

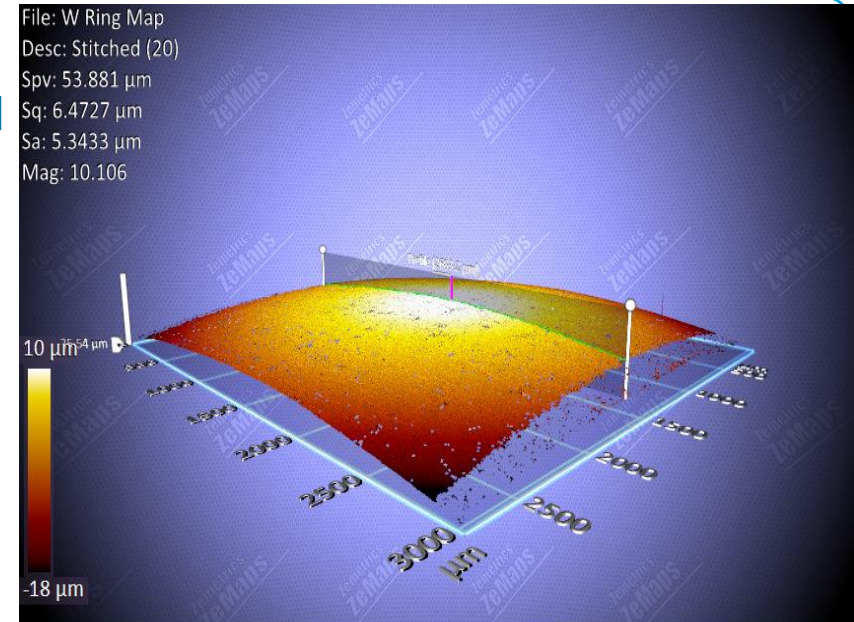
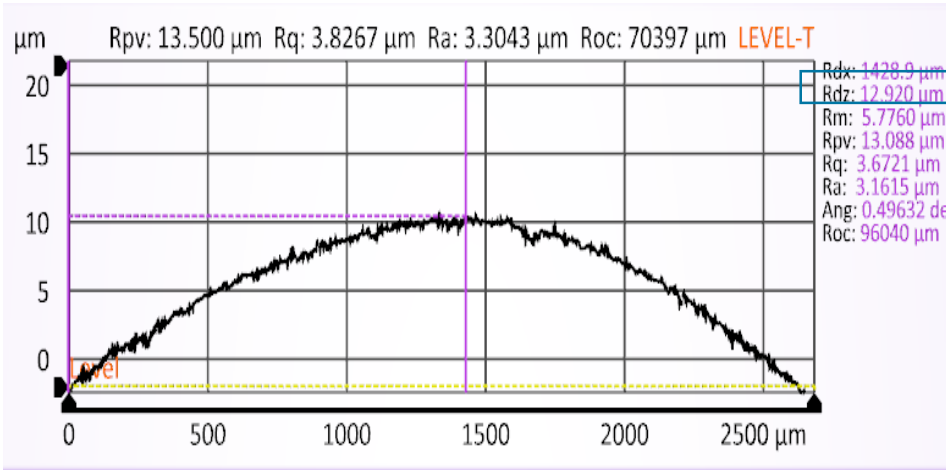
MACK T-12 “W” RING ANALYSIS

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Mack Surveillance Panel Meeting
September 20, 2016

Performance you can rely on.



Top Ring Barrel Rise



Top Ring Batch	Barrel Rise (μm)
S	24.7 – 25.8
T	11.1 – 14.9
U	13.5 – 14.8
W	11.4 – 12.9

Top Ring Coating Elemental Analysis

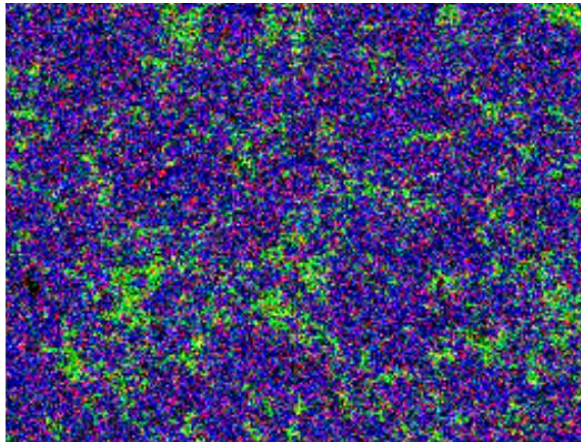


Element	“N” Ring Mole %	“P” Ring Mole %	“S” Ring Mole %	“T” Ring Seg 1 Mole %	“T” Ring Seg 2 Mole %	“U” Ring Seg 1 Mole %	“W” Ring Seg 1 Mole %	“W” Ring Seg 2 Mole %	“W” Ring Seg 3 Mole %
Cr	40.92	29.54	41.42	30.68	25.59	19.09	49.96	48.98	49.32
Mo	1.60	1.92	1.88	2.01	1.67	1.46	5.48	6.57	6.5
Ni	8.91	10.13	7.99	8.73	6.64	5.05	16.37	16.53	16.11
Al	0.62	1.20	0.25	0.54	6.88	16.91	0.28	0.26	0.27
C	41.43	42.09	42.39	48.22	46.48	48.81	22.78	22.22	23.01
O	4.51	11.18	5.18	7.50	10.05	7.65	4.43	4.5	4.18
Si	0.18	1.06	0.55	0.77	0.60	0.79	0.5	0.64	0.35
Zn	0.40	0.48	0.35	0.59	0.38	0.25	0.2	0.3	0.25

- Aluminum levels found in the “T” & “U” batch rings are not present in the “W” batch ring
- Coating alloy metals are more prominent in the SEM analysis due to the reduction of pores in the coating structure

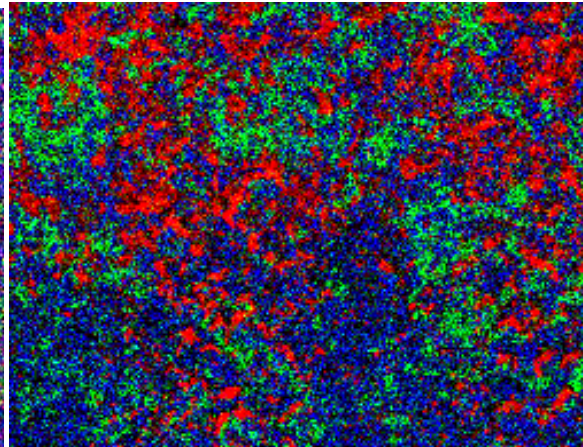
Top Ring Coating Elemental Analysis

“S” ring



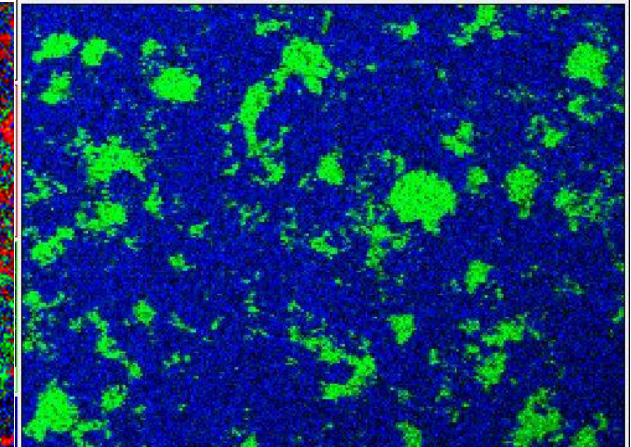
0.2 mm

“U” ring



0.2 mm

“W” ring



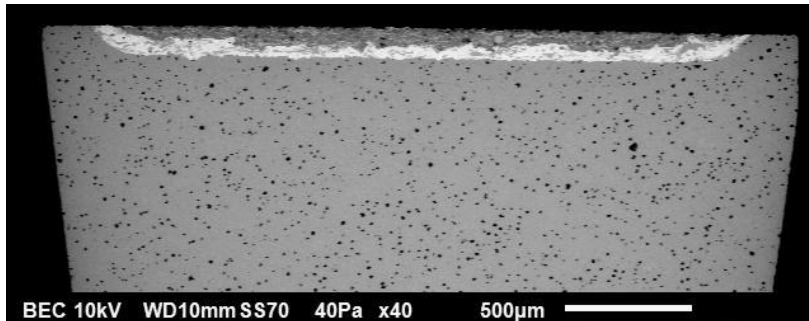
0.2 mm

Red = Al, Blue = Cr, Green = Mo

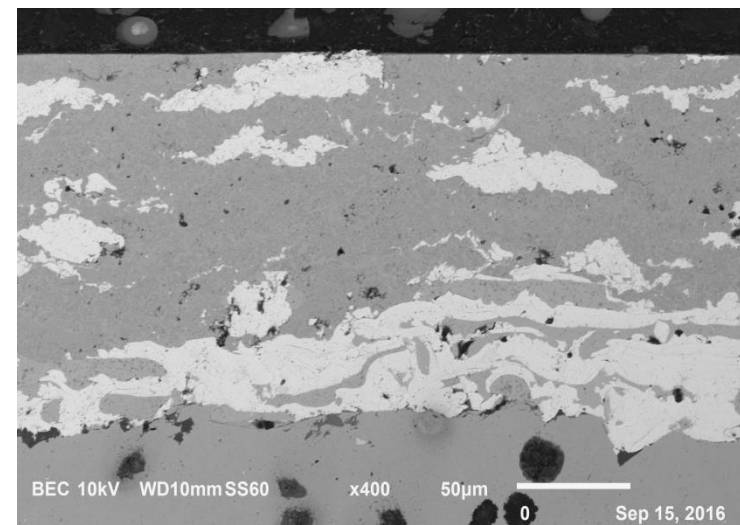
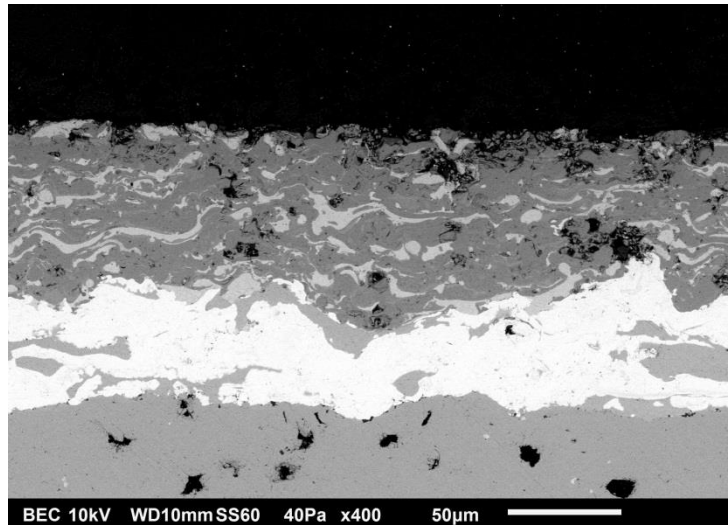
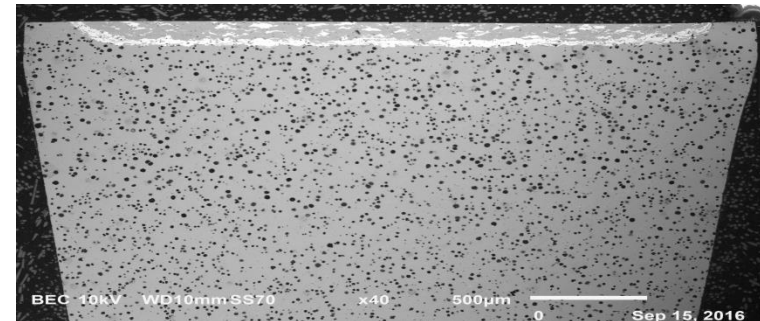
- Surface Aluminum present in the “U” batch ring is no longer present in the “W” batch ring.
- Larger Mo-rich domains are present in the coating structure of the “W” batch ring than of previous batches.

Cross Section Analysis of Rings

“U” ring

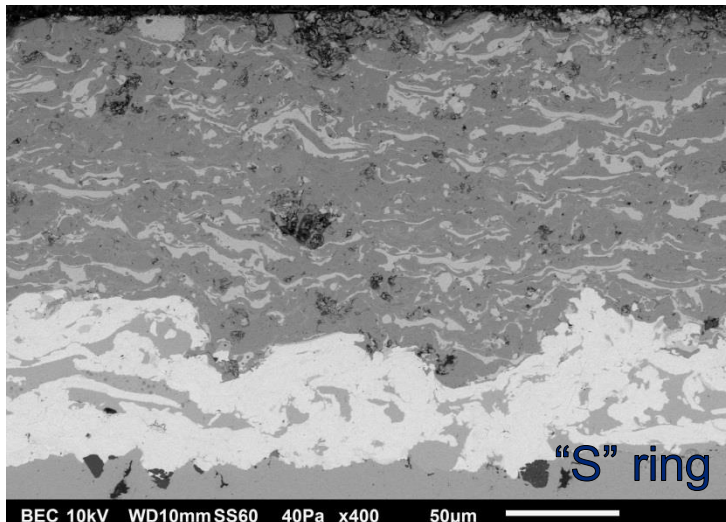
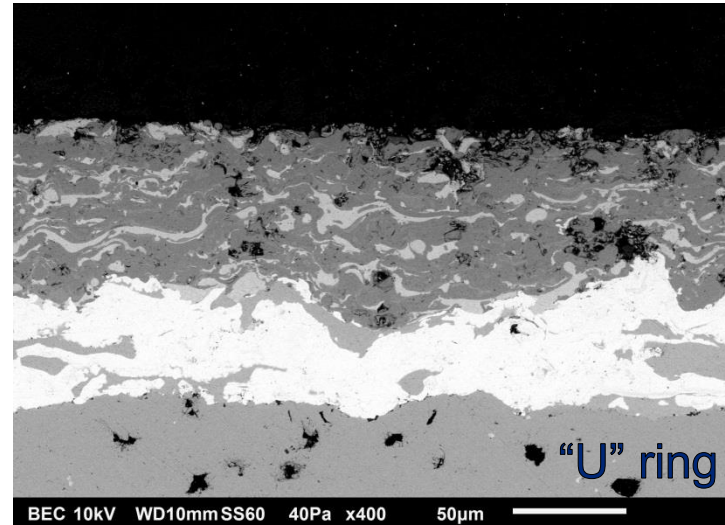
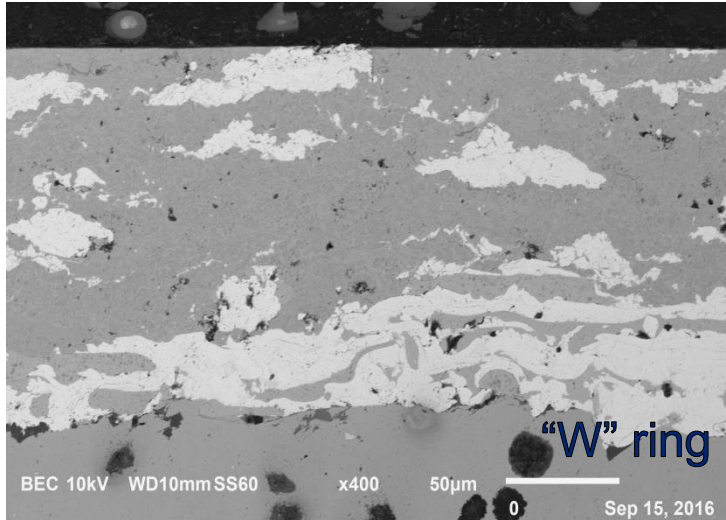


“W” ring



- Coating structure has changed with the new “W” batch ring

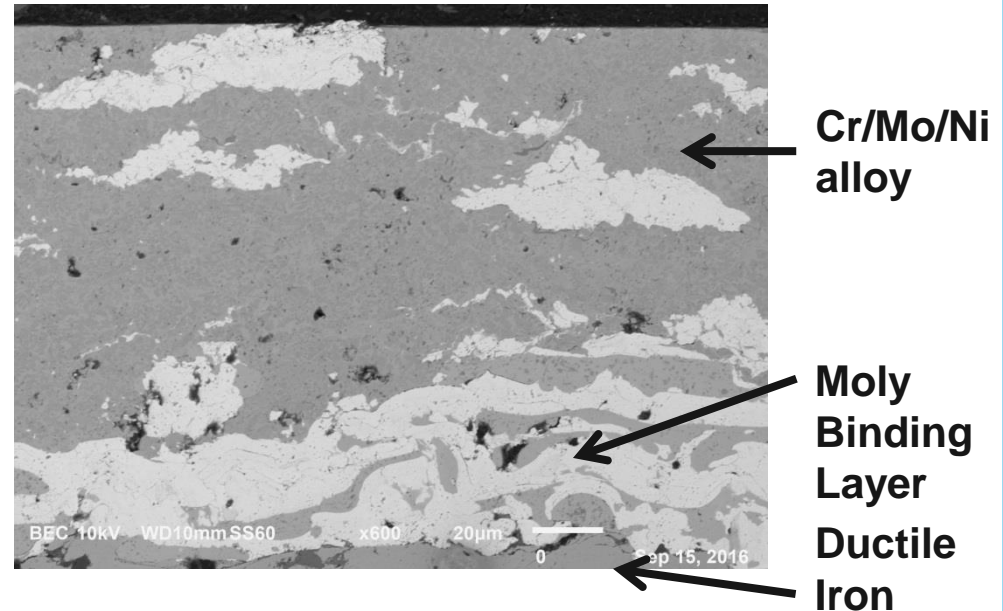
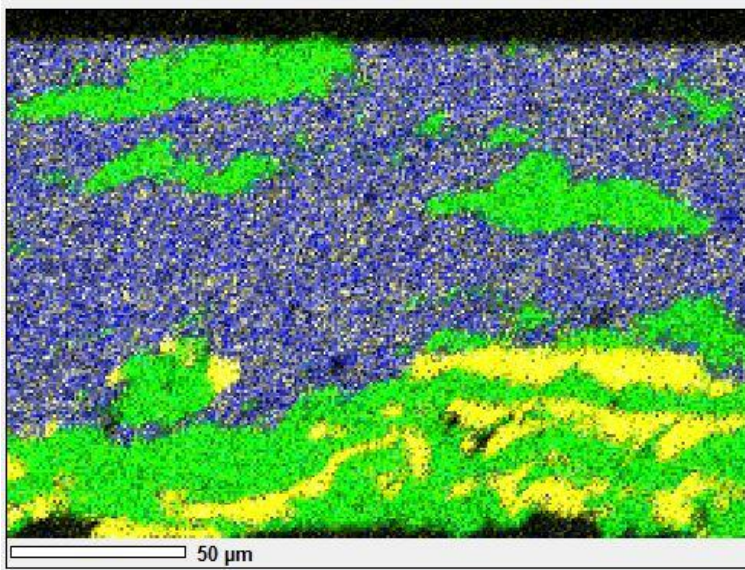
Cross Section Analysis of Rings



Ring Batch	Coating Thickness (µm)
S	200
U	127
W	154

- Coating in “W” batch is extremely smooth compared previous batch rings due to loss of pore structure
- Mo alloy domains are larger and less interspersed in “W” batch ring

Cross Section Analysis W-ring

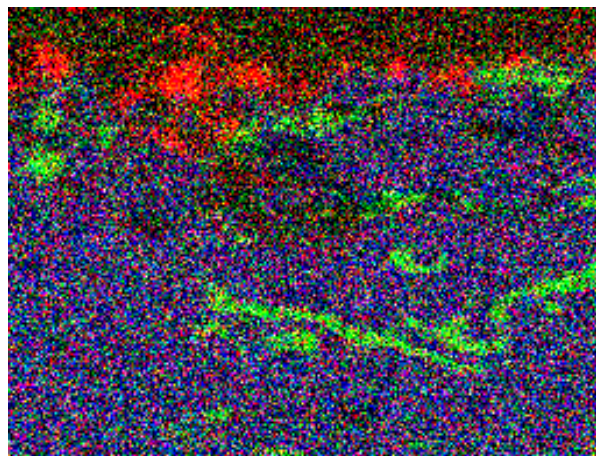
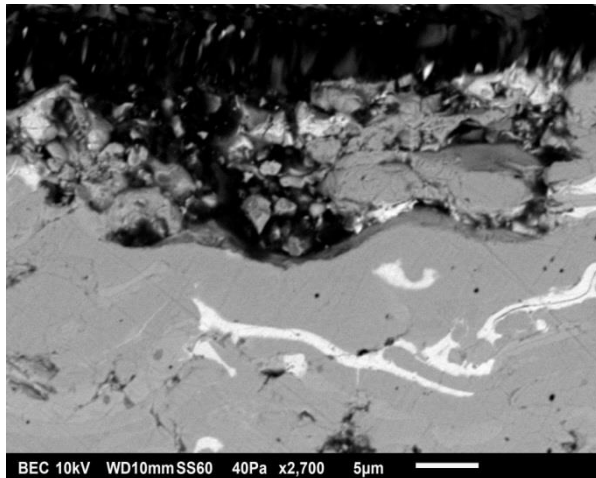


Yellow = Ni, Blue = Cr, Green = Mo

- Aluminum domains found at the surface of the “U” batch are no longer present.
- Coating contains large Mo domains that can be found at surface and in substructure.

Cross Section Pore Analysis W-ring and U-ring

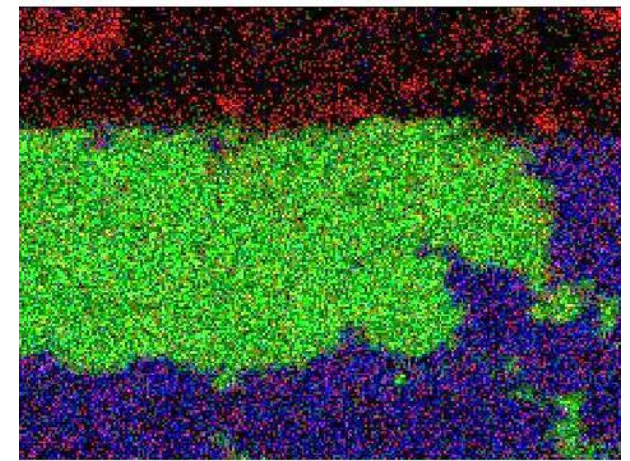
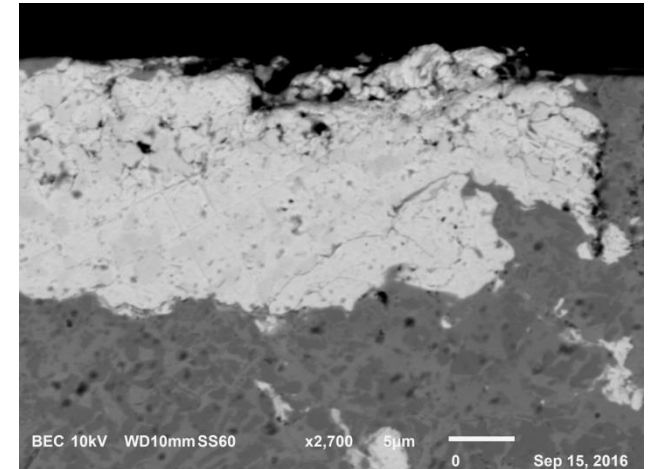
U batch



20 µm

- Overall “W” batch rings contain less pores.
- Surface aluminum particles found in “U” batch rings are not present in “W” batch.
- Large Mo domains found at surface of “W” batch rings. Not present in previous batches.

W batch

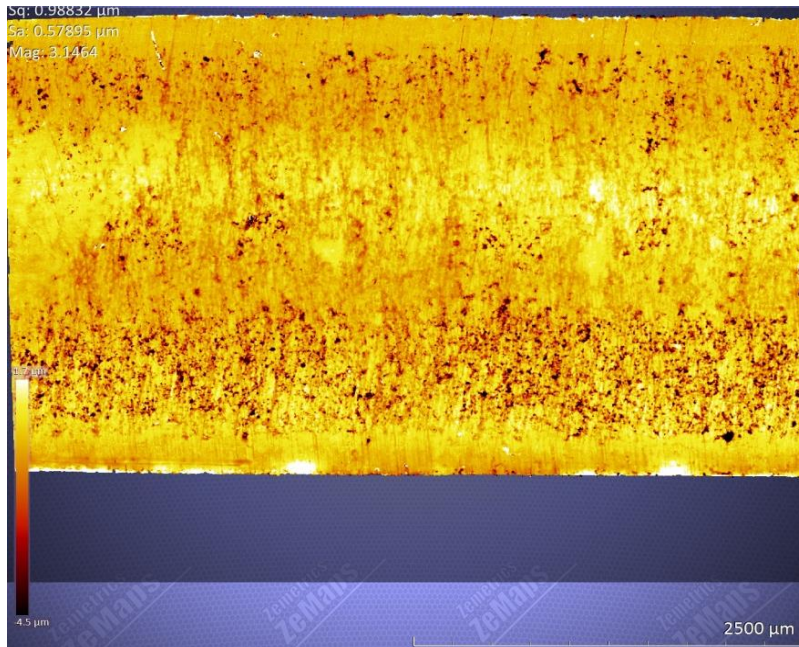


20 µm

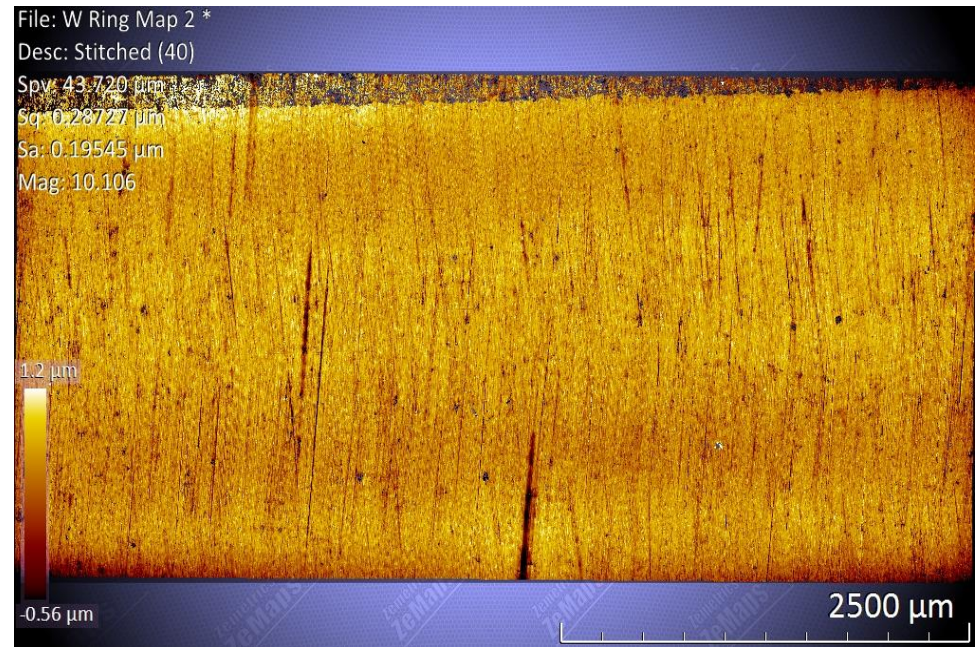
Red = Al, Blue = Cr, Green = Mo

Top Ring Pore Density

“U” ring



“W” ring

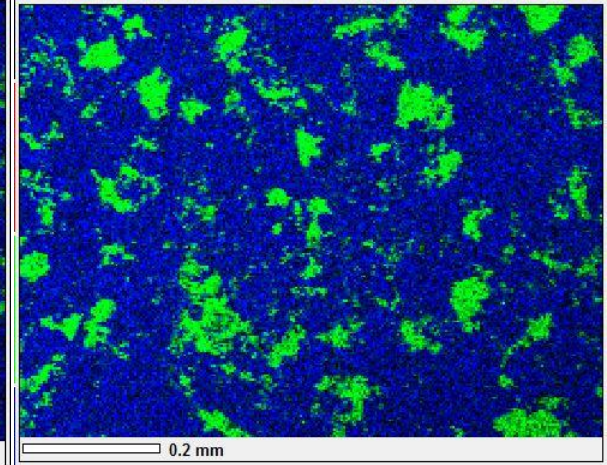
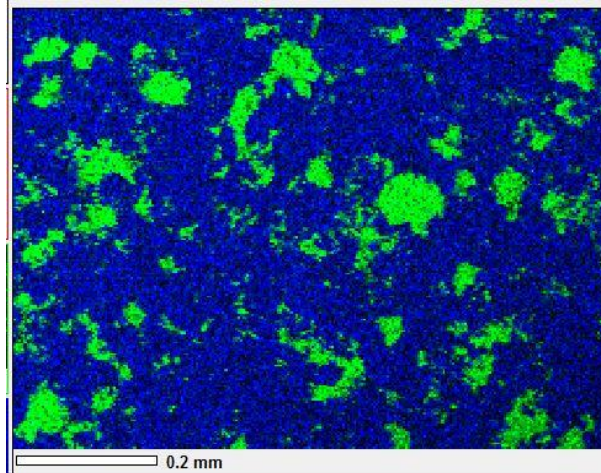
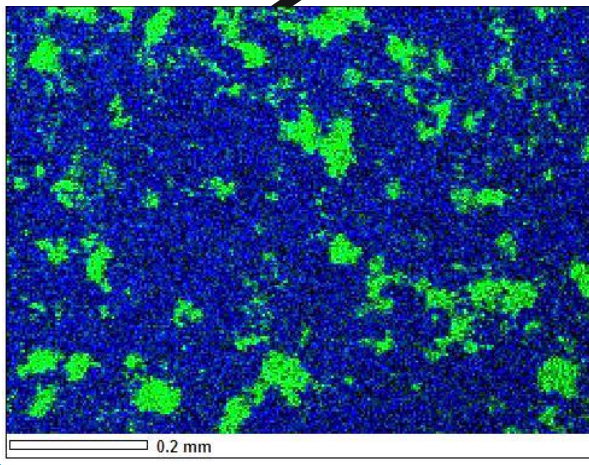
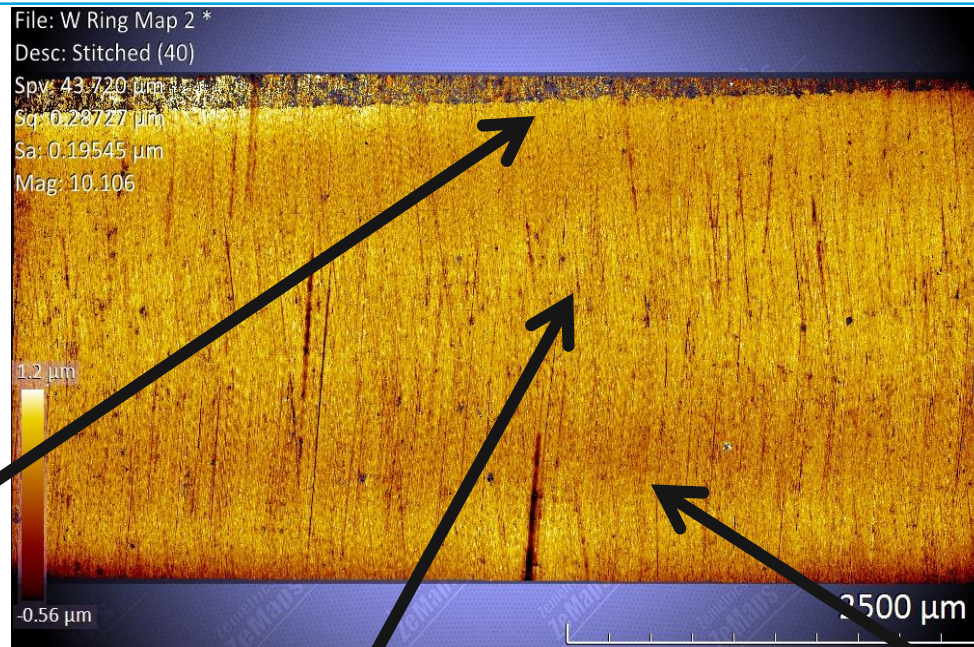


- Surface of “W” batch ring has minimal pore structure compared to “U” batch ring.
- “W” batch ring is very smooth due to the loss of this pore structure

Molybdenum Domain Uniformity W-ring

- Molybdenum domains are uniformly large throughout coating surface

Blue = Cr
Green = Mo



Conclusion



- The structure of the ring coating has changed between batches
 - Aluminum surface domains present in previous batches of rings (“T” & “U”) have been removed.
 - Large Mo domains are present in coating both at the surface and in substructure
 - Coating surface is much smoother for the “W” batch than previous batches
 - Ring coating has limited pores in surface and substructure that were present in previous batches and added roughness to the ring
- The barrel rise and symmetry is similar to the previous couple of batches of rings

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