Evaluation of a Portable Laser Depainting System

Marta A. Jakab

Southwest Research Institute

Report Documentation Page

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Outline

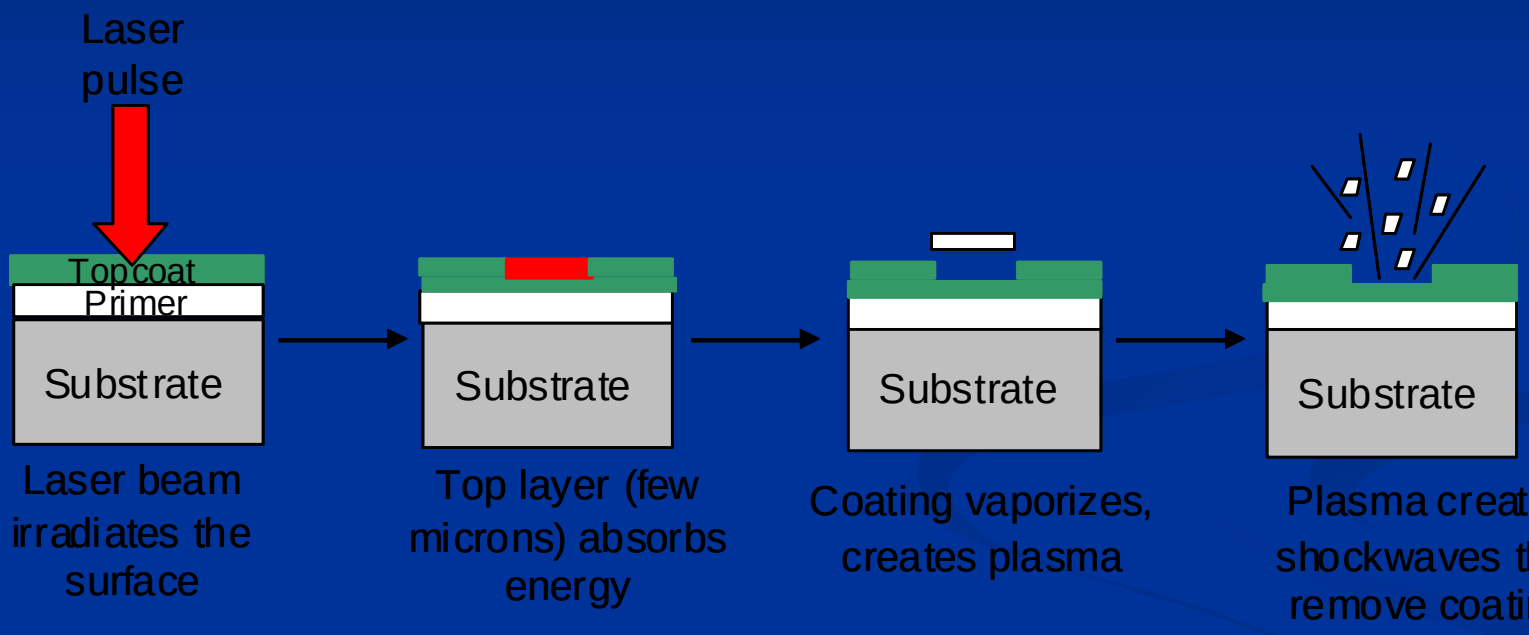
- Introduction
- Evaluation Criteria
- Evaluation of CARC coated 1018 Carbon Steel Substrate
- Removal of Corrosion Products
- Summary

Introduction

Types of hazardous waste generated by conventional paint removal processes:

Current Process	Hazardous Waste
Chemical Stripping	methylene chloride, methyl ethyl ketone
Dry Media Pressure Blasting	sand media and coating residue
	plastic media and coating residue
	wheat starch and coating residue
Hand Sanding	coating residue

Mechanism of Laser Ablation



Performance Evaluation Parameters*

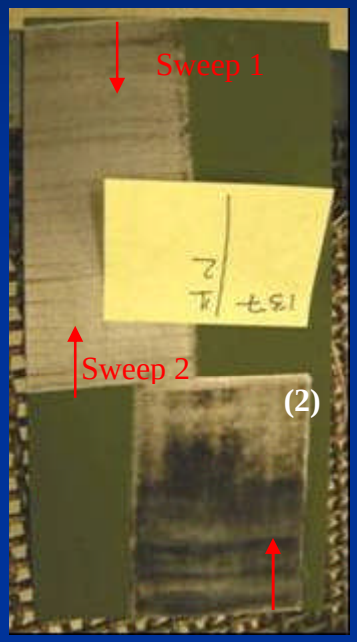
- Coating Removal Efficiency
- Coating Removal Rate
- Surface Erosion and Surface Roughness
- Thermal Load during Laser Depainting
- Adhesion Properties Following Laser Paint Removal and Re-coating
- Microhardness
- Electrochemical Properties
- Corrosion Product Removal

* *compared with sandblasting*

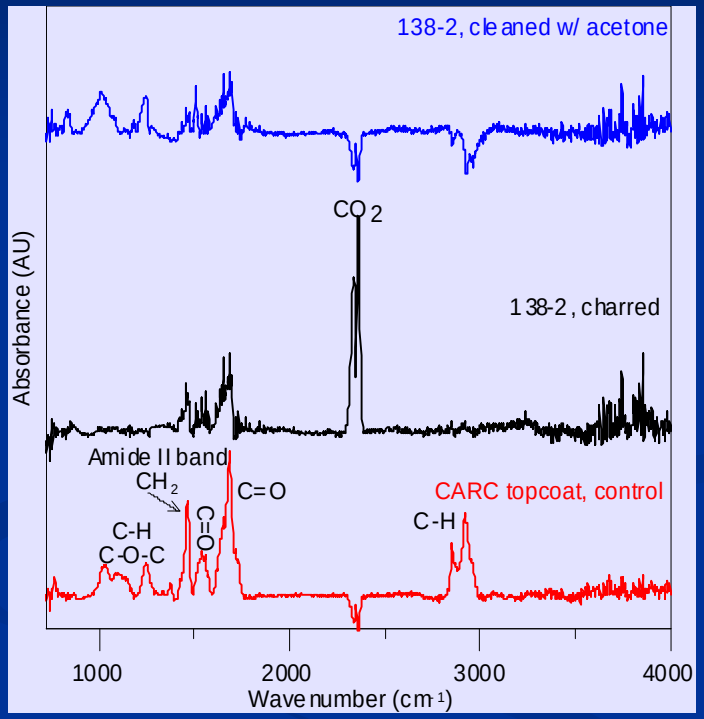
Experimental Details

- Substrate: 3 in. by 6 in. 1018 Carbon Steel Panel
- Coatings used in this evaluation:
  MIL-P-53030 water reducible primer
  MIL-DTL-64159 waterborne CARC topcoat
- Measurement of thermal load: thermocouples attached to back-side of panel
- Evaluation of removal of corrosion product: uncoated panels exposed to GM9540P environment for 1-3 days

Coating Removal Efficiency



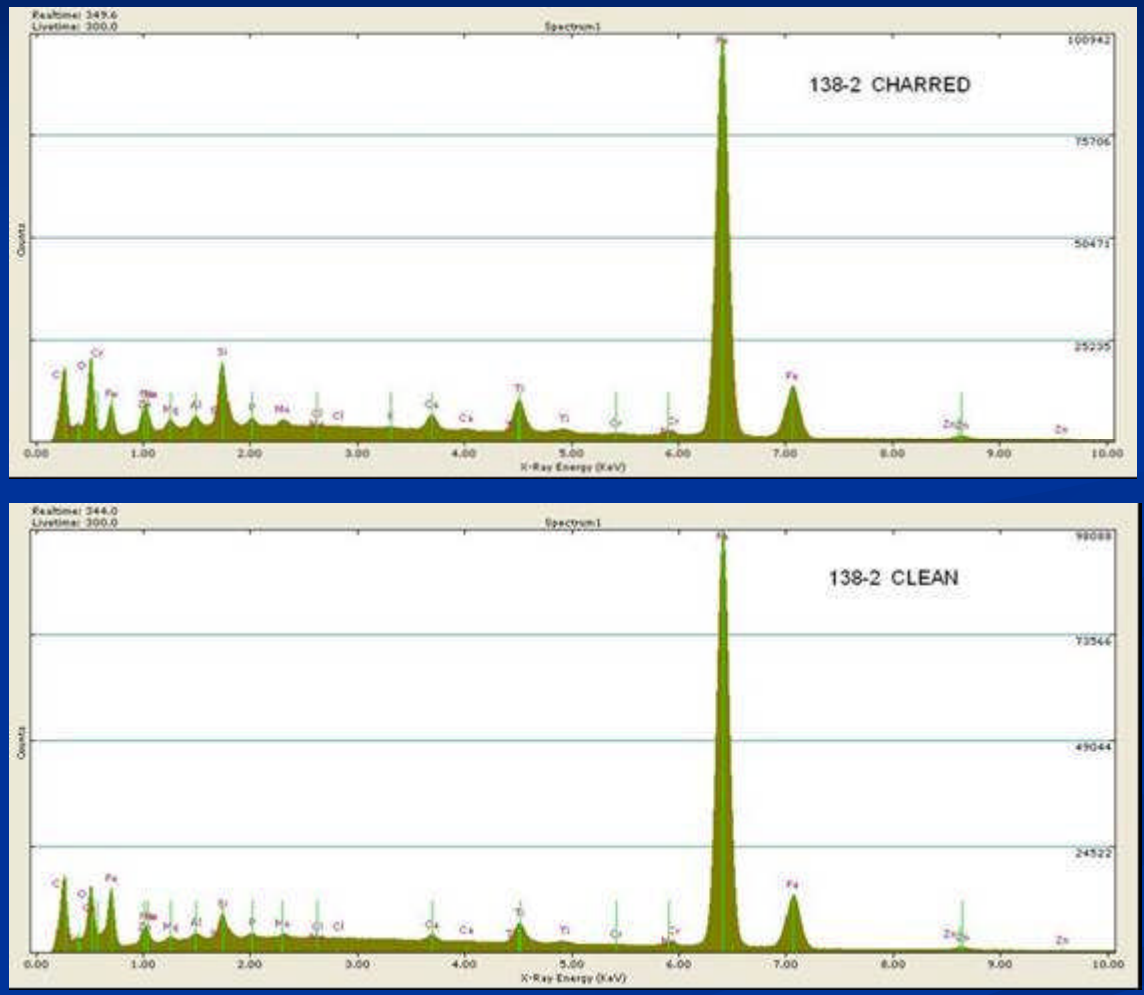
Cleaning with acetone



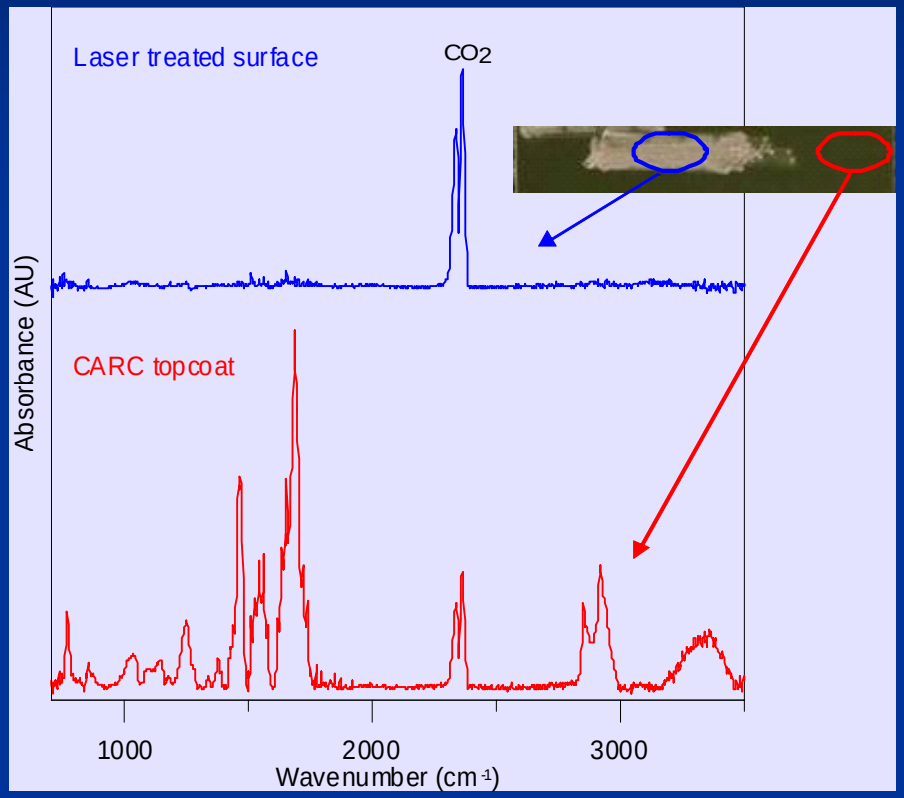
Laser parameters:

voltage: 3.61 kV, current: 0.75A, beam energy: 0.79 J/pulse, gas mixture: 12.5 % CO_2 + 22.5 % N_2 + bal. He, distance of end effector from test panel: 3.81 cm

Coating Removal Efficiency



Coating Removal Efficiency



If no charring is present, coating is removed completely from the surface.

Charring can be avoided by optimizing the laser fluence (optimum range: 8-12 J/cm^2).

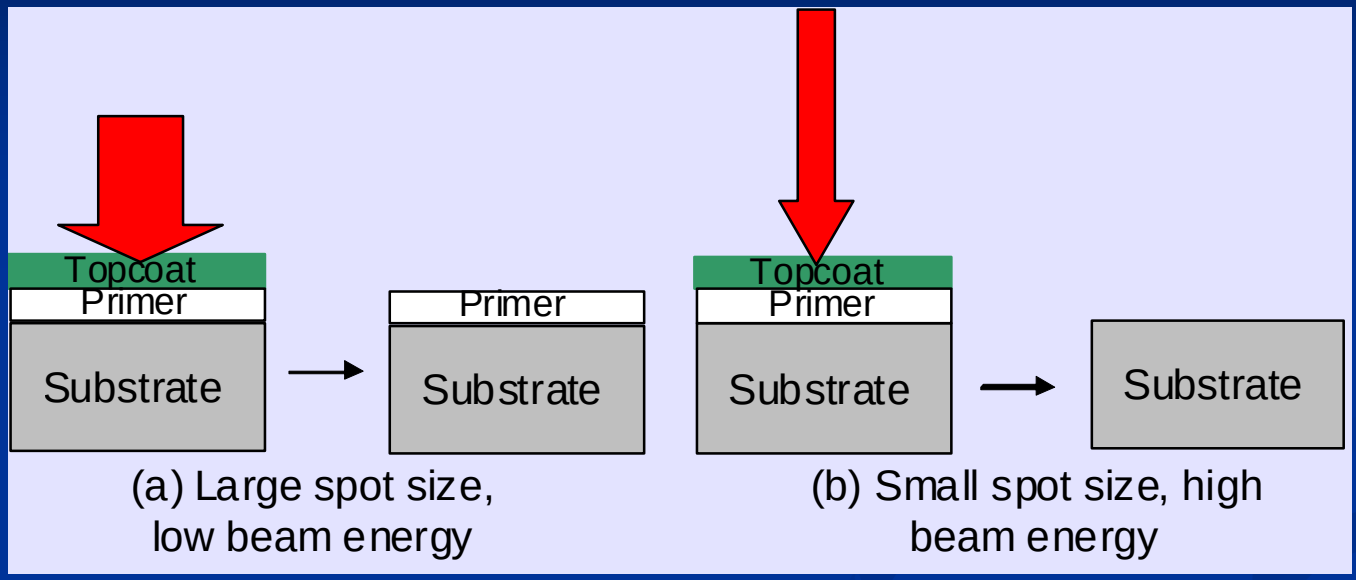
Coating Removal Rate

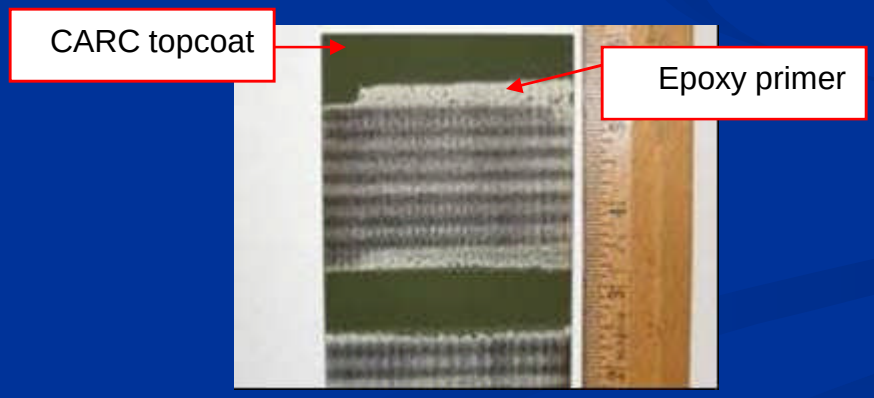
Test ID#	Voltage (kV)	Current (A)	Gas Mixture	Pulse Energy (J/pulse)	Panel Distance from End Effector (cm)	# Sweeps	Paint Removal Rate (cm^2/min)
137-1	3.61	0.75	A†	0.79	3.81	2	7.61
137-2					1.27	1	6.84
138-1	3.61	0.75	A†	0.79	1.27	1	20.12
138-2					1.91	1	13.83
36-1-1	3.52	0.52	B†	0.90	1.91	1	18.02
36-1-2					0.32	1	8.80
60-1-1	3.52	0.52	B†	0.90	1.27	2	6.24
60-1-2					2.54	2	3.21
120-1-1	3.90	0.45	B†	1.10	1.91	1	4.30
120-1-2					1.83	N/A*	N/A
D-1-1	3.52	0.52	B†	0.90	1.27	1	9.53
D-1-2					1.91	1	6.35

*: test was stopped prior to completion due to problems with laser

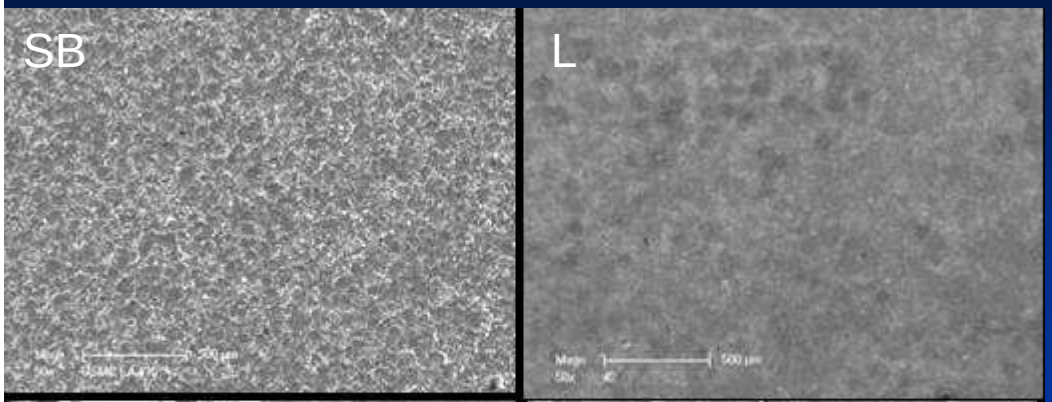
Paint removal rate using gritblasting: 4.5 ± 1.1 cm^2/min

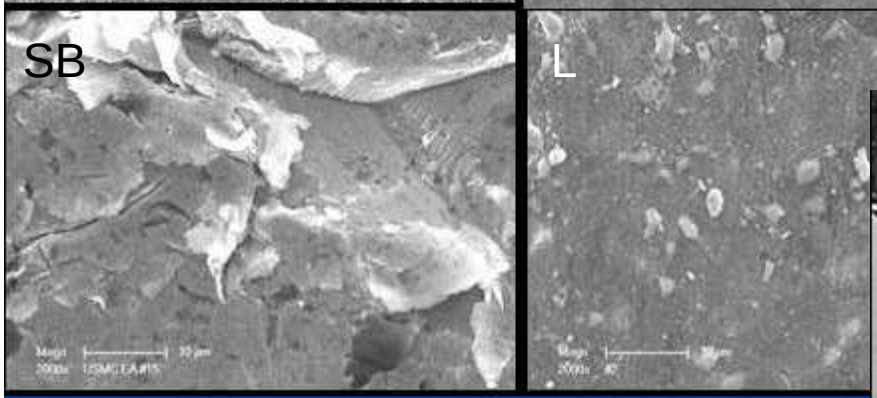
Selective Paint Removal

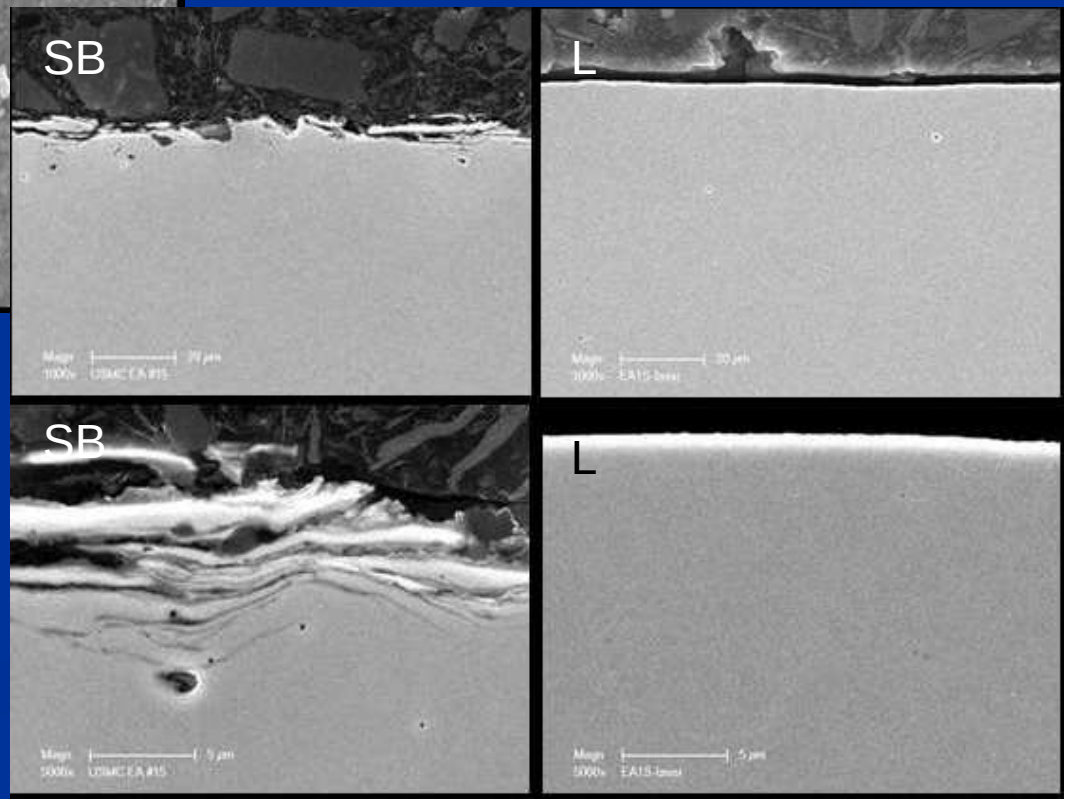




Surface Erosion and Surface Roughness



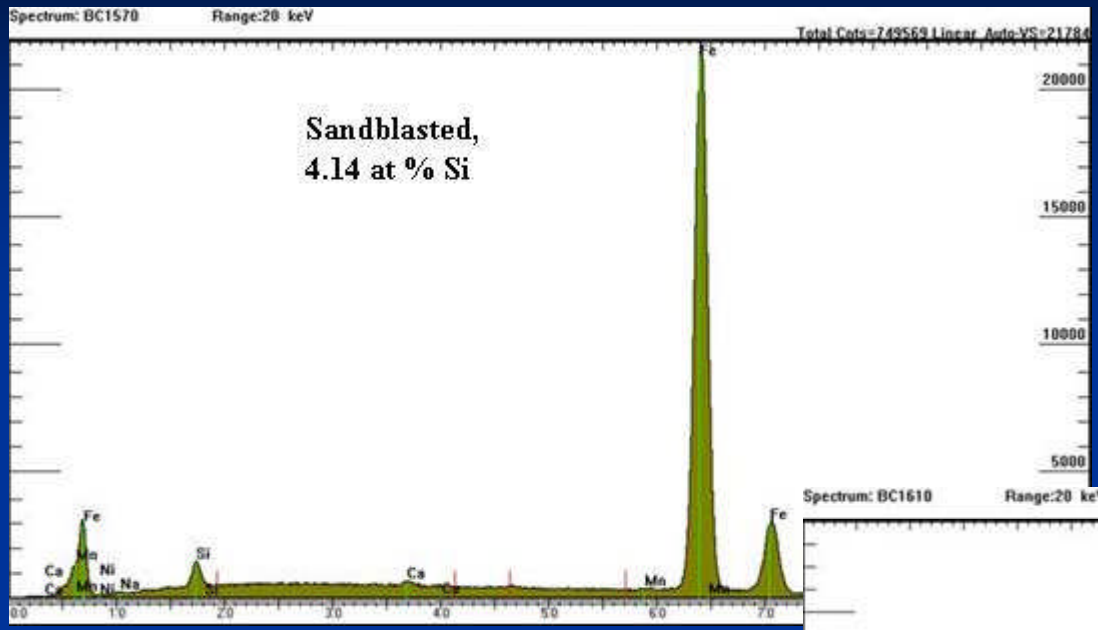


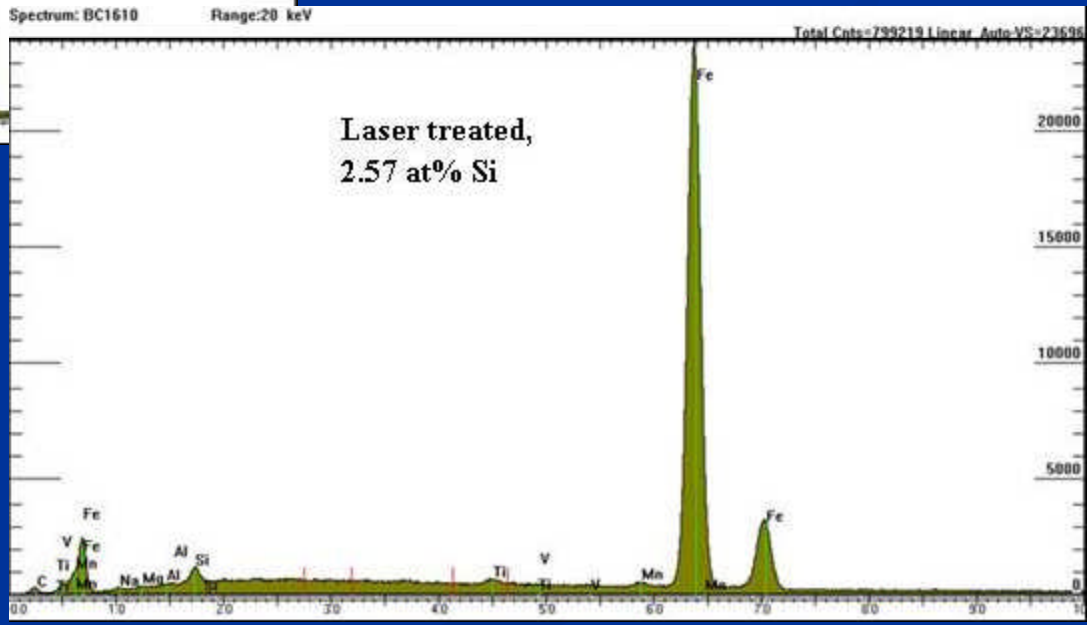


Sandblasted: 6.180 um

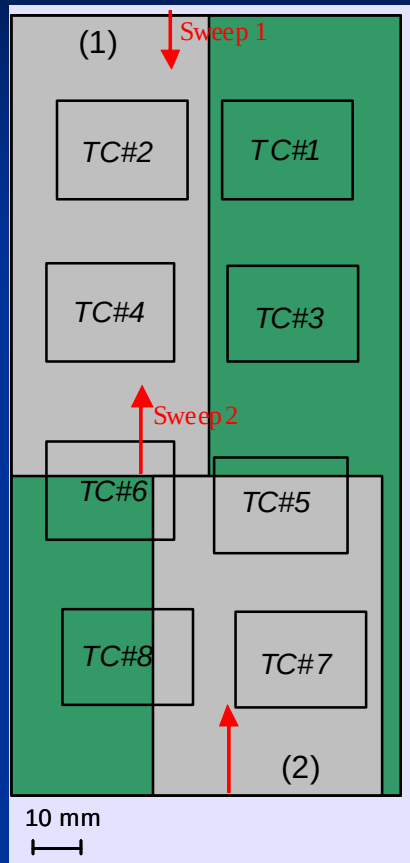
Laser Treated: 0.687 um

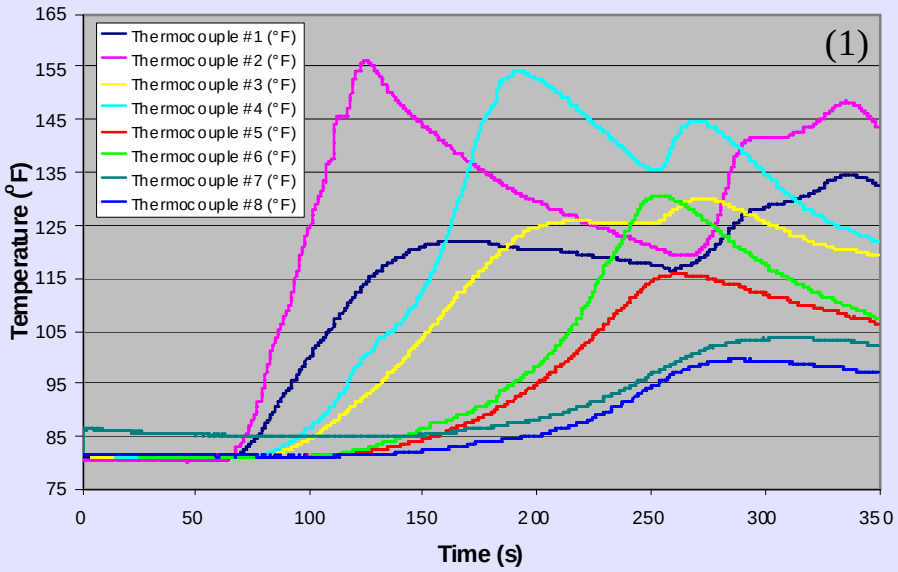
Surface Contamination

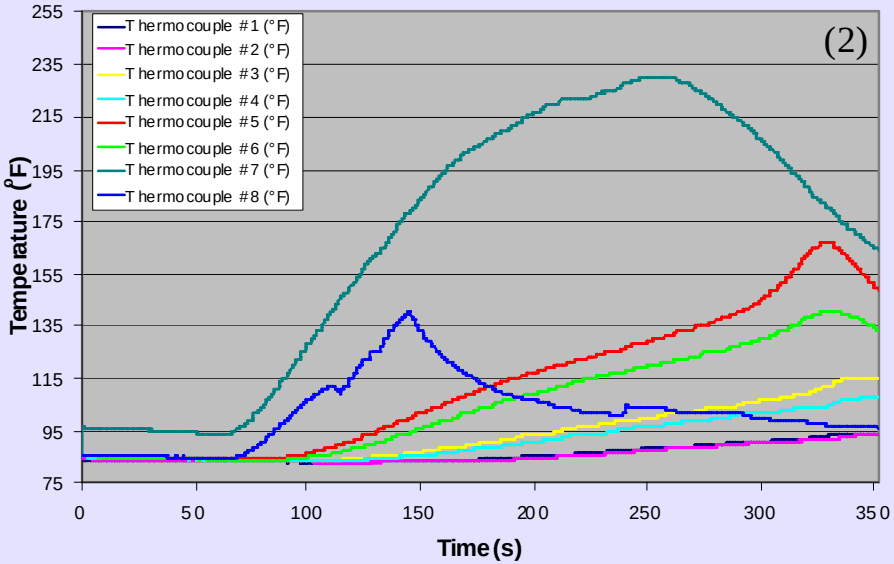




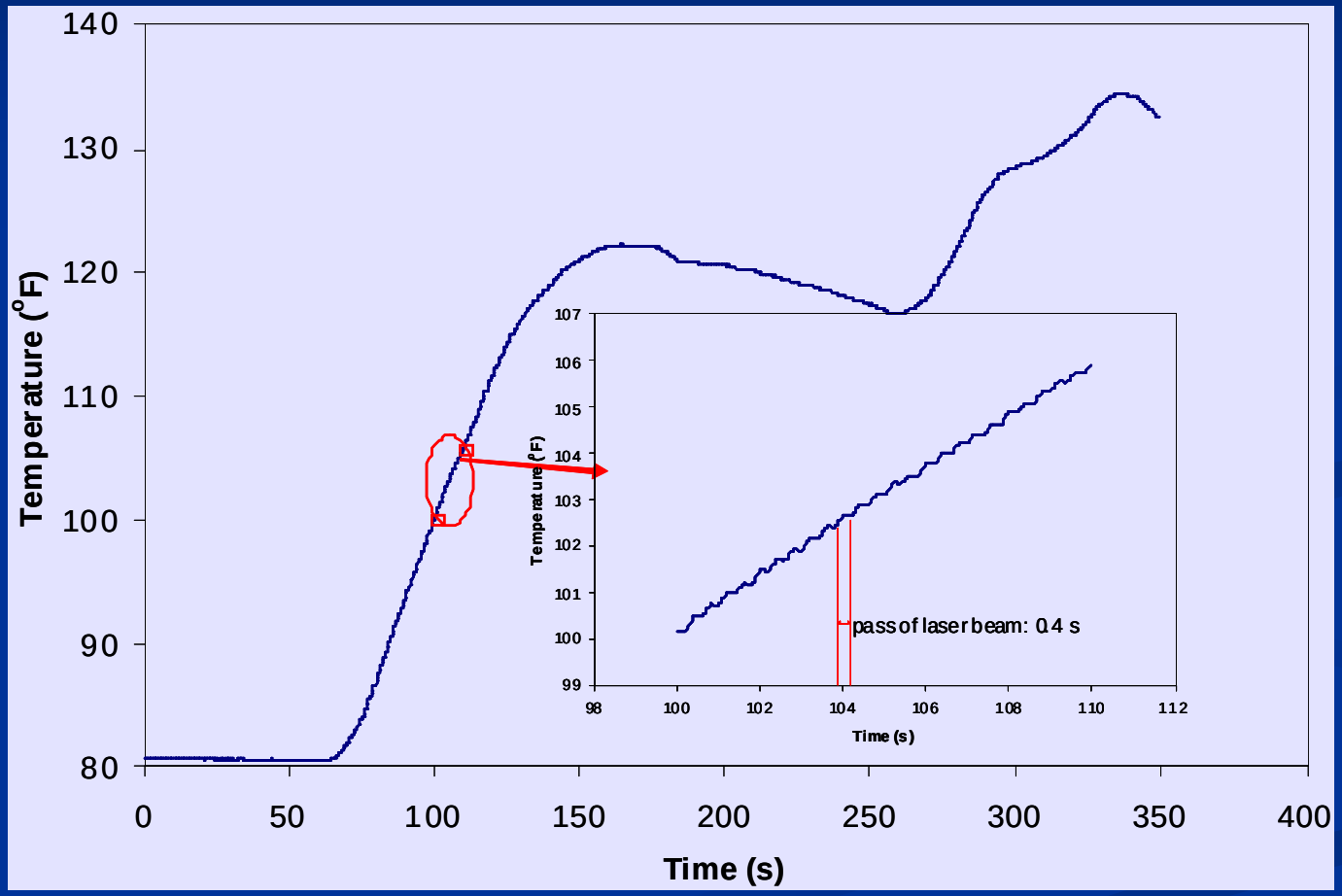
Thermal Load During Laser Depainting







Thermal Load During Laser Depainting



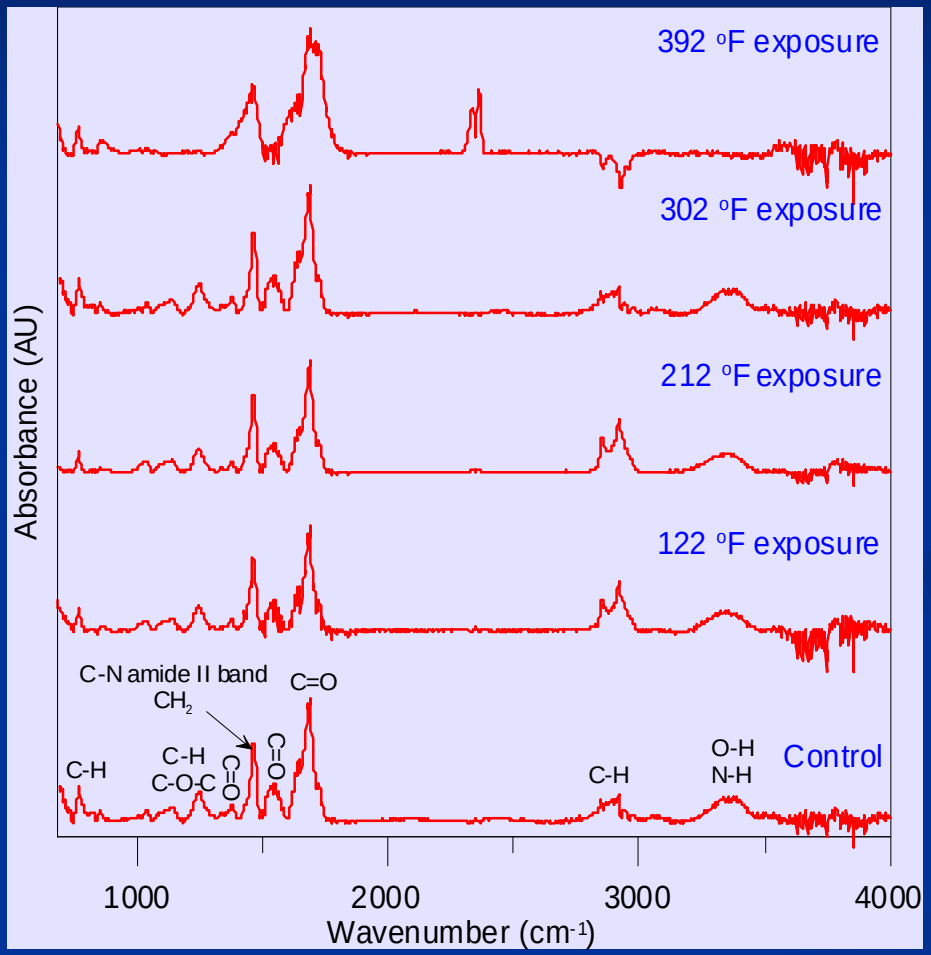
Thermal Load During Laser Depainting

Test ID	Pulse Energy (J/pulse)	Sample Distance from End Effector (cm)	# Sweeps	T_{max} (°F)
137-1	0.79	3.81	2	156.25
137-2		1.27	1	230.71
138-1	0.79	1.27	1	128.06
138-2		1.91	1	160.17
36-1-1	0.9	1.91	1	176.68
36-1-2		0.32	1	251.76
60-1-1	0.9	1.27	2	274.84
60-1-2		2.54	2	236.19
120-1-1	1.1	1.91	2	N/C†
120-1-2		1.83	N/A*	181.82
D-1-1	0.9	1.27	1	199.60
D-1-2		1.91	1	219.83

† N/C: not collected

* N/A: not available, the test was terminated prior to completion of second sweep.

Thermal Resistance of CARC



No changes in FTIR spectrum (chemical bonds) up to 302 °F.

No damage is expected to surrounding coated areas.

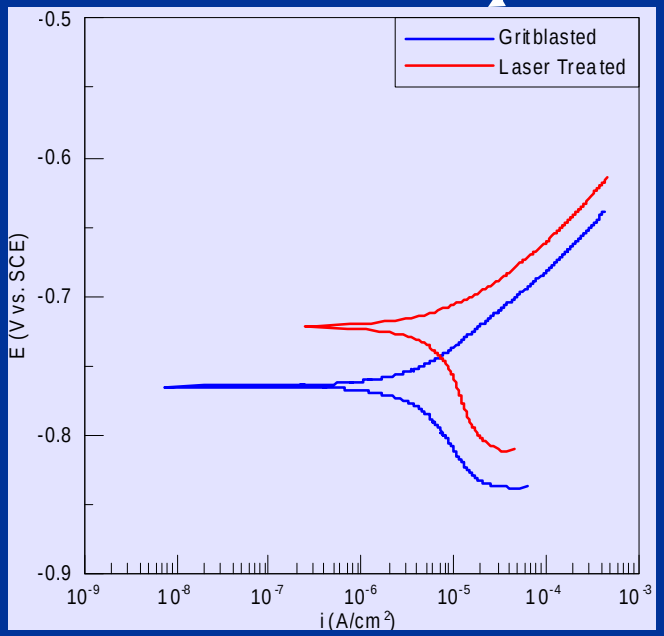
Adhesion and Microhardness

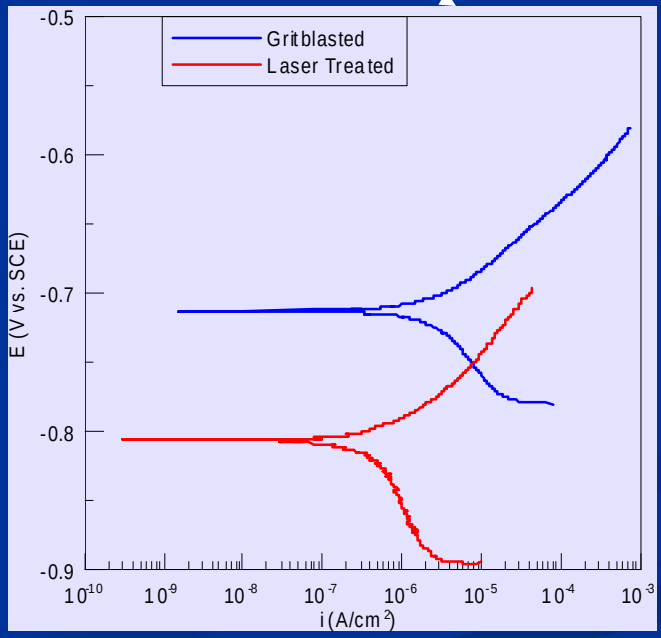
Paint Removal Method		ASTM D3359, Method B	
		Average	Standard Deviation
None (control)		3.50	0.55
Gritblasting		3.75	0.50
Laser Treatment	Clean Area	3.50	0.70
	Clean Area*	3.00	0.00
	Charred Area*	3.50	0.7

Paint Removal Method	Vickers Microhardness (ASTM E384, 100 g load)	
	Average	Standard Deviation
None (control)	110.4	1.8
Gritblasting	107.0	5.2
Laser Treatment	101.2	2.7

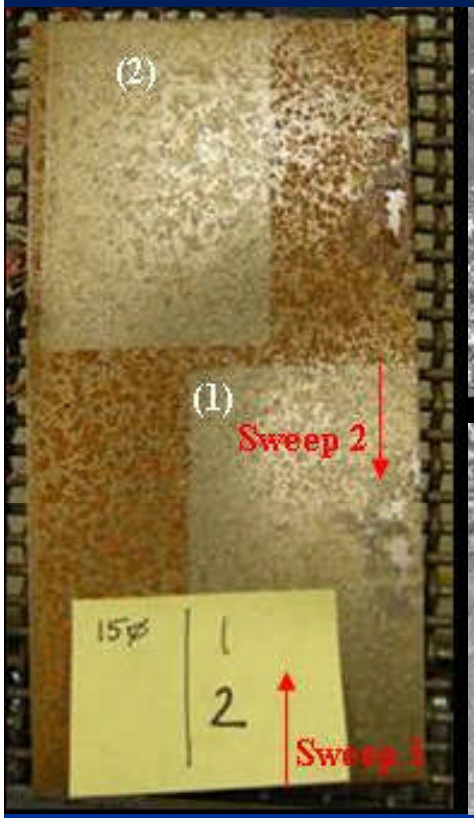
Electrochemical Properties

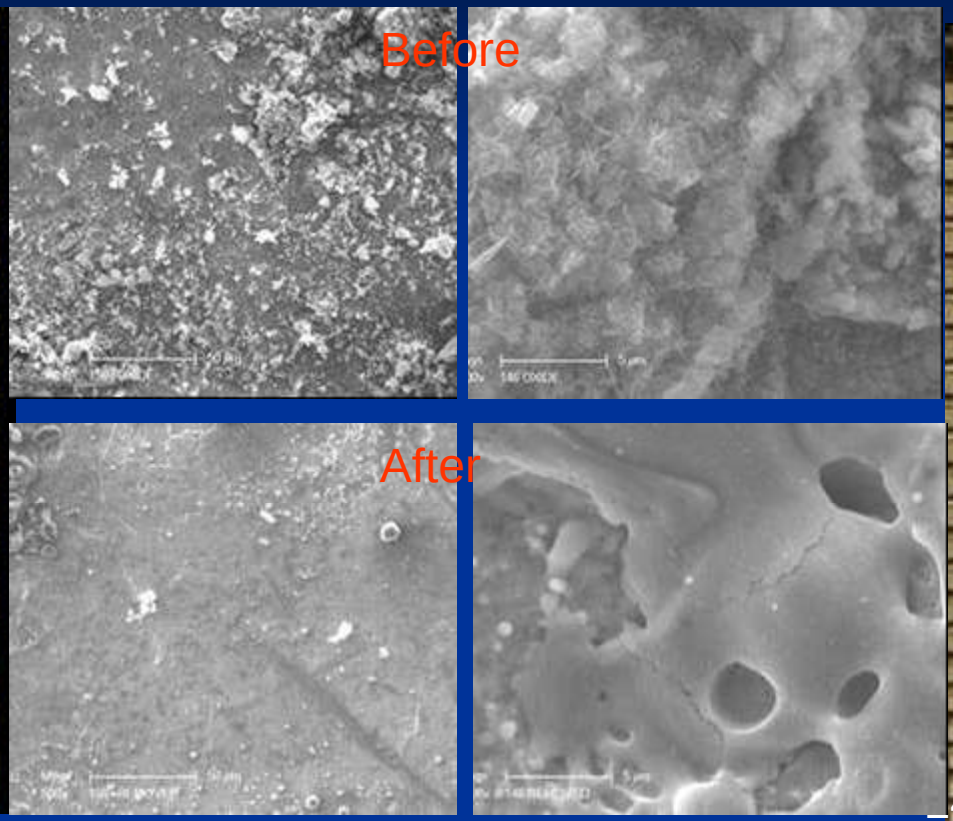
Paint Removal Method	R_p(Non-deareated), Ω	R_p(Deareated), Ω
Gritblasting	1877 ± 73	497 ± 14
Laser Treatment	1143 ± 190	1610 ± 40

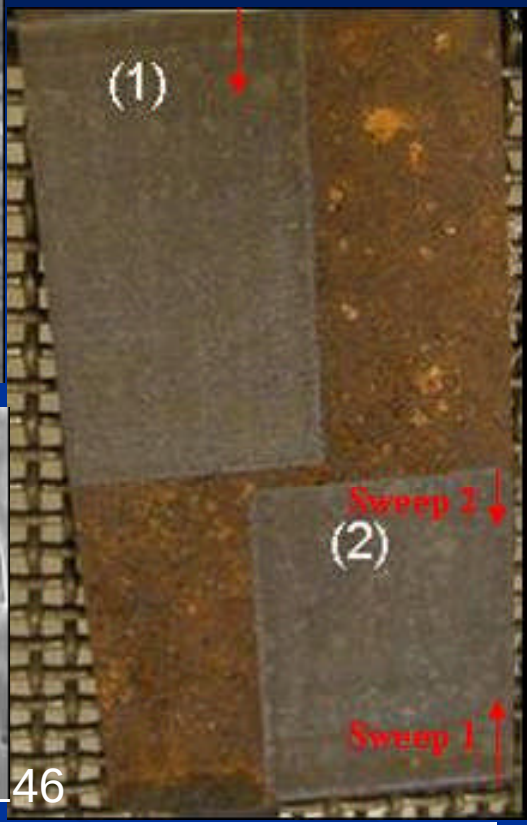




Removal of Corrosion Products



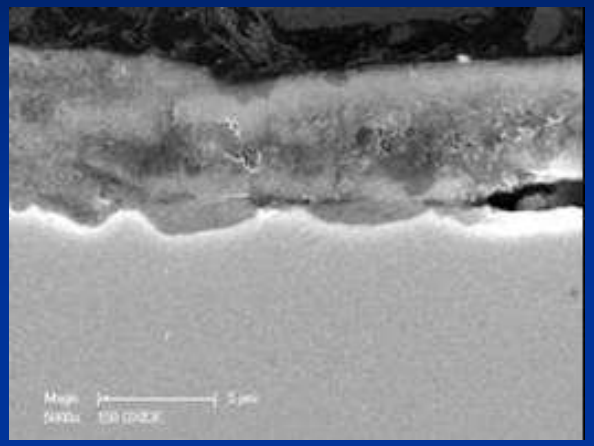




Test ID#	Scan Dist.	Scan Vel.	Laser Pulse Rep. Rate	Voltage	Current	Pressure	Pulse Energy	Gas Mixture	Panel Dist. From End Effector
150-1	150 cnts	400 cnts/s	80 Hz	3.61 kV	0.75 A	40 Torr	0.79 J/ pulse	12.5% CO_2 + 22.5 % N_2 + bal. He	0.953 cm
150-2									0.317 cm
146-1									1.270 cm
146-2									1.905 cm

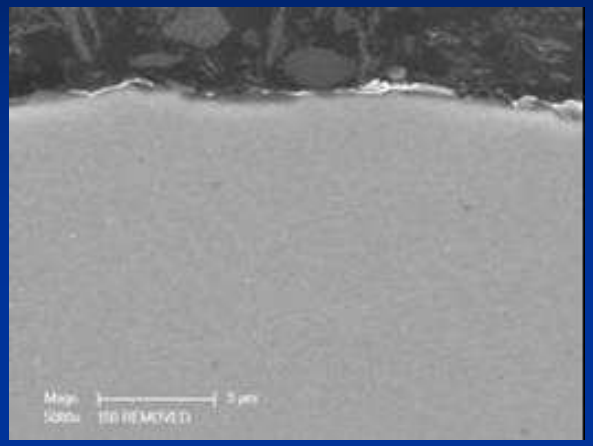
Removal of Corrosion Products

Lightly Rusted Panel:



Fe/O
= 0.72

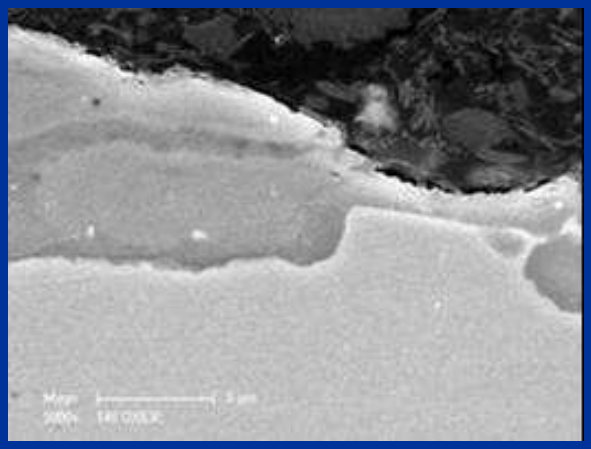
BEFORE



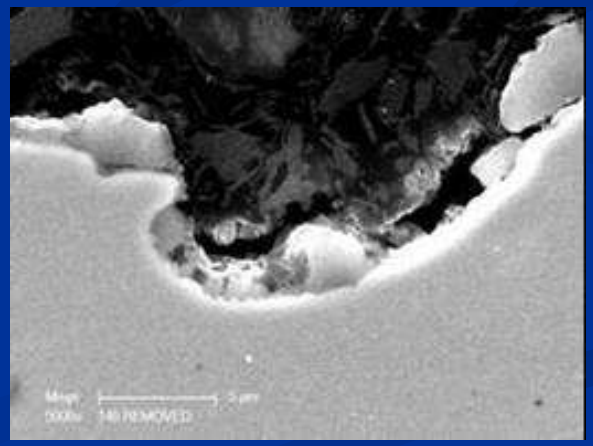
Fe/O
= 2.73

AFTER

Heavily Rusted Panel:



Fe/O
= 0.38



Fe/O
= 0.58

Thermal load during corrosion product removal: T(max) = 315.20 °F

Summary

- The laser was found to be efficient in removing CARC with coating removal rates comparable to those of sandblasting. Charring was observed in some cases during laser decoating, probably due to low laser fluence. Paint residue was found on the charred surface indicating incomplete paint removal.
- Preliminary studies of selective coating removal showed that the laser can be optimized to remove the topcoat without damaging the primer layer.
- The laser treatment did not affect the surface roughness of the test panels, while sandblasting markedly increased the surface roughness and caused significant damage to the oxide layer. The impingement of high velocity sand particles also led to Si contamination of the surface.
- Thermal load of the substrate during lasing was measured using thermocouples attached to the back surface of the test panels. The temperature of the carbon steel substrate increased with each pass of the laser beam across the surface. The maximum temperature value found during laser treatment of CARC-coated test panels did not exceed 302°F, which was determined to be the upper limit for the thermal stability of CARC.

Summary

- No effect of the laser treatment on adhesion properties of the surface was found.
- The microhardness of the laser decoated panels also did not change compared to that of as-received control and gritblasted test panels.
- No significant effect of the laser treatment was found on the electrochemical properties of the substrate.
- The investigatewd laser system was also successfully used to remove corrosion products from 1018 carbon steel. Most of the corrosion product layer was removed in case of lightly rusted surfaces, while only the top corrosion product layer was removed when heavy rust was present on the surface. The thermal loading, however, was higher during the removal of heavy rust, exceeding 302°F, which was the upper limit of the thermal stability of CARC.

Acknowledgements

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- The author acknowledges the guidance provided by Mr. Matthew Koch, USMC CPAC and Mr. Hancel Porterfield.
- The author also acknowledges the technical assistance provided by Albert Faz, Byron Chapa, Jim Riggs and Chris Wolff in the laboratory tests.