective barriers**
- **Written Plan- Laser system operators should have a working laser program and written plan prior to the use of lasers**

Personal Protective Equipment:

- **Respiratory Protection- VDOT results are below the AL as an 8-hr TWA for lead in the field and lab for laser with fume extraction.**
- **Other PPE- employees using the LACR and ICR should wear full body coveralls, cut resistant gloves, laser protective eyewear, hardhat, etc.**

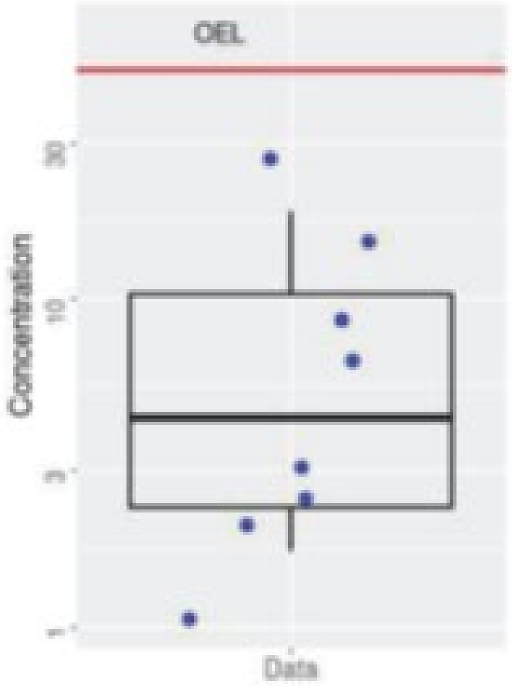
Fume Extraction Unit

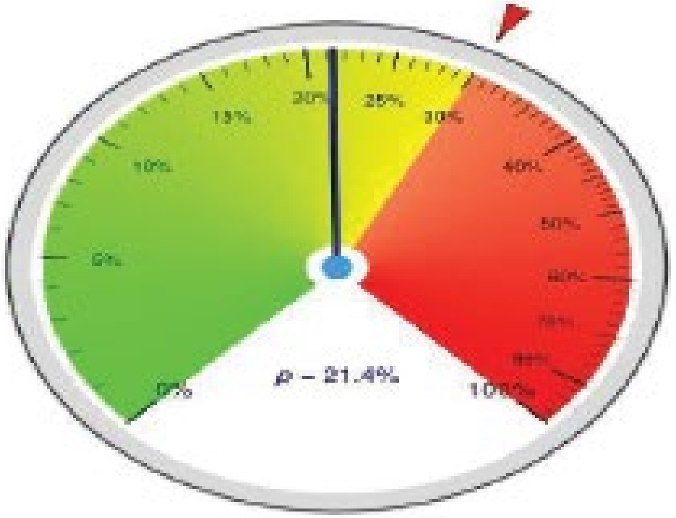


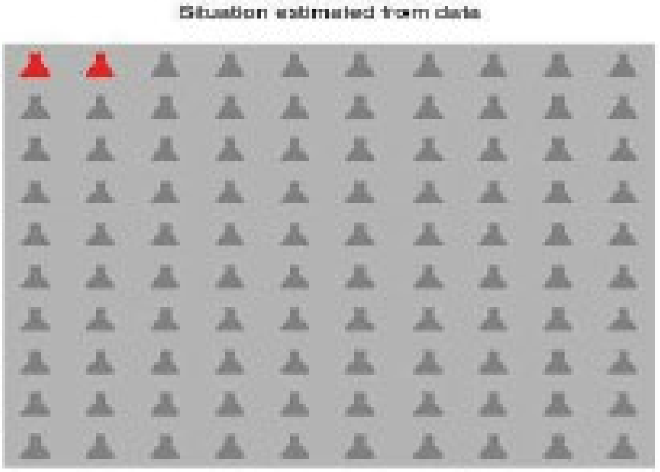
Built-in fume extraction on device head measured at 1500ft/m with 50’ of ducting

Future Research

- **Field testing on bridge structures within curtained/contained areas**
- **Increase sample size to increase confidence and reduce variability**







Participant Poll #4

LASER ABLATION AND INDUCTION COATING REMOVAL:

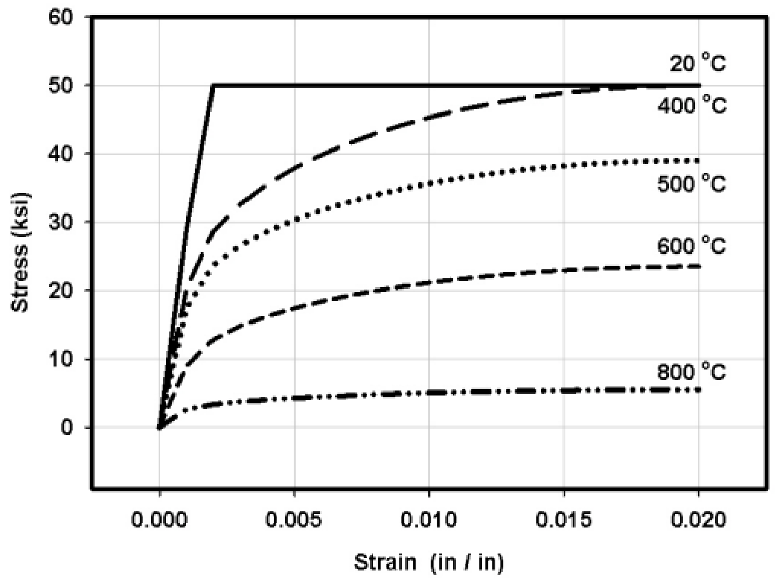
EFFECT ON PROPERTIES OF STEEL SUBSTRATE

Jason T. Provines, P.E.
Virginia Transportation Research Council, VDOT

August 21, 2023

Steel Exposure to Elevated Temperature

- Can cause changes in properties
  - Yield strength
  - Elastic modulus
  - Ductility
  - Creep, if long duration exposure
  - Heat affected zone, fatigue



Change in shape of the stress-strain curve for Grade 50 steel based on the Eurocode model.

Source:
Guide Specification for Fire Damage Evaluation in Steel Bridges, Wright et al., 2013

Steel Exposure to Elevated Temperature

- **Highway Bridge Fire Hazard Assessment Final Report (NCHRP 12-85)**
  - **Common bridge steels heated to ~2000ºF during rolling process**
    - If heat is less, no change in properties expected
  - **Heat treated steels more susceptible to changes due to heat**
    - High performance steel (HPS) plates
      - AWS D1.5 limits heat forming operations to 1100ºF
    - High strength bolts (Grade A325 or A490)
      - Strength loss possible if temps exceed 1100ºF
      - Creep deformation possible if temps exceed 550ºF for extended duration

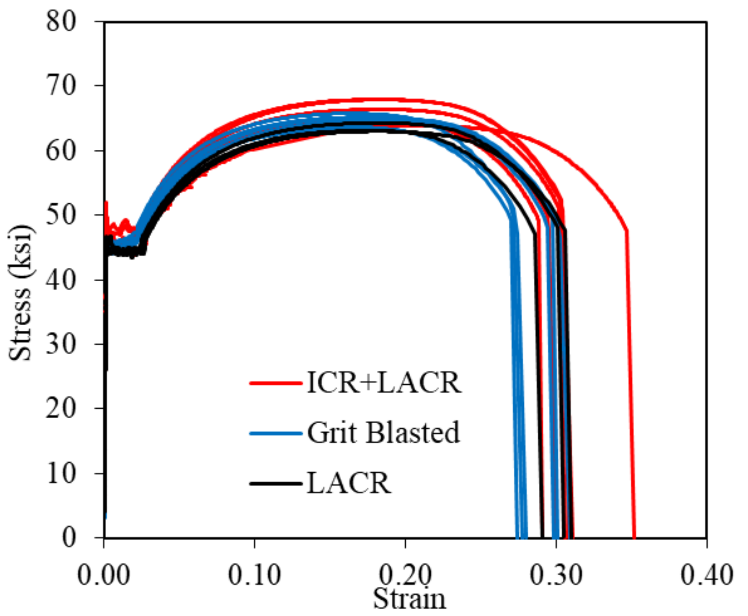
Source:
Highway Bridge Fire Hazard Assessment, Wright et. al, 2013

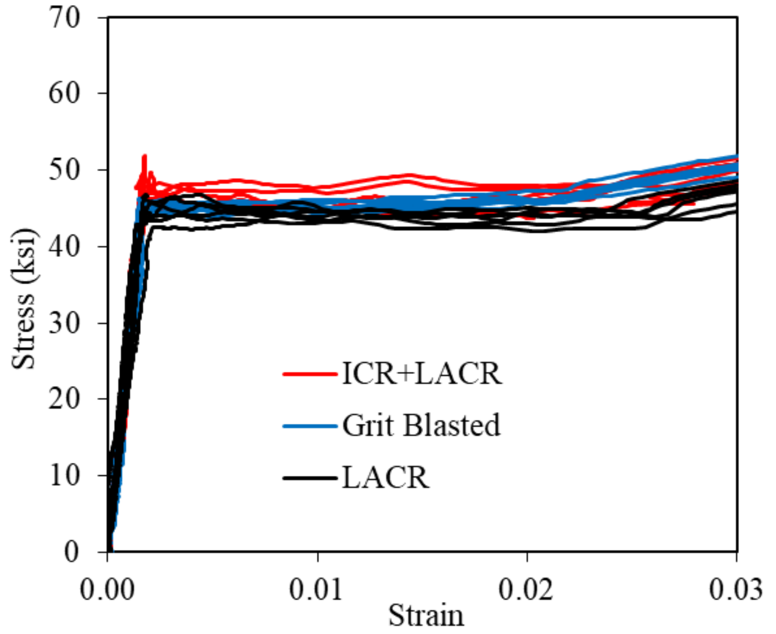
Measurements During LACR & ICR

- Steel temperature measurements
- No quenching, air cooled

Tension Testing

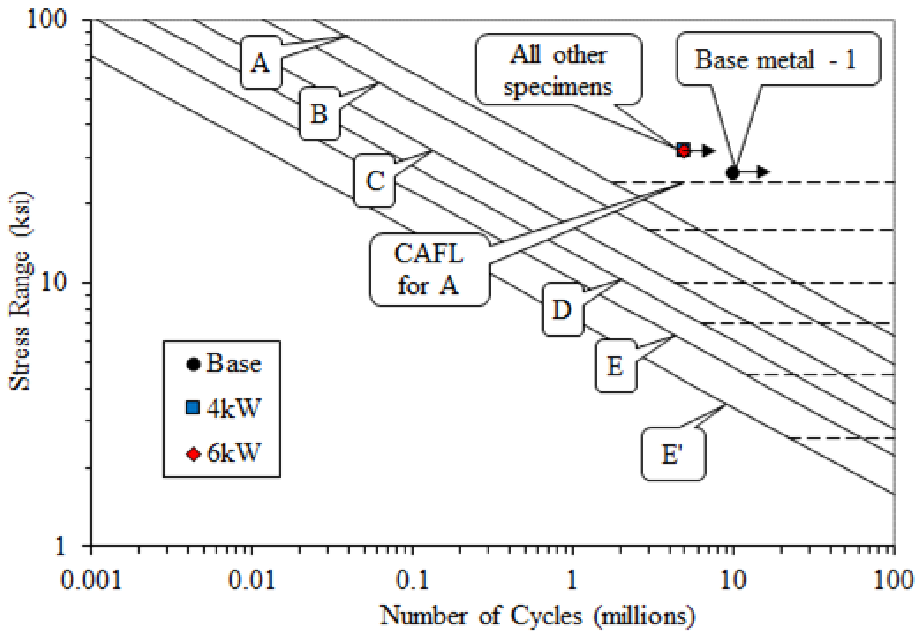
- Cut samples out of plates exposed to (a) grit blasting, (b) LACR, & (c) ICR+LACR
- 6 tests each, according to ASTM E8
- All samples met specifications





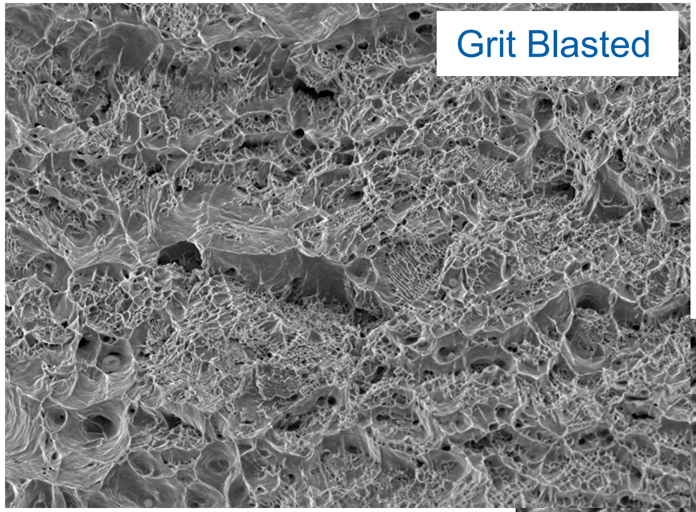
Fatigue Testing

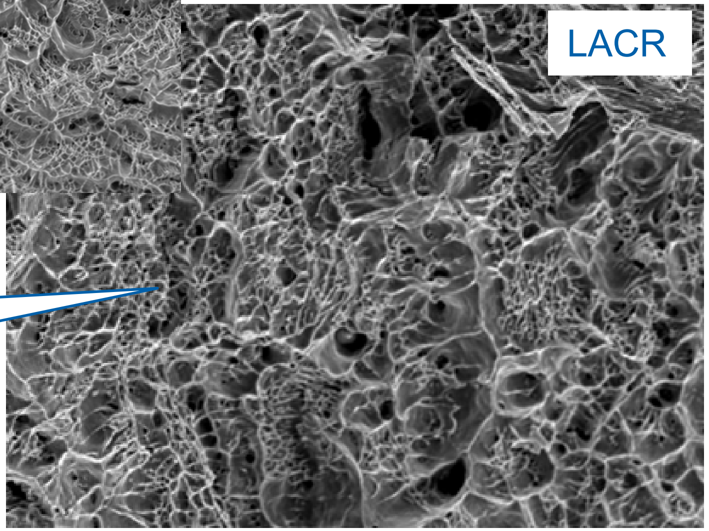
- Testing on ICR+LACR specimens ongoing
- Previous tests on LACR at different power levels (4 & 6 kW)
- 6 tests each, stress range = 26 or 32 ksi
- No failures, all runouts
- No detriment to fatigue performance, all Category A details



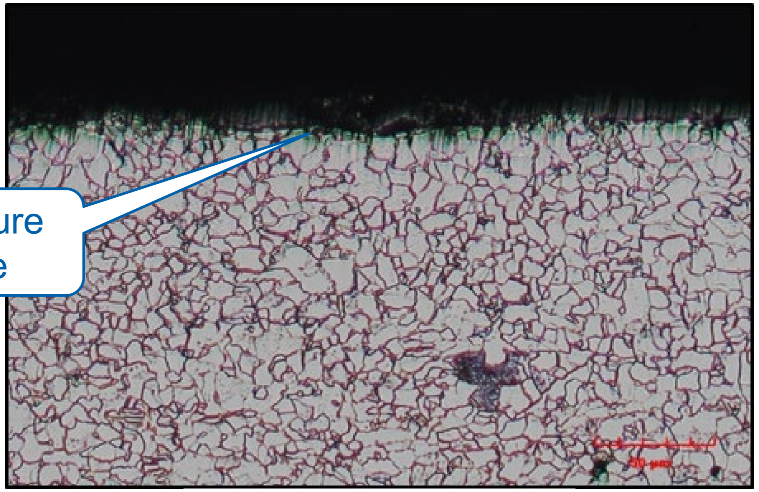
Metallography

- **Examined fracture surfaces, microstructure, and hardness**
  - **No detrimental effects**





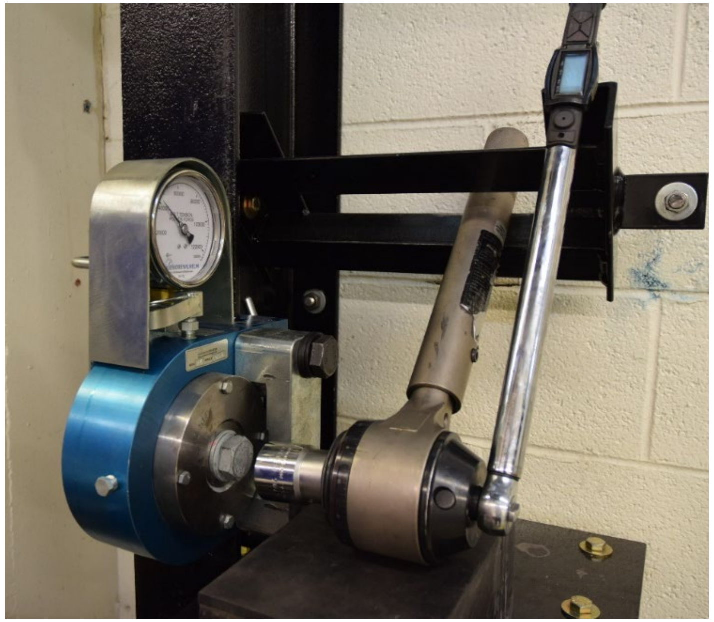
Fracture Surfaces



Microstructure

Bolt Testing

- 4 Grade A325 bolts subjected to ICR
- Rotational capacity (ROCAP) tests according to ASTM F3125 Annex A2
- All bolts met specifications



LASER ABLATION AND INDUCTION COATING REMOVAL:

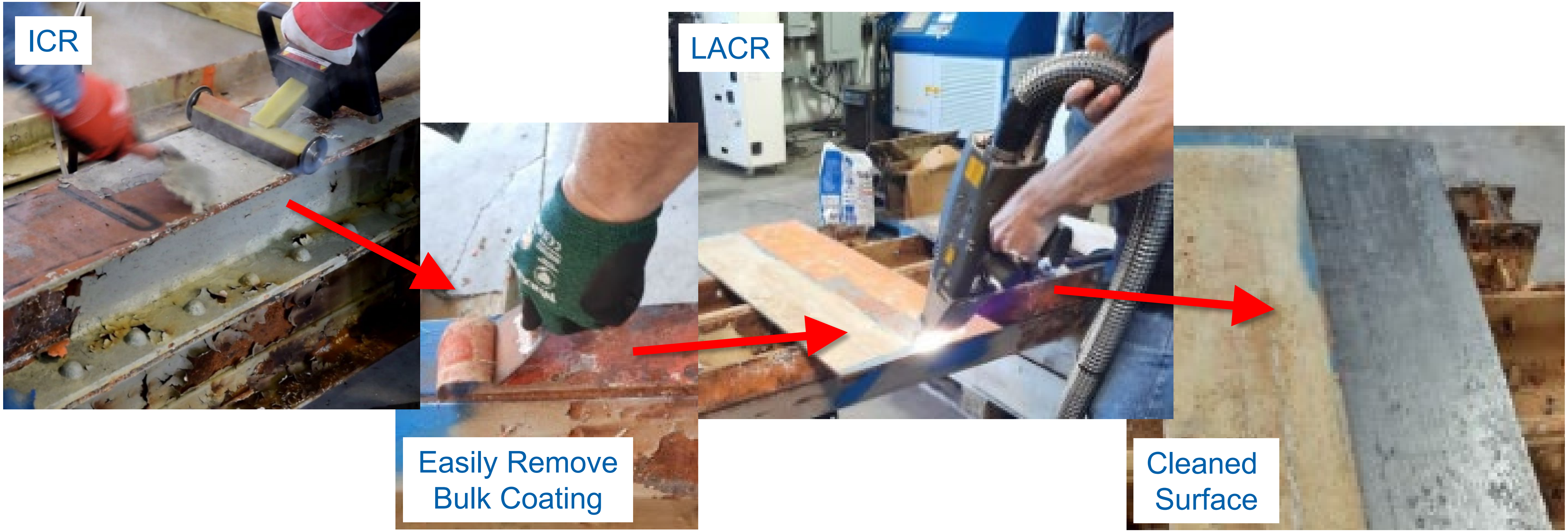
WRAP UP

Jason T. Provines, P.E.
Virginia Transportation Research Council, VDOT

August 21, 2023

Innovative Coating Removal Techniques

- **ICR and LACR are complementary techniques to safely and effectively remove bridge coatings**



Conclusions

Adhesion

- ICR + LACR surfaces show equivalent adhesion to grit blasting
- ICR + LACR effectively cleans the surface without thermal damage

Environmental and IH

- Lead exposure from LACR/ICR much less than grit blasting
- Controls needed for both LACR & ICR (fume extraction, area, PPE, etc.)

Effect on Steel Properties

- Max surface temp was 120ºF for LACR & 325ºF for ICR
- No detrimental change in properties for steel plates or bolts

Available Resources

VTRC Documents

- *Innovative Coating Removal Techniques for Coated Bridge Steel*. Fitz-Gerald et al., VTRC No. 20-R1, Virginia Transportation Research Council, 2019.
- *Evaluation of a Continuous Laser Ablation Coating Removal Device for Steel Bridges.* Provines et al., Transportation Research Record, 2676(5), 1/22/2022.

UVA Documents

- *Implementation of Laser Ablation Coating Removal Technique for Steel Components on VDOT Bridges*, William Moffat, M.S. Thesis, 2019.
- *The Effects of Laser Ablation Coating Removal on the Fatigue Performance of a High Strength Structural Steel*, Md Shamsujjoha, Ph.D. Dissertation, 2017.

Related Documents

- *Laser Cleaning*, Final Panel Project Report, Agreement 2005-341-049, Newport News Shipbuilding, 7/31/2018.

Towards Implementation

AASHTO AII Site

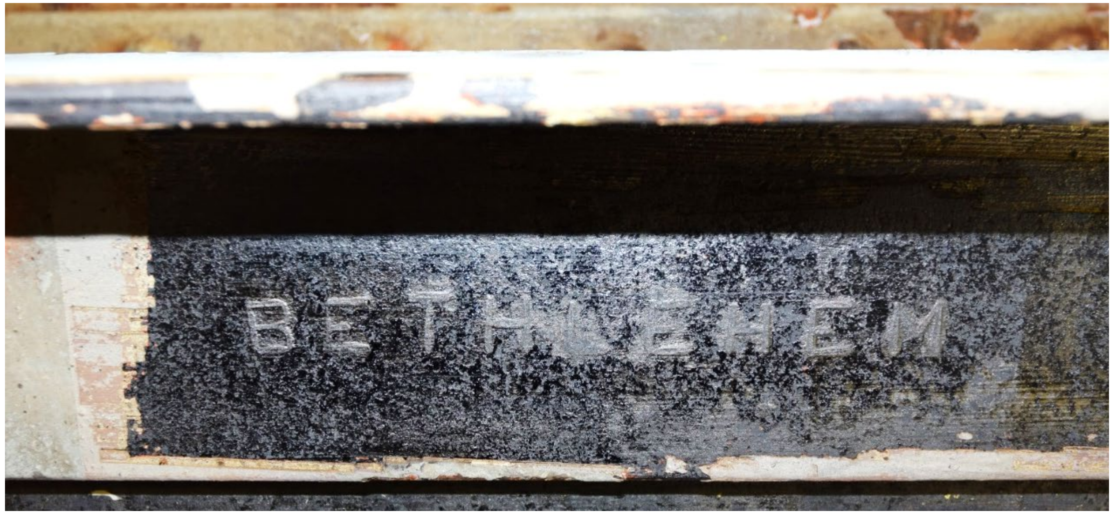
https://aii.transportation.org/Pages/Laser-Ablation-Coating-Removal.aspx

- VDOT Alternate Bid Item Special Provision (pdf)
- VDOT Equipment LACR ICR Acceptance Criteria (pdf)
- VDOT LACR Standard Operating Procedure Template (pdf)

Future VDOT Field Work

- Identify bridges with planned coating removal work
- Use ICR + LACR on beam ends, then recoat

Thank You



ICR then LACR removed several coating layers on a 1940s steel beam, which revealed the name of steel company that originally produced the bridge beams, Bethlehem Steel.

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Question and Answer Session

AASHTO Innovation Initiative

Thank you!

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