

# MACK T-12 “X” TOP RING ANALYSIS

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**Mack Surveillance Panel Meeting**

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# Mack T-12 New Top Ring Batch

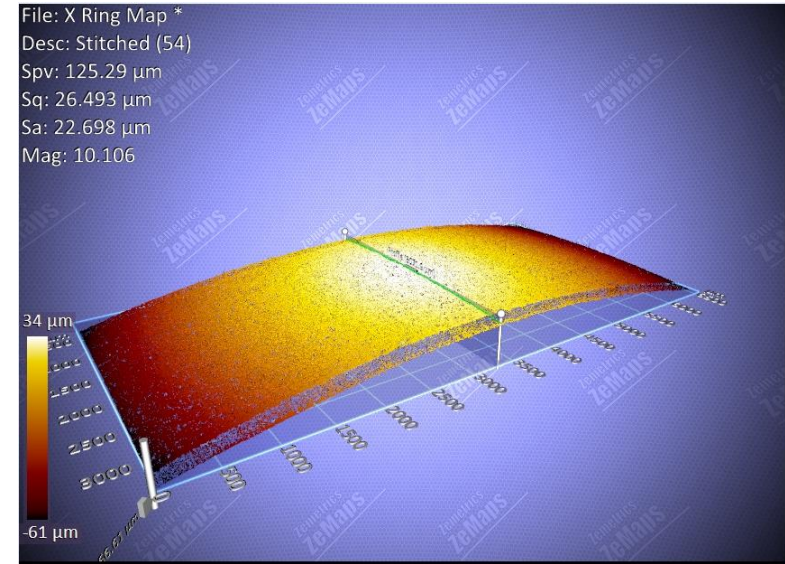
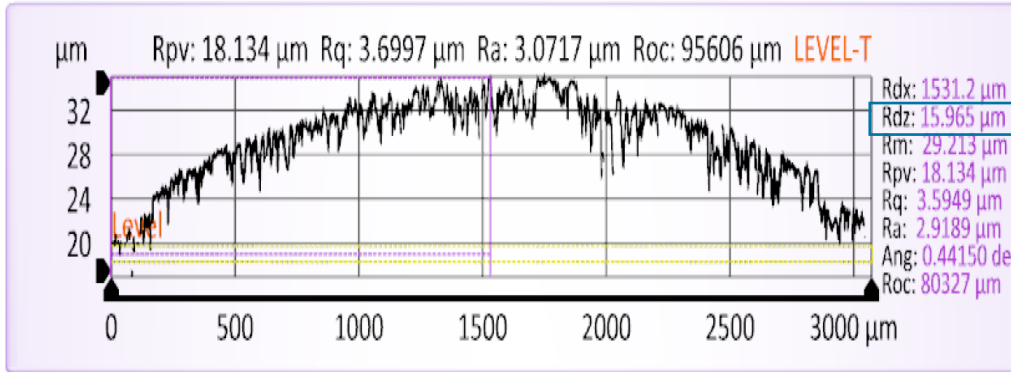


- Recently a new batch of top rings was introduced into the Mack T-12 and is currently undergoing reference testing at the labs
- The new top ring batch that was introduced was the “X” batch
- Infineum has conducted analysis of this “X” top ring batch and has compared it to data of previous top ring batches that was previously shared with the Surveillance Panel

## Rings used in this analysis

- “N” used top ring
- “P” used top ring
- “S” new top ring
- “T” new top ring
- “U” new top ring
- “X” new top ring

# Top Ring Barrel Rise



Top Ring Batch	Barrel Rise ( $\mu\text{m}$ )
S	24.7 – 25.8
T	11.1 – 14.9
U	13.5 – 14.8
X	12.1 – 16.0

# Top Ring Coating Elemental Analysis

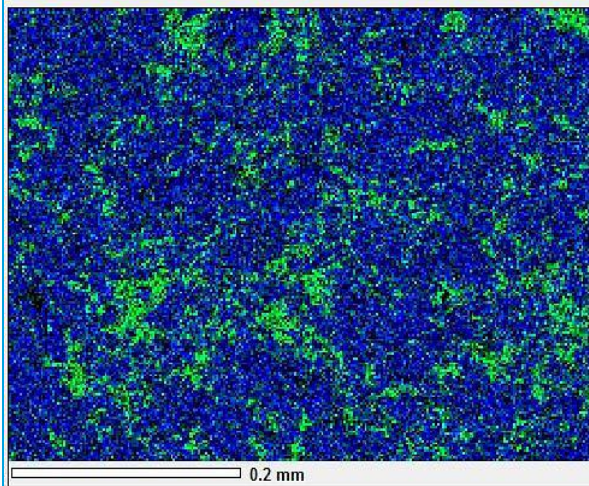


Element	“N” Ring Mole %	“P” Ring Mole %	“S” Ring Mole %	“T” Ring Seg 1 Mole %	“T” Ring Seg 2 Mole %	“U” Ring Seg 1 Mole %	“X” Ring Seg 1 Mole %	“X” Ring Seg 2 Mole %	“X” Ring Seg 3 Mole %
Cr	40.92	29.54	41.42	30.68	25.59	19.09	37.93	38.38	36.53
Mo	1.60	1.92	1.88	2.01	1.67	1.46	1.99	1.9	1.96
Ni	8.91	10.13	7.99	8.73	6.64	5.05	7.77	7.6	7.44
Al	0.62	1.20	0.25	0.54	6.88	16.91	0.13	0.15	0.16
C	41.43	42.09	42.39	48.22	46.48	48.81	47.24	47.19	48.59
O	4.51	11.18	5.18	7.50	10.05	7.65	4.56	4.4	4.91
Si	0.18	1.06	0.55	0.77	0.60	0.79	0.3	0.37	0.41
Zn	0.40	0.48	0.35	0.59	0.38	0.25	0.08	0	0

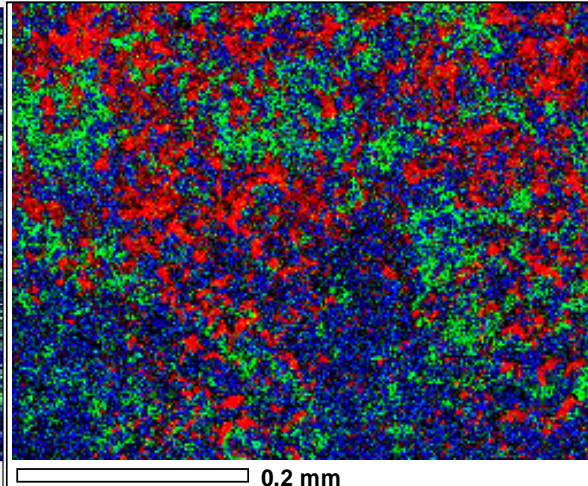
- New “X” batch similar to “S” batch. Ni and Mo domains are consistent in both batches.

# Top Ring Coating Elemental Analysis

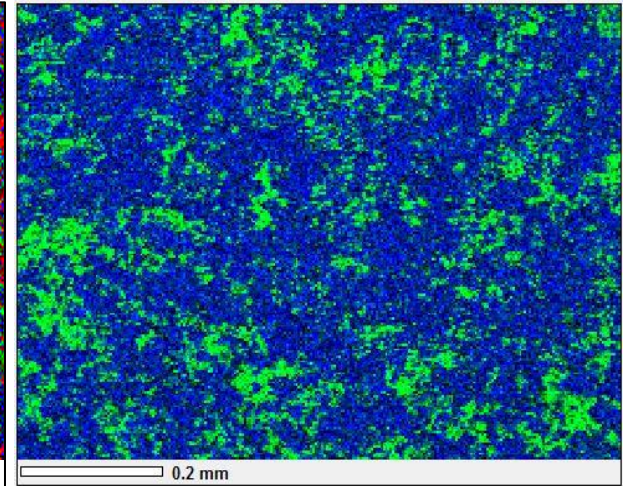
“S” ring



“U” ring



“X” ring



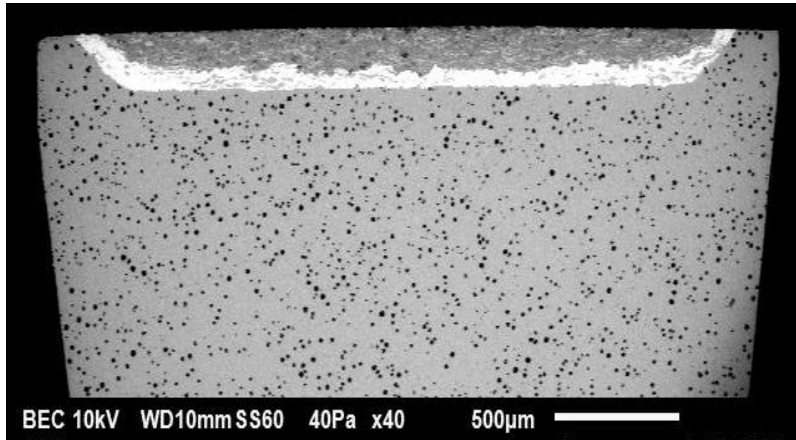
Red = Al, Blue = Cr, Green = Mo

- Surface Aluminum added in the “U” batch ring is no longer present in the “X” batch ring.
- Mo/Ni-rich domains are present in the coating structure of the “X” batch ring similar to “S” batch.

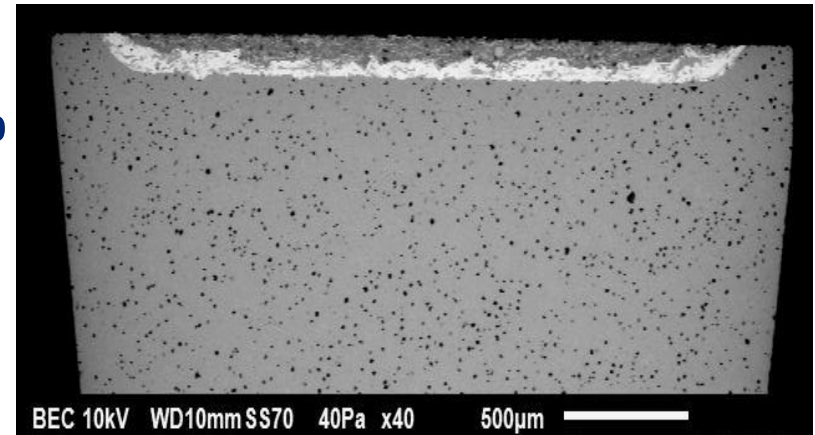


# Cross Section Analysis of Rings

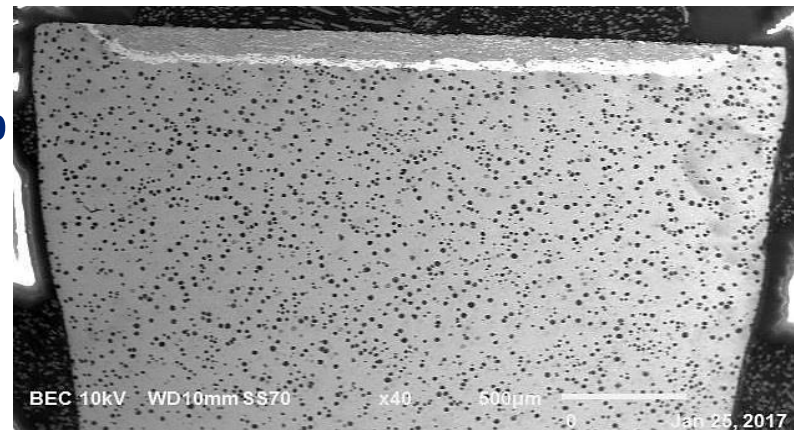
“S” ring



“U” ring



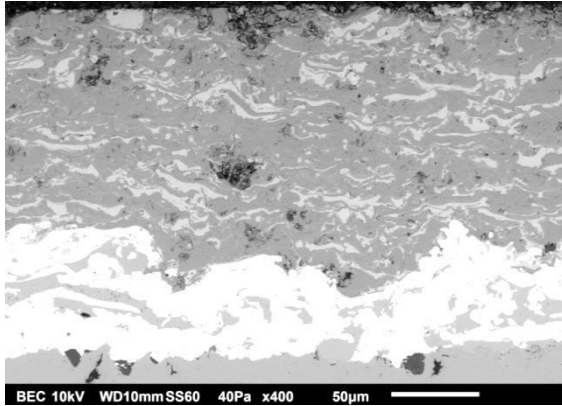
“X” ring



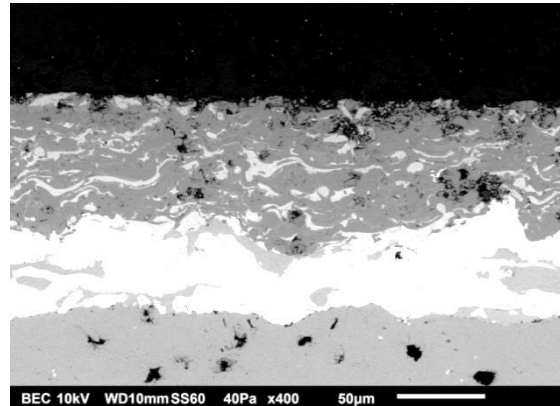
- Coating bulk structure seems to be similar in all 3 batches
- Substrate material is ductile iron and similar for all 3 batches

# Cross Section Analysis of Rings

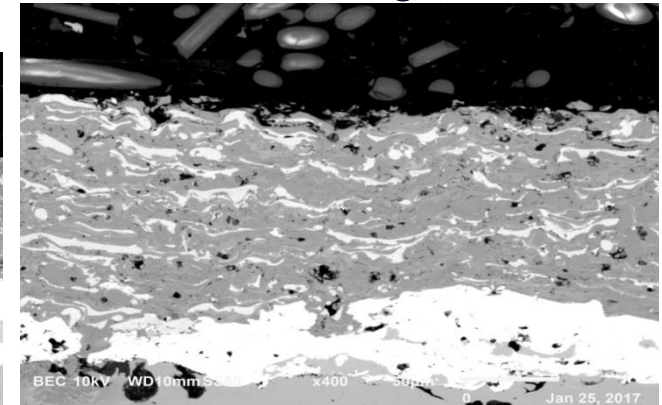
“S” ring



“U” ring



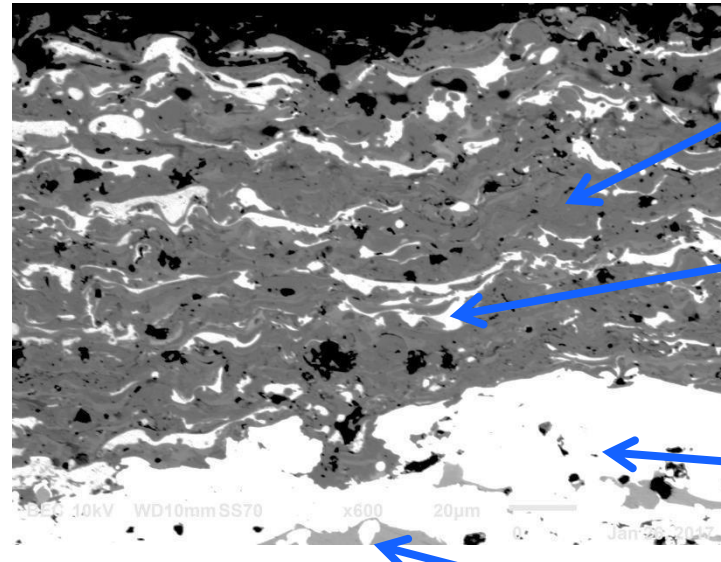
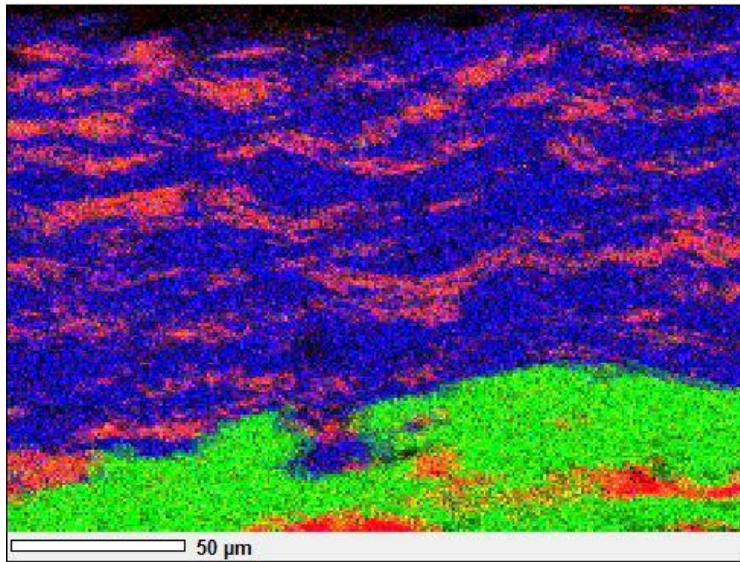
“X” ring



Ring Batch	Coating Thickness ( $\mu\text{m}$ ) Including Mo Layer
S	200
U	127
X	161

- Mo/Ni alloy domains are evenly distributed close to the surface as seen in previous “S” and “U” batches.
- Mo binding layer present between ductile iron substrate and coating
- “X” ring coating has a thickness in between the “S” and “U” batches

# Cross Section Analysis X-ring



Cr  
Carbide

Mo/Ni  
alloy

Moly  
Binding  
Layer

Ductile  
Iron

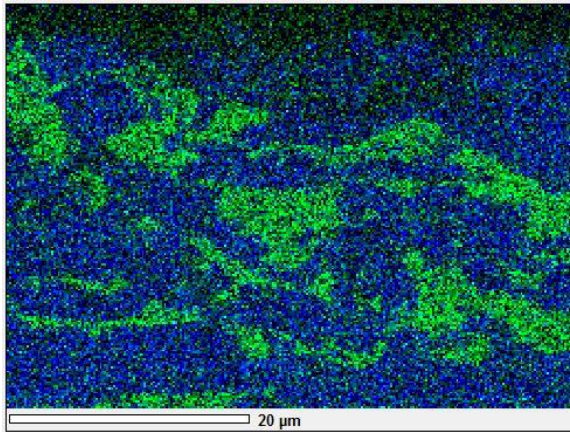
Red = Ni, Blue = Cr, Green = Mo

- Coating contains Ni/Mo domains that can be found at surface and in substructure.
- “X” ring has a substantial surface and bulk pore structure

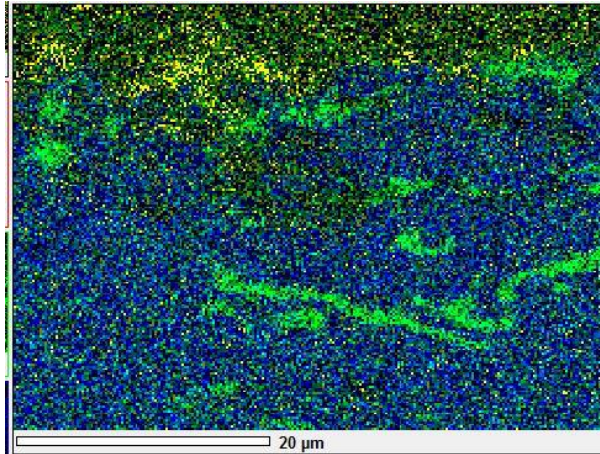


# Cross Section Analysis of Rings

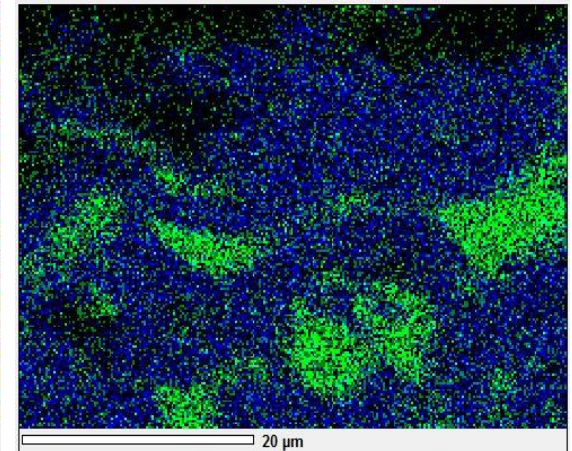
“S” ring



“U” ring



“X” ring



Blue = Cr, Green = Mo, Yellow=Al

- Surface aluminum particles found in “U” batch rings are not present in “S” or “X” batch.
- Cross-section of “X” batch indicates similarity to “S” batch.

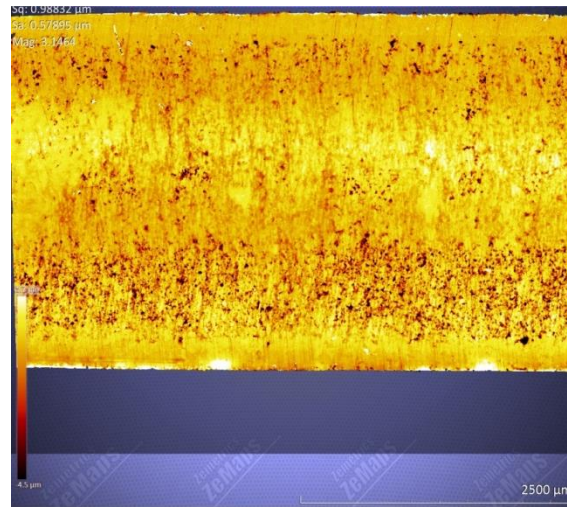
# Top Ring Pore Density

“S” ring



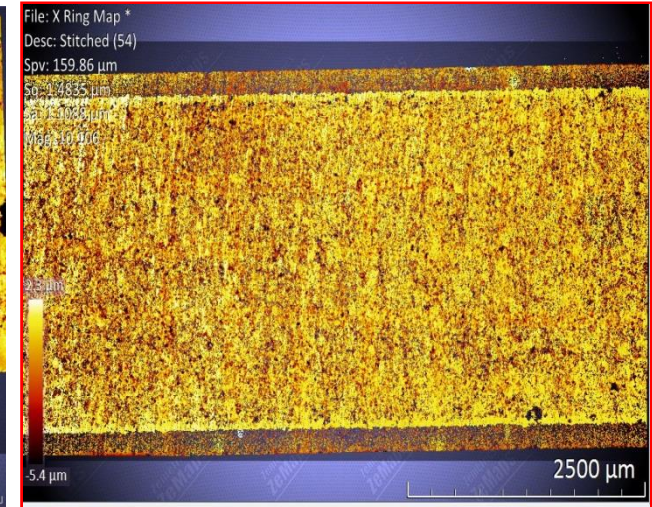
Sa = 0.426

“U” ring



Sa = 0.579

“X” ring



Sa = 1.108

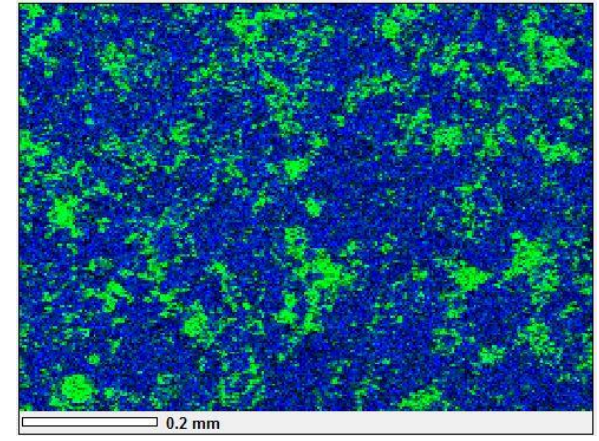
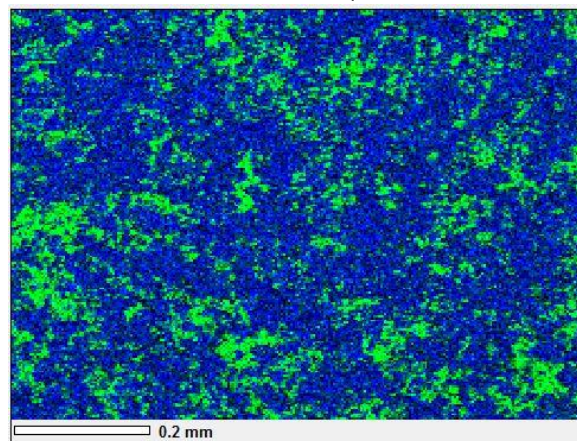
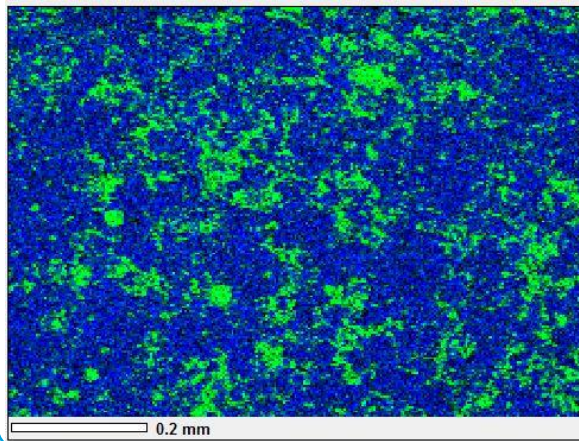
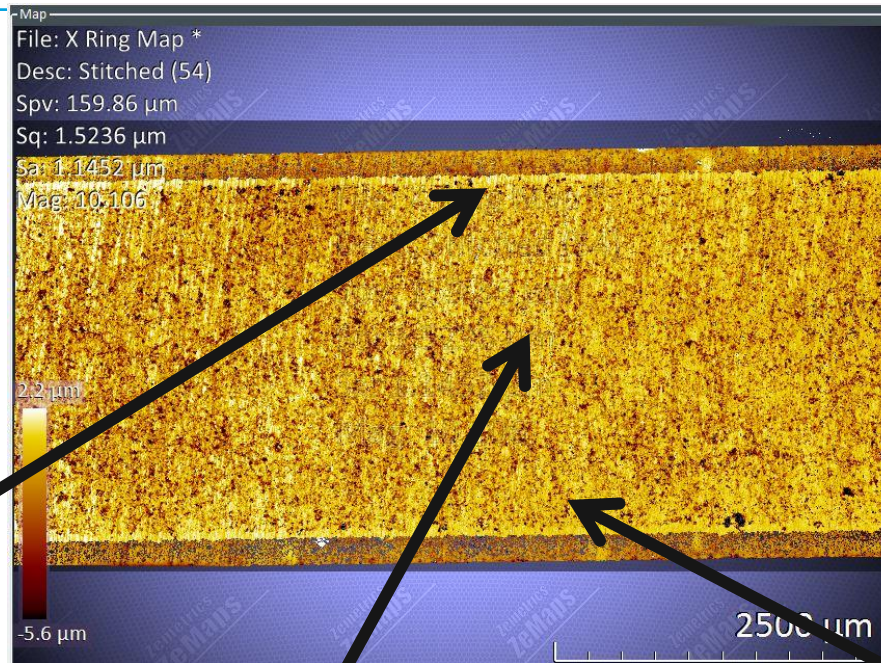
- Surface of “X” batch ring has a higher amount of pores compared to previous ring batches
- Surface roughness of “X” batch rings is also higher than previous batches
- “U” batch ring had pores more concentrated to lower half of ring
- “X” batch pore distribution is uniform as previously seen in “S” batch.



# Molybdenum Domain Uniformity X-ring

- Molybdenum domains are uniform in size throughout coating surface, similar to “S” batch.

Blue = Cr  
Green = Mo



# Ring Side Coating Elemental Analysis

Element	“T” Ring Mole %	“U” Ring Mole %	“X” Ring Mole %
P	9.64	9.9	5.32
Fe	8.3	13.67	4.19
C	32.6	24.91	61.65
O	35.38	36.84	25.04
Si	0.54	0.73	0.39
Zn	12.3	13.96	0
Mn	0	0	3.41
Ca	1.24	0	0

“T” Ring



“U” Ring



“X” Ring



- “T” and “U” batch rings have a Zinc Phosphate coating on the sides and back
- “X” batch rings have a Manganese Phosphate coating on the sides and back



- The barrel rise and symmetry is similar to the previous couple of batches of rings.
- The structure of the ring coating has changed between batches.
  - Coating elemental composition is similar between “X” and “S” batch rings.
  - Aluminum surface domains present in previous batches of rings (“T” & “U”) have been removed to match earlier ring batches.
  - Coating thickness has been increased from the “U” to “X” batch in the direction of earlier ring batches.
  - Surface pore distribution is uniform in both “X” and “S” batch rings.
    - Concentrated pore distribution to lower half of “U” batch rings has been removed
  - Roughness of “X” batch rings and pore concentration has increased compared to previous batches of rings.
- Corrosion protection layer on side and back of ring has changed composition from “T”/”U” batch ring to the “X” batch ring.

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