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# **Multilayer Coatings and Composite Coatings for Water Droplet Erosion Resistance Improvement**

**Concordia University**

**June 17<sup>th</sup>, 2013**

# Content



- **Boronizing coatings**
- **Work to be done in 2013**



- **Boronizing coatings**

# Boronizing coatings

## Experiment Design

Composition #	B (wt%)	Na <sub>2</sub> CO <sub>3</sub> (wt%)	C(wt%)	Holding Time@1050C	Holding Time@1200C
B0	100%	-	-	24hrs	
B1	50%	45%	5%	24hrs	
B2	50%	35%	15%	12, 24, 48hrs	12 hrs
B3	50%	25%	25%	12, 24, 48hrs	12 hrs, 72hrs
B4	50%	15%	35%		72hrs
B5	50%	5%	45%	24, 72hrs	72hrs

← Old

# Boronizing coatings

Old results: B4 @ 1200°C X 72 hours

- **RIG testing parameter:**

**Speed: 14000 RPM**

**Time: 0-10 minutes**

**Nozzle size: 400 μm**

**Flow Rate: 0.050-0.070 L/min**

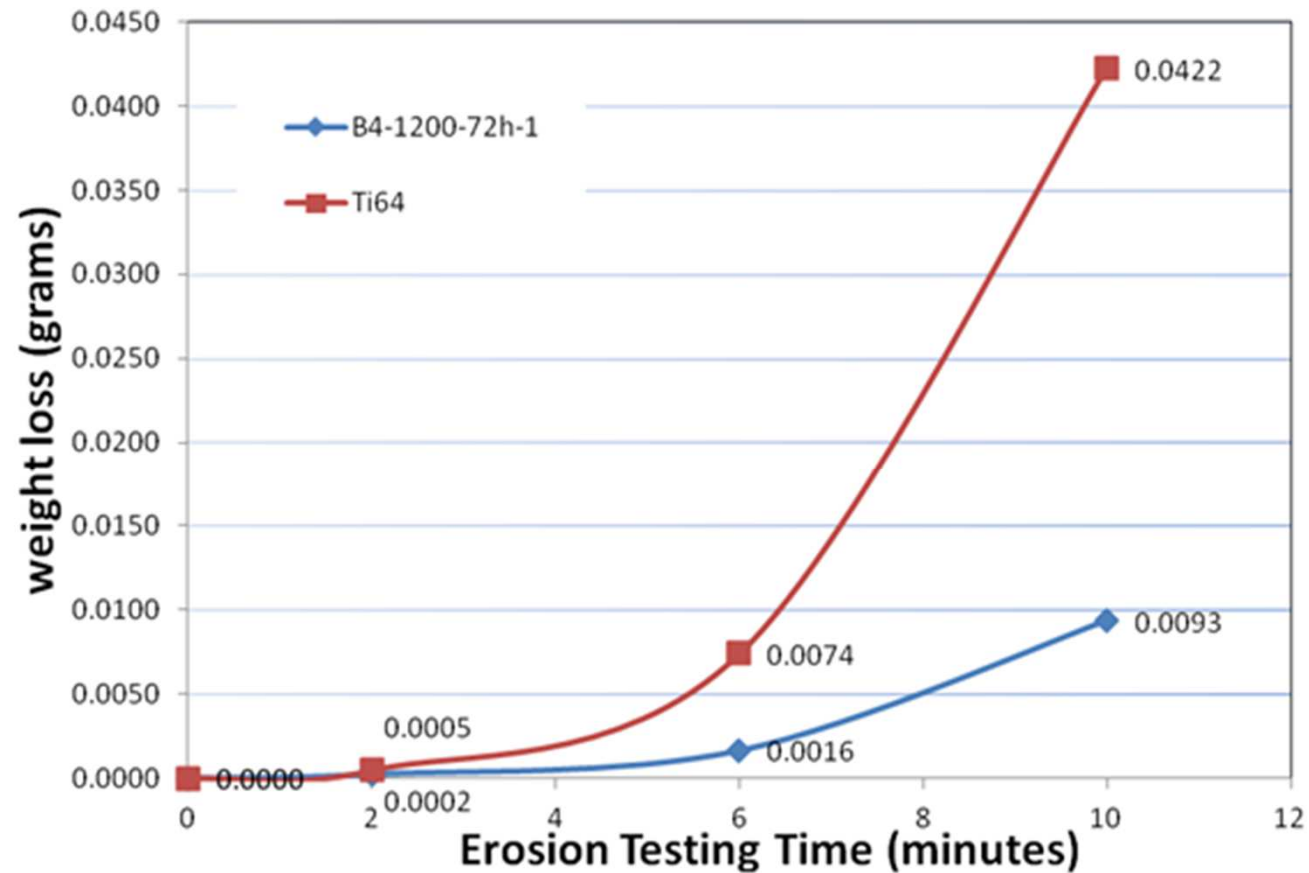
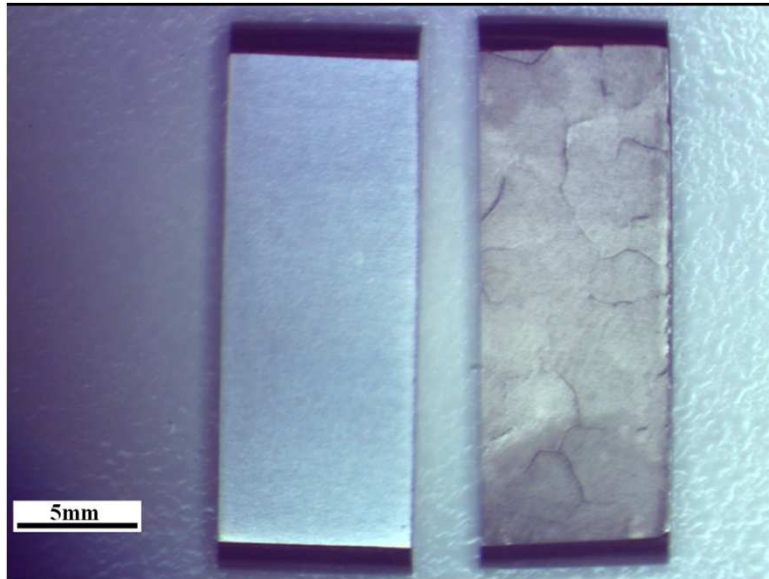
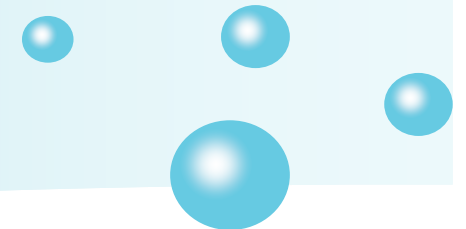


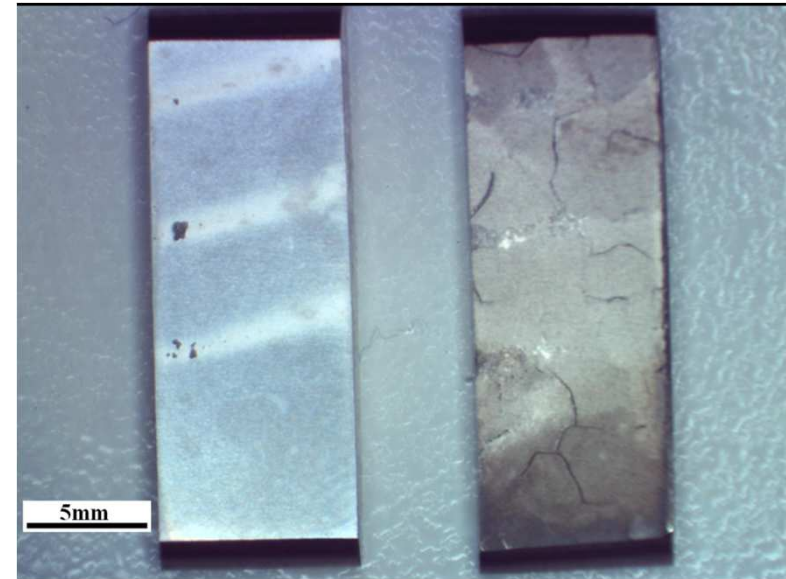
Fig. 1 Weight loss Vs. Erosion testing time

# Boronizing coatings

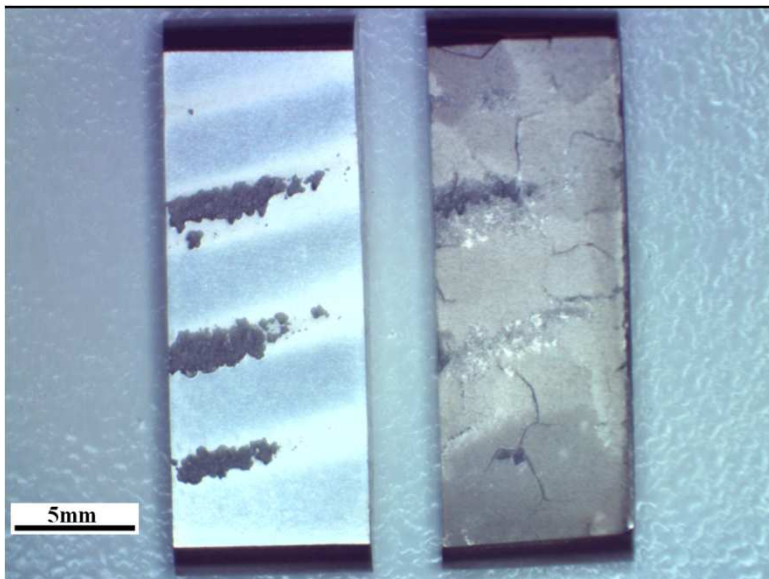
Old results: B4 @ 1200°CX72hous



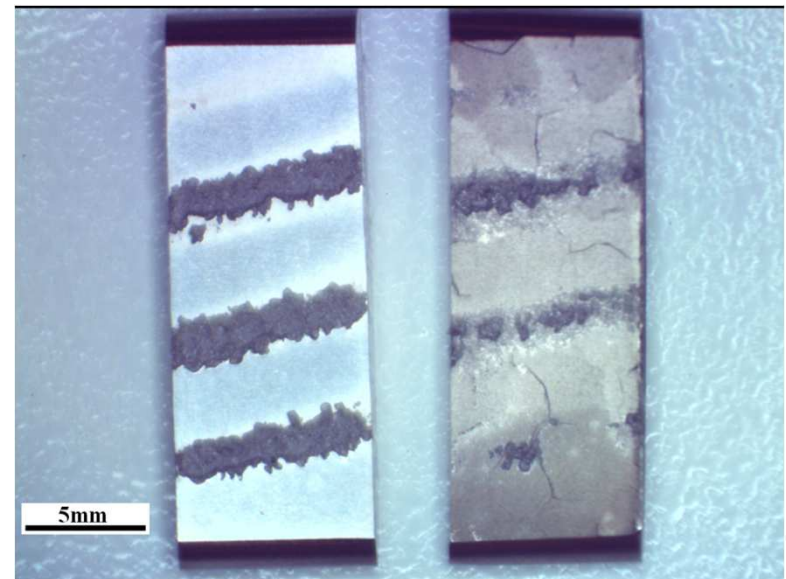
0 min



2 min



6 min



10 min

# Boronizing coatings

## Experiment Design

Composition #	B (wt%)	Na <sub>2</sub> CO <sub>3</sub> (wt%)	C(wt%)	Holding Time@1050C	Holding Time@1200C
B0	100%	-	-	24hrs	
B1	50%	45%	5%	24hrs	
B2	50%	35%	15%	12, 24, 48hrs	12 hrs
B3	50%	25%	25%	12, 24, 48hrs	12 hrs, 72hrs
B4	50%	15%	35%		72hrs ← Old
B5	50%	5%	45%	24, 72hrs	72hrs ← New

# Boronizing coatings

New results: **B5** @1200°CX72hours

- **RIG testing parameter:**

**Speed: 14000 RPM**

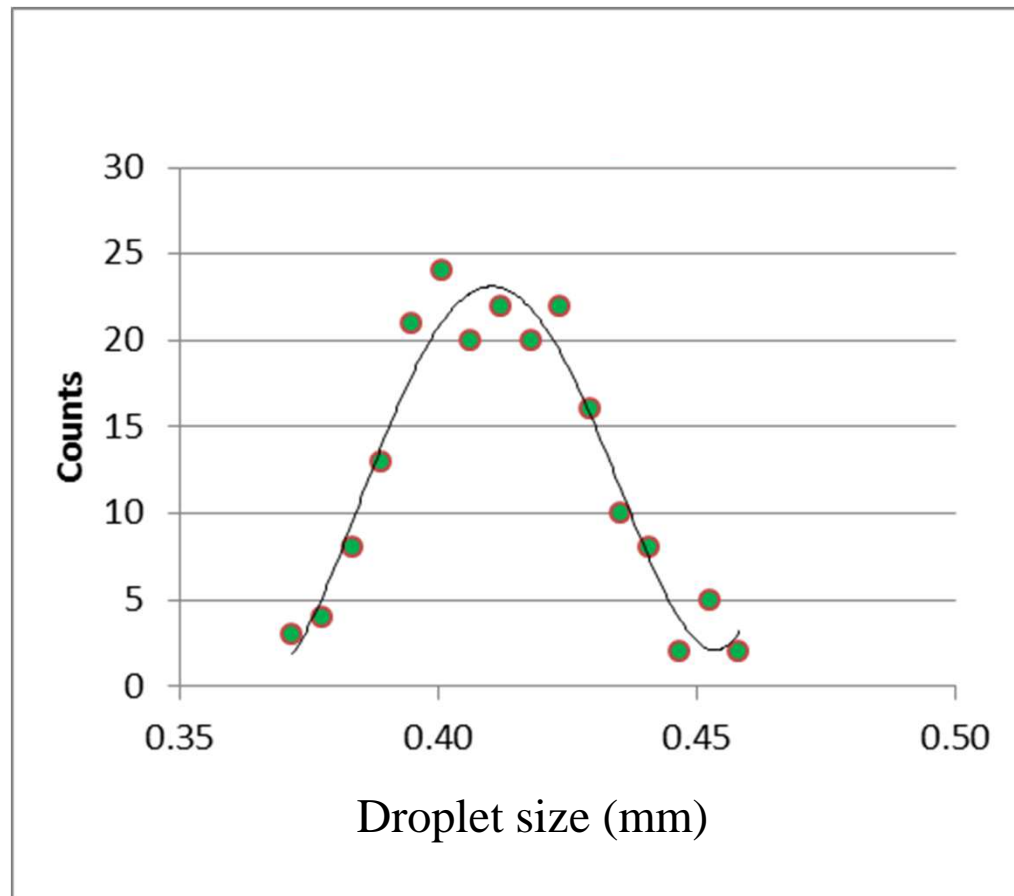
**Time: 0-13 minutes**

**Nozzle size: 400  $\mu\text{m}$**

**Representative droplet size: 411  $\mu\text{m}$**

**Initial water pressure: 30 psi**

**Flow Rate: 0.050 L/min**

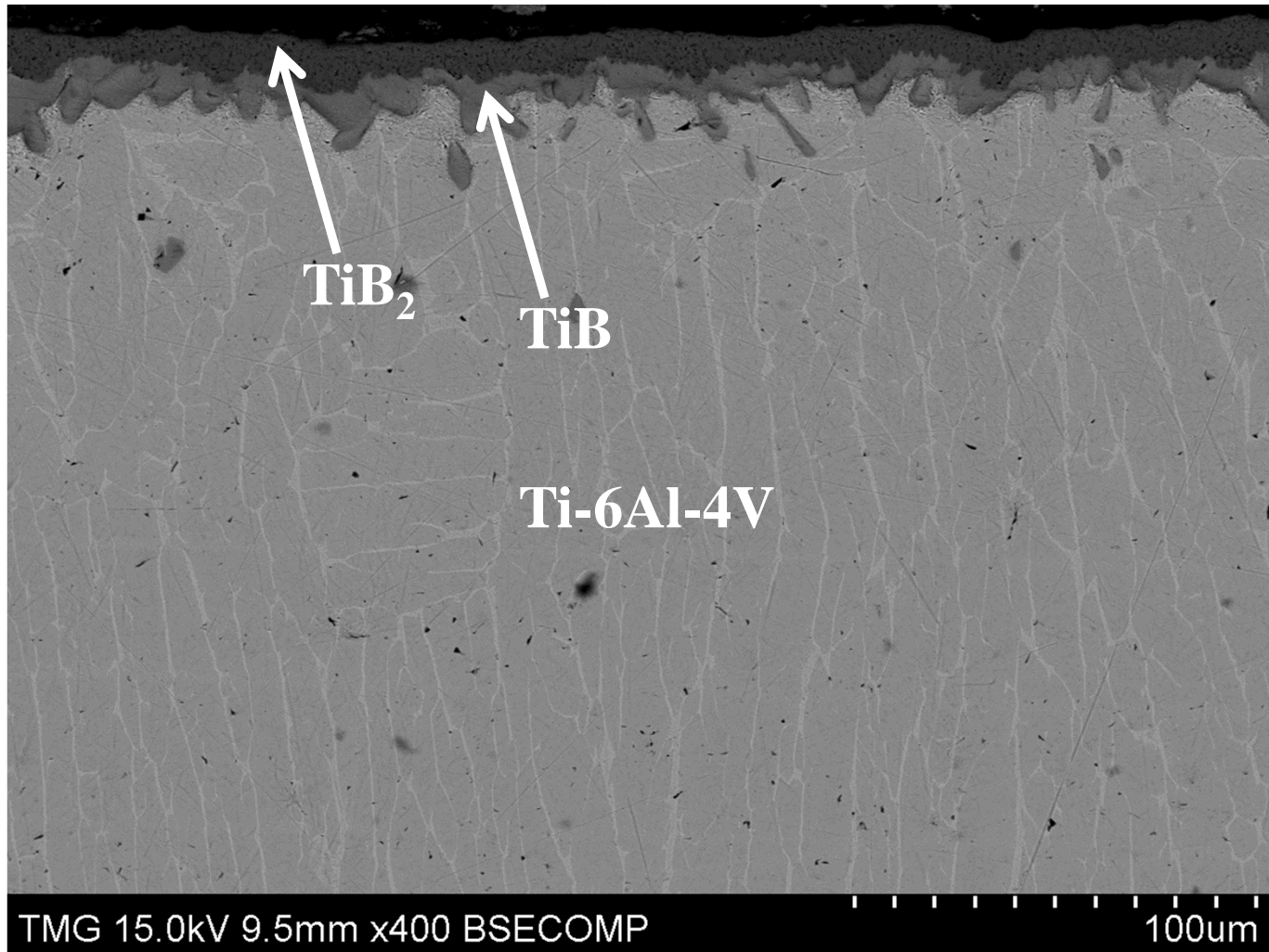




# Boronizing coatings

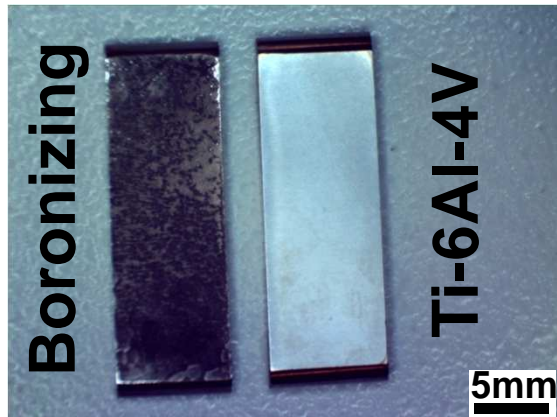
New results: **B5** @ 1200°C X 72 hours, Side A

## Side A, with original coating

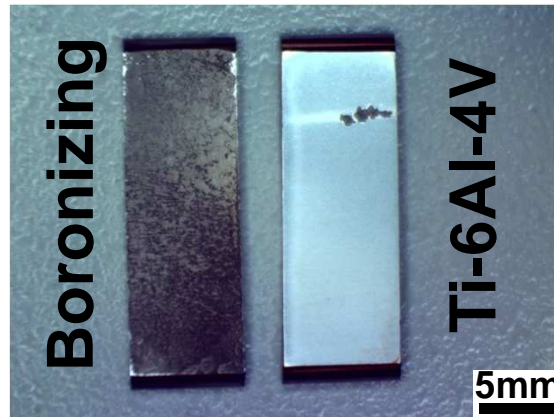


# Boronizing coatings

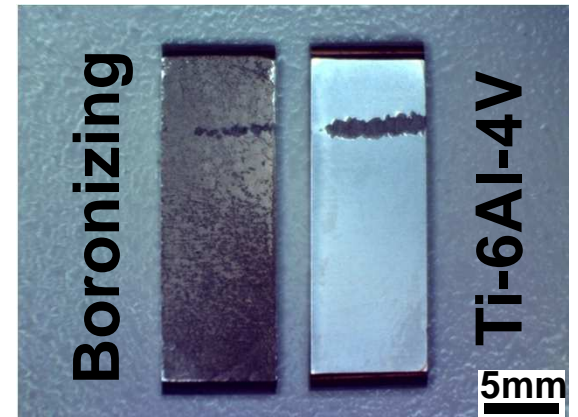
New results: **B5** @ 1200°C X 72 hours; Side A



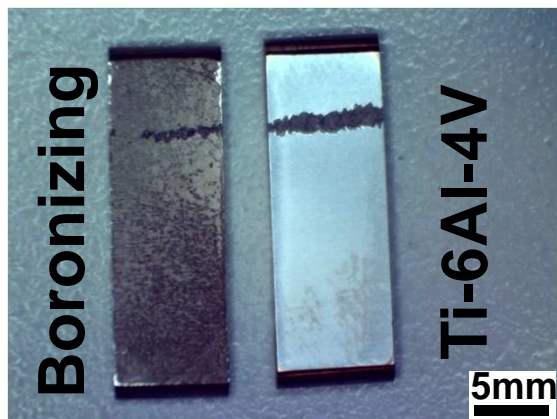
Before erosion



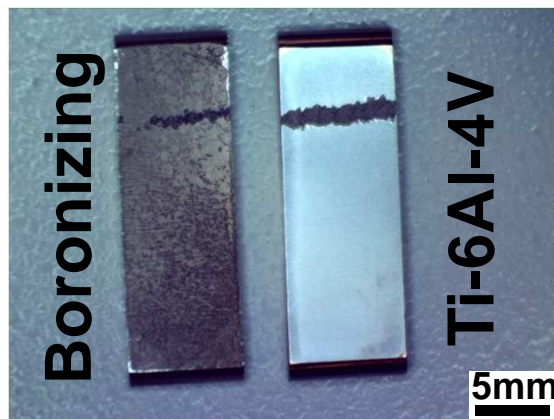
2 min



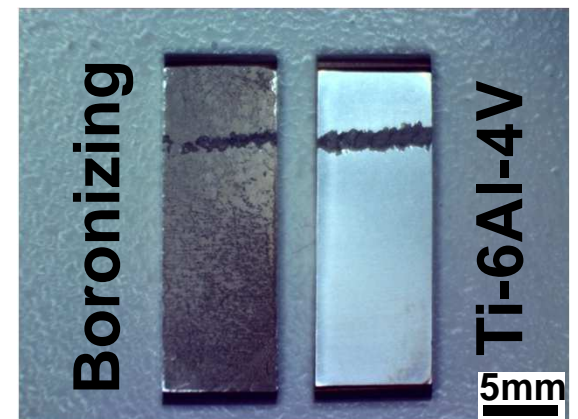
5 min



7 min



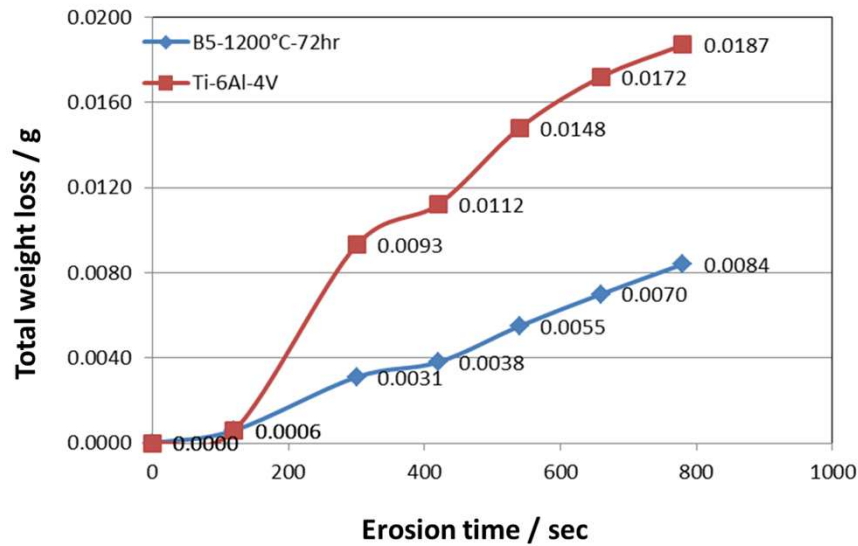
9 min



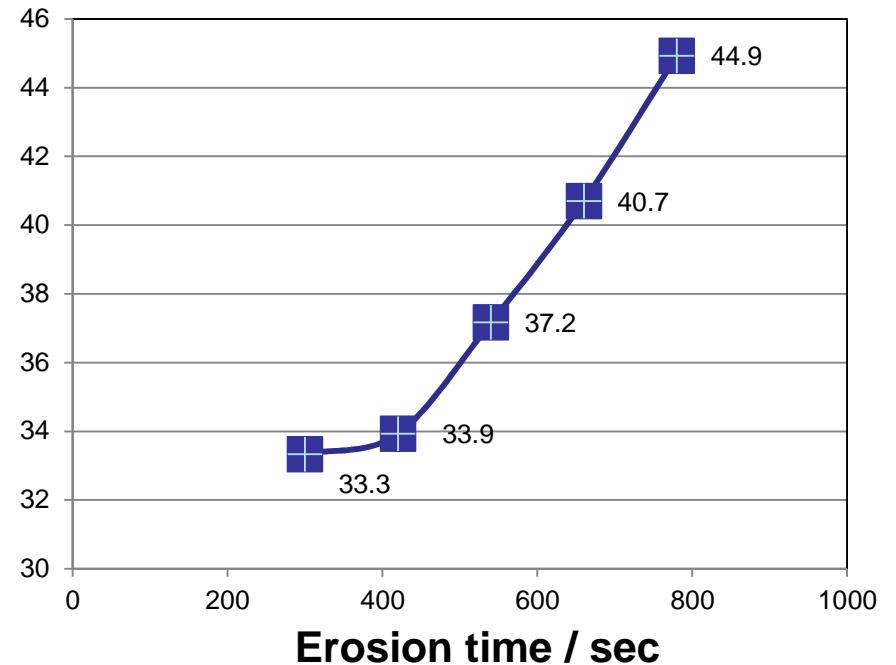
13 min

# Boronizing coatings

New results: **B5** @ 1200°C X 72 hours, Side A



Percentage of weight loss (coating vs. Ti64) / %

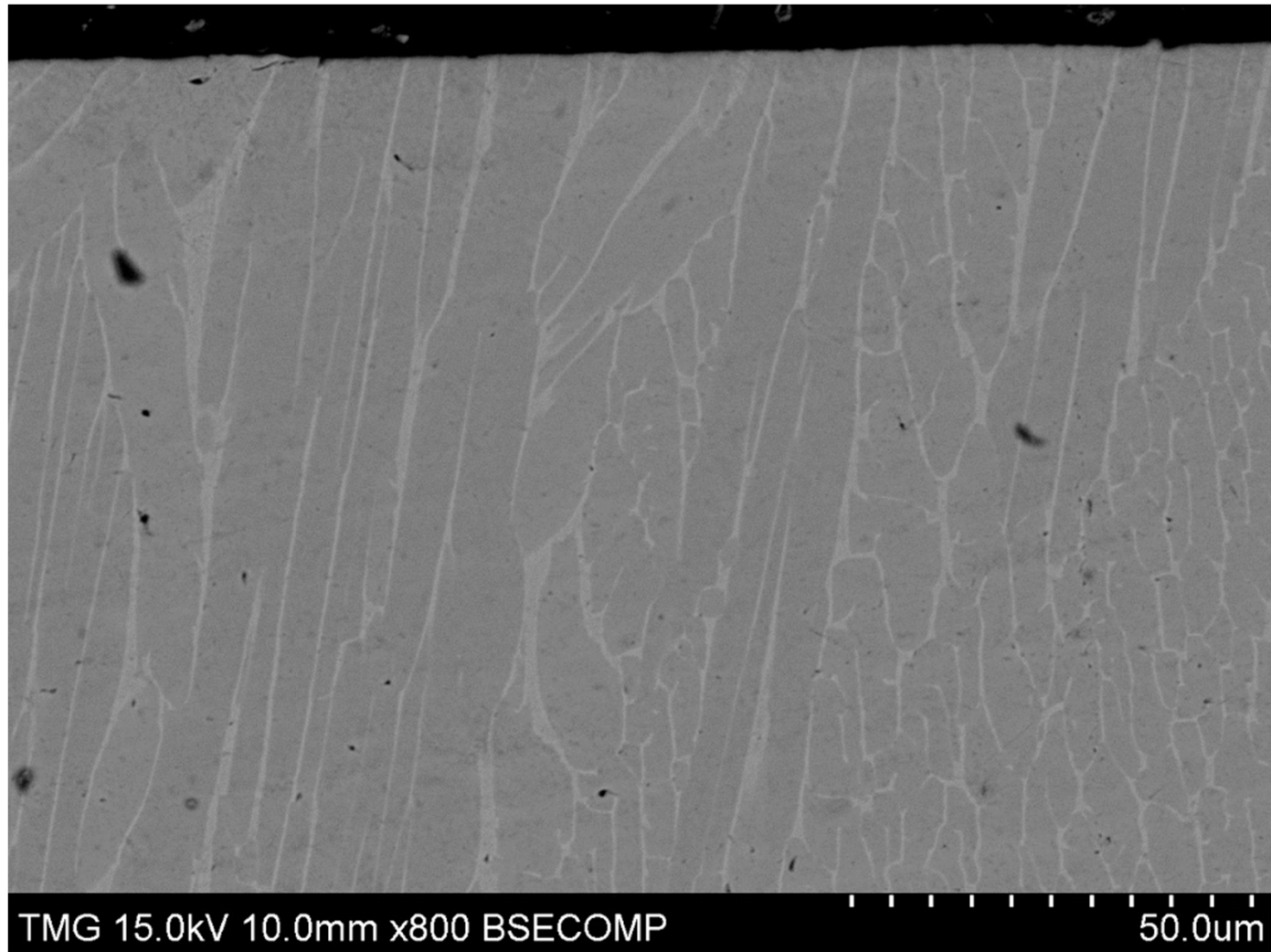


Erosion curves of the original side vs Ti64

# Boronizing coatings

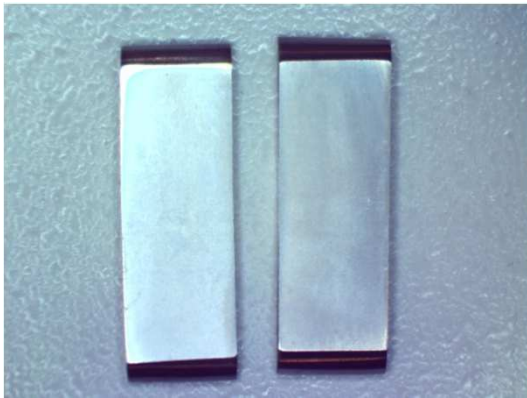
New results: **B5** @ 1200°C X 72 hours, Side B

## Side B, coating removed

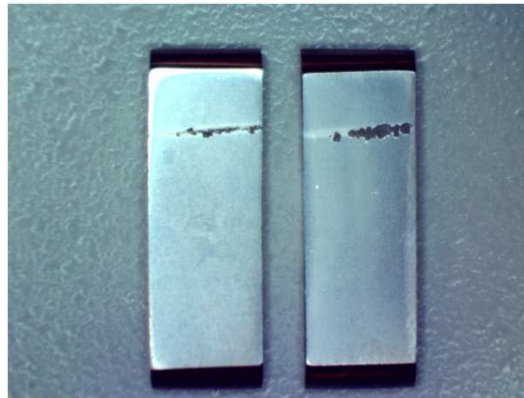


# Boronizing coatings

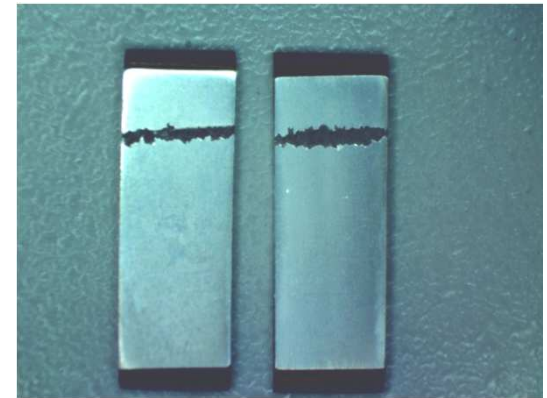
New results: **B5** @ 1200°C X 72hous, Side B



**Before erosion**



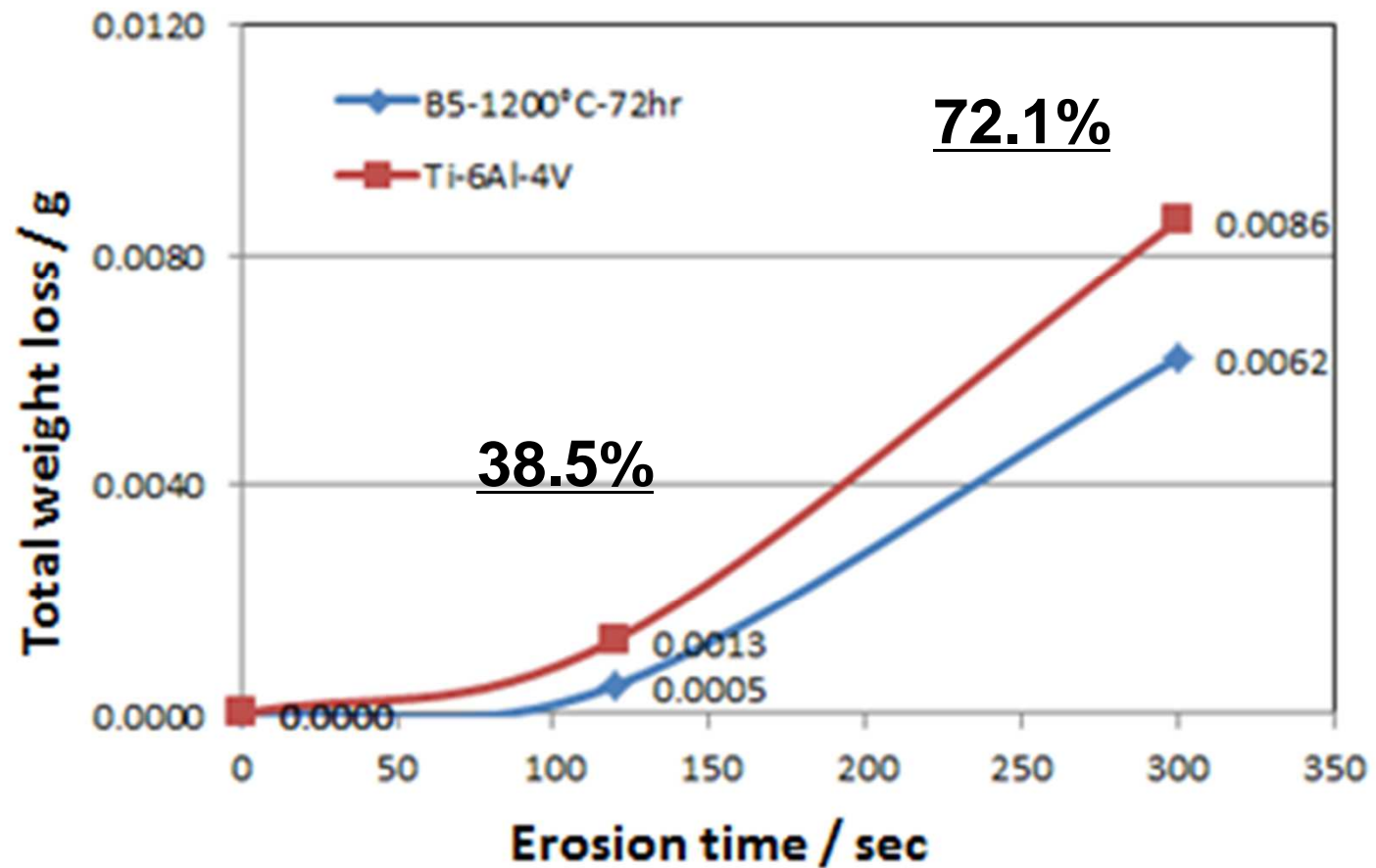
**2 min**



**5 min**

# Boronizing coatings

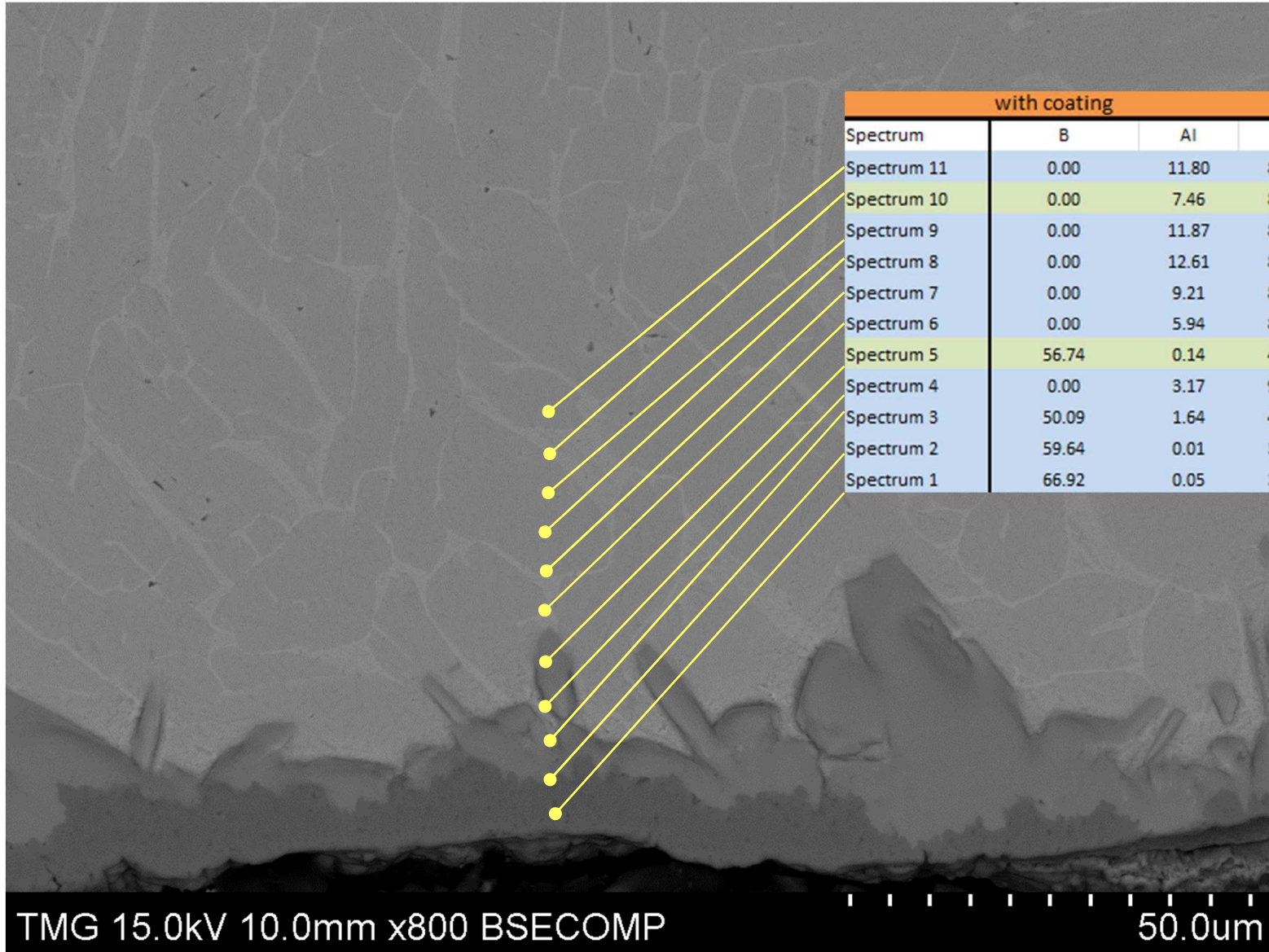
New results: **B5** @ 1200°C X 72 hours, Side B



# Boronizing coatings

New results: **B5** @ 1200°CX72hous, Side A

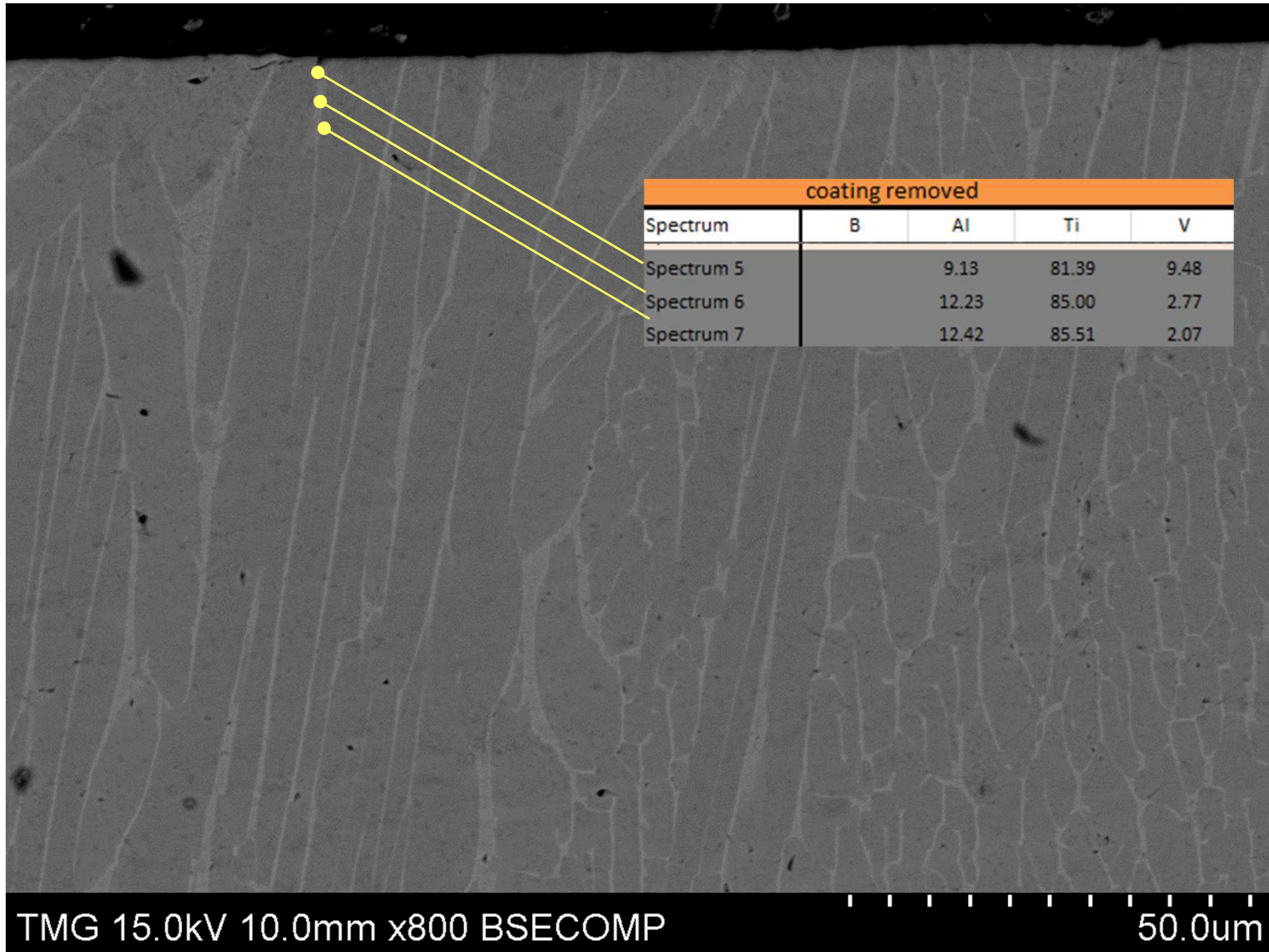
Side A  
Coated



# Boronizing coatings

New results: **B5** @ 1200°CX72hous, Side B

**Side B  
Coating  
Removed**





# Boronizing coatings

New results: **B5** @ 1200°CX72hours, Side B

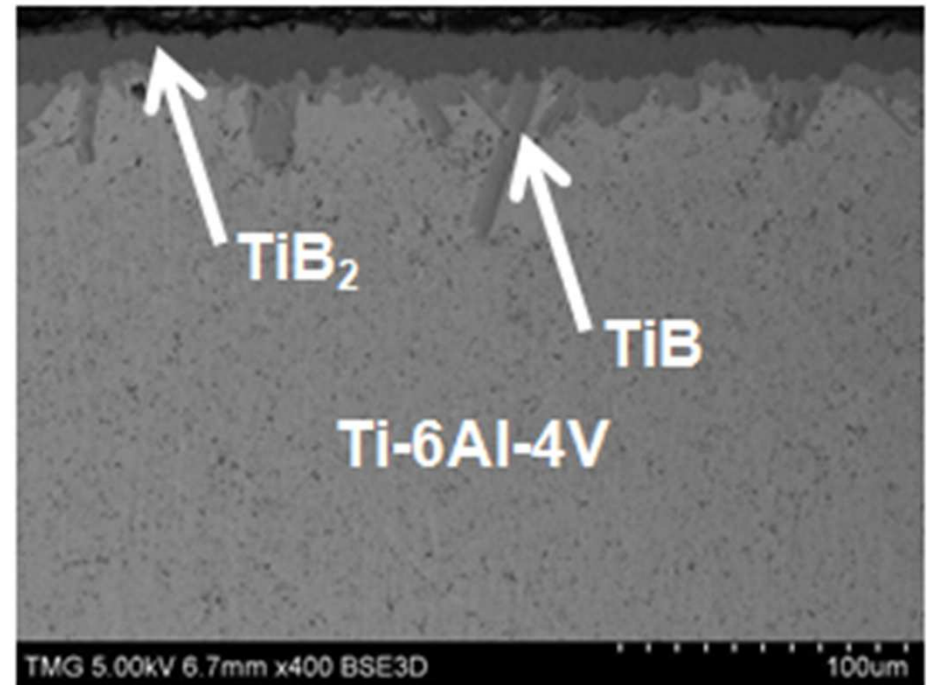
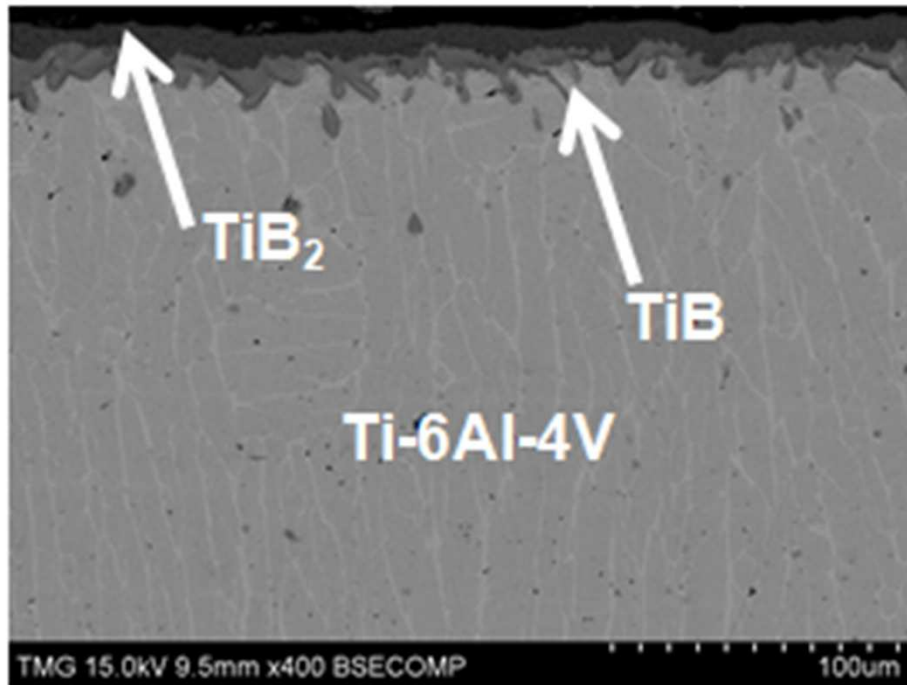
## Experiment Design

Composition #	B (wt%)	B <sub>4</sub> C (wt%)	Na <sub>2</sub> CO <sub>3</sub> (wt%)	C (wt%)	Holding Time@1050C	Holding Time@1200C
B0	100%		-	-	24hrs	
B1	50%		45%	5%	24hrs	
B2	50%		35%	15%	12, 24, 48hrs	12 hrs
B3	50%		25%	25%	12, 24, 48hrs	12 hrs, 72hrs
B4	50%		15%	35%		72hrs
B5	50%		5%	45%	24, 72hrs	72hrs
B10		50%	5%	45%		72hrs

# Boronizing coatings

B5 @ 1200°C×72hr, **pure boron**

B10 @ 1200°C×72hr, **B<sub>4</sub>C**



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- **Work to be done in 2013**

# Work to be done in 2013

## (1) Boronizing: 4 factors response surface design

Factor 1	Factor 2	-	Factor 3	Factor 4
B4C %wt	Na2CO3 %wt	C %wt	Temperature	Time
30	5	65	1050	84
60	35	5	1050	24
45	20	35	1150	54
60	35	5	1050	84
30	20	50	1150	54
45	20	35	1150	54
45	20	35	1150	84
60	35	5	1250	24
45	5	50	1150	54
30	5	65	1050	24
45	35	20	1150	54
30	35	35	1250	24
45	20	35	1150	54
45	20	35	1150	54
60	35	5	1250	84
60	20	20	1150	54
45	20	35	1150	54
30	35	35	1250	84
60	5	35	1250	84
60	5	35	1050	84
45	20	35	1150	54
60	5	35	1250	24
30	5	65	1250	24
60	5	35	1050	24
30	35	35	1050	84
45	20	35	1150	54
45	20	35	1050	54
30	5	65	1250	84
30	35	35	1050	24
45	20	35	1150	24
45	20	35	1250	54

Response: Erosion weight loss

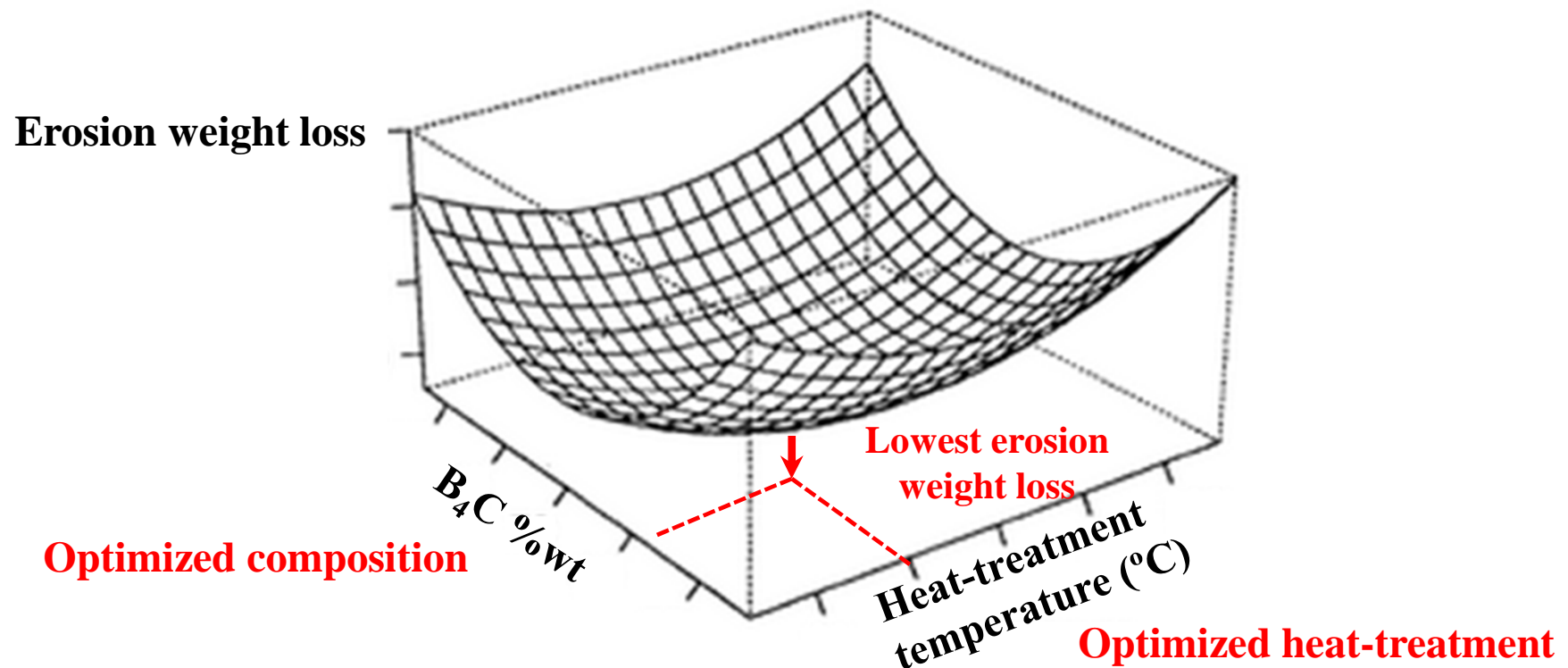
Preparation period: 32 days

Output: Optimized coating technique with best erosion resistance.

# Work to be done in 2013

(1) **Boronizing**: 4 factors response surface design

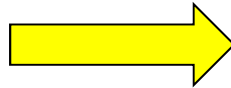
**Expected output with response surface experiment design**



# Work to be done in 2013

(1) Boronizing: new improvement

20ml crucible  
(50×20×20)

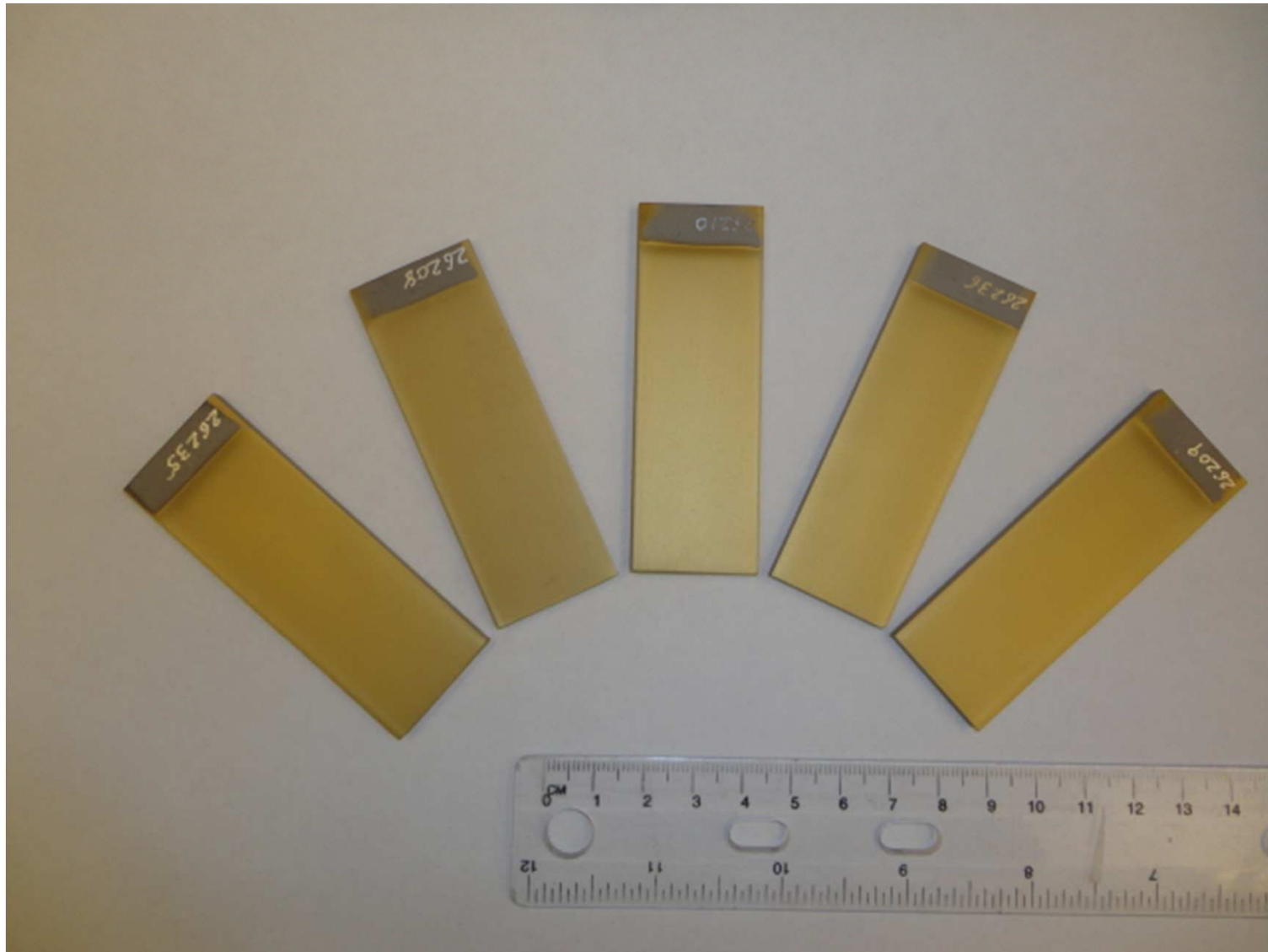


70ml crucible  
( $\phi$ 50×35)



# Work to be done in 2013

## (2) Multilayer coatings: erosion testing



# Work to be done in 2013

## (3) Stress wave analysis

- MATLAB programming  
Reproduce stress wave analysis result  
at least in 1-D mode
- Output:  
A Stress wave analysis Software for  
multilayer coating design



# Work to be done in 2013

## (4) Laser cladding

- Erosion testing  
for previous  $\text{Al}_2\text{O}_3$  cladded samples.



**Thank you**