PITTING ON CARBON CATHODES IN ALUMINIUM ELECTROLYSIS CELLS

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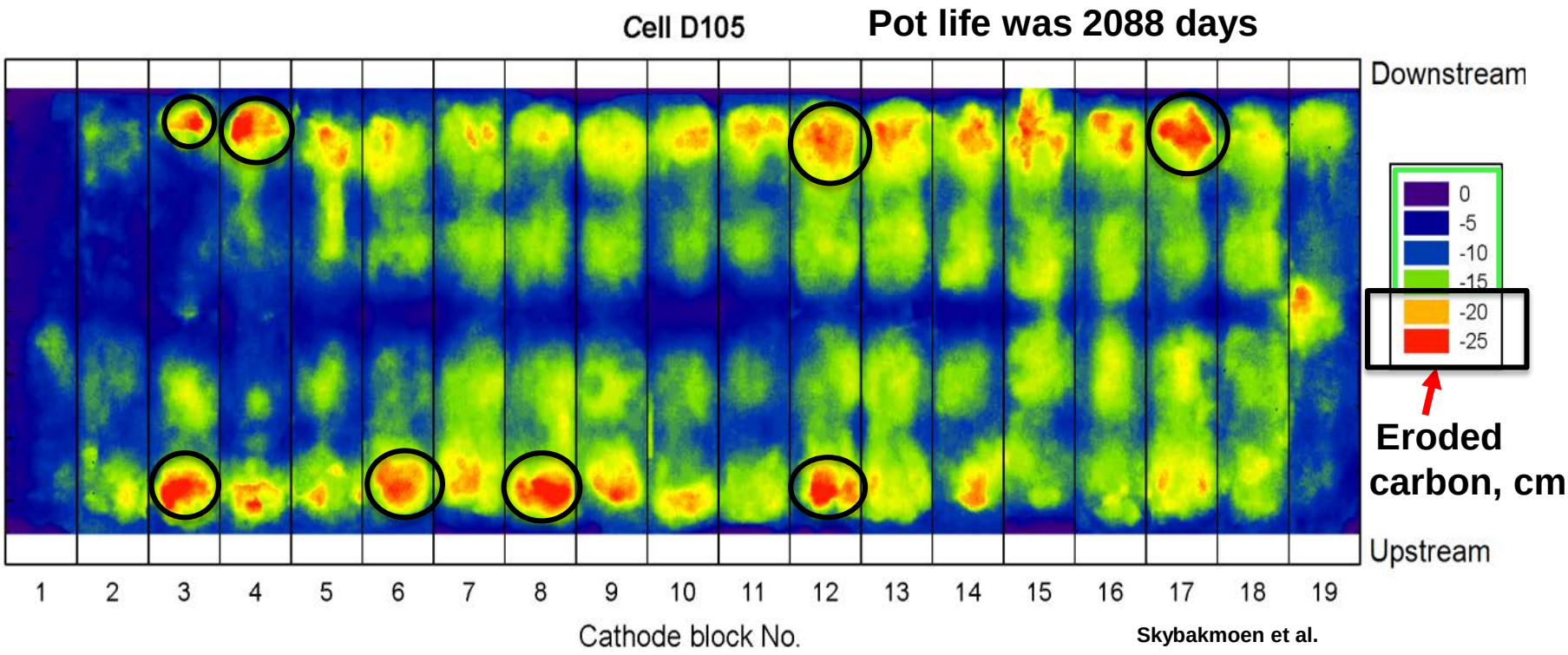
Presented by: Samuel Senanu

Belem, 29 October – 1 November 2018

Presenter's Bio

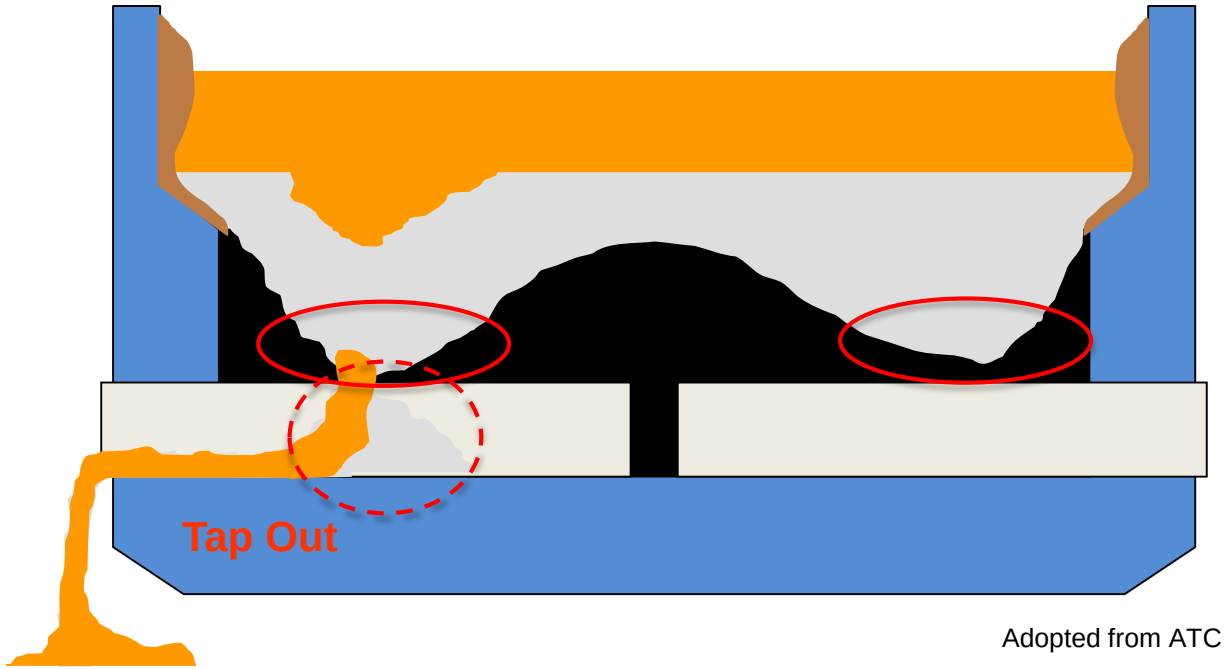
- **Name: Samuel Senanu**
- **Degrees and date earned: MSc Light Metals Production, August 2008.**
- **Affiliation: NTNU - Norwegian University of Science and Technology**
- **Present position: PhD Candidate**
- **Work experience: Process Engineer Potrooms, Alcoa Norway (2008-2016)**

Motivation


Cell D105
Pot life was 2088 days
Downstream
0
-5
-10
-15
-20
-25
Upstream
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Cathode block No.
Eroded carbon, cm
Skybakmoen et al.

Motivation

A single pothole is enough to kill a cell!



Adopted from ATC

Autopsy Analysis

- **Visual observations, profilometer and 3D Scanning**
  - **Topography of wear**
  - **Variation in wear patterns**

- **Micro analysis (SEM, EDS, XRD, CT Scanning)**
  - **Interface analysis**
  - **Chemical composition**
  - **Microstructure**

Overview of Autopsied SPL

Pot	Arrangement/ Technology	Amperage(kA)/ Cathode Current Density(A/cm^2)	Pot age (days)	Carbon Cathode Type	Wear Pattern	Comments
1	Side by Side/ Prebaked	313 / 0.8	2461	Graphitized and Impregnated	WW	Planned shutdown
2	End to End/ Prebaked	175 / 0.8	1028	Graphitic (100% Graphite agg.)	W	Tapout
3	End to End/ Prebaked	175 / 0.8	3154	Graphitic (100% Graphite agg.)	W	Planned shutdown
4	End to End/ Prebaked	175 / 0.8	2849	Graphitic (100% Graphite agg.)	W	Planned shutdown
5	Side by Side/ Prebaked	313 / 0.8	1731	Graphitized and High Density	WW	Tapout

What was Done

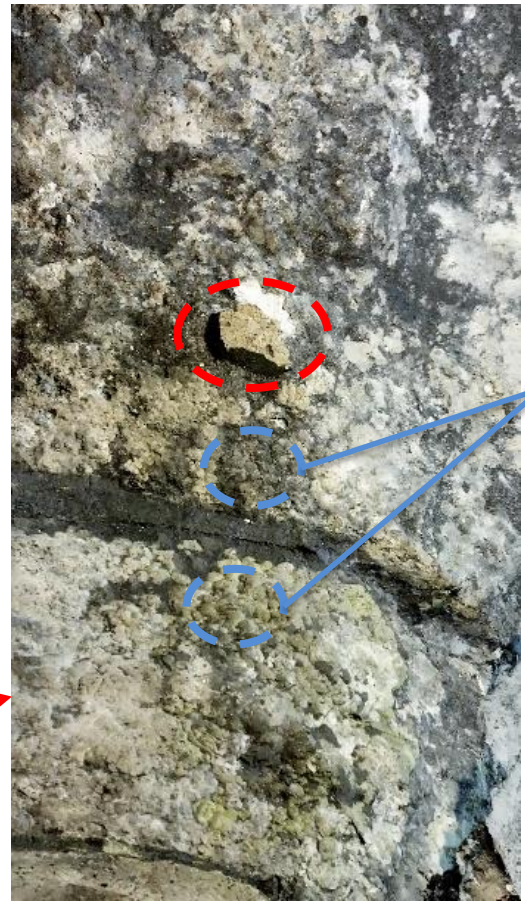
Size of the Spent potlining = 4 m X 15 m

Wear pattern measurements

Photography

Sample Collection

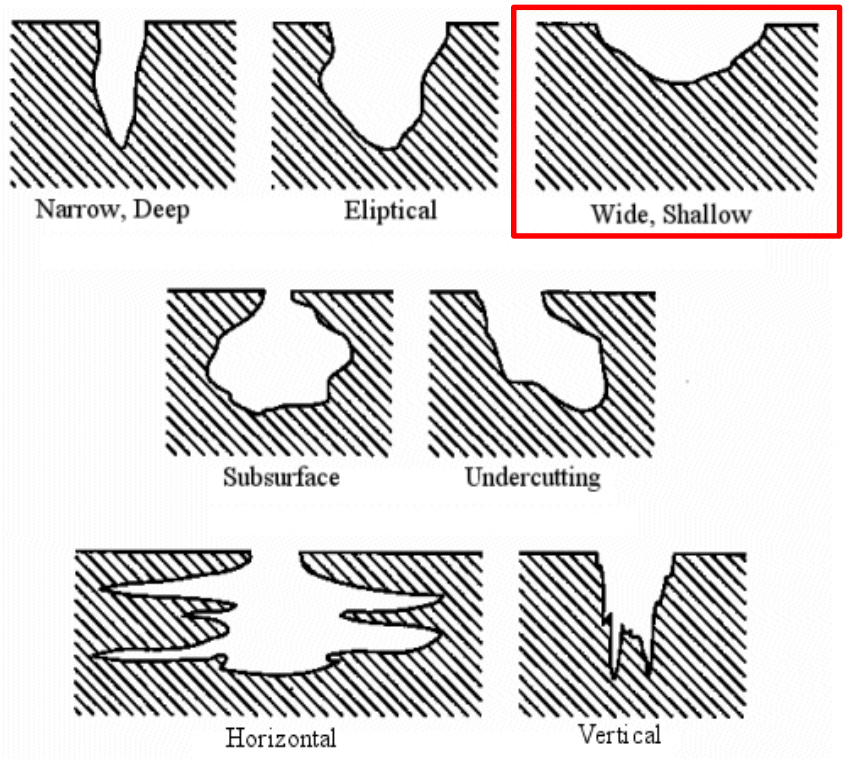
Pitting on Spent Potlining



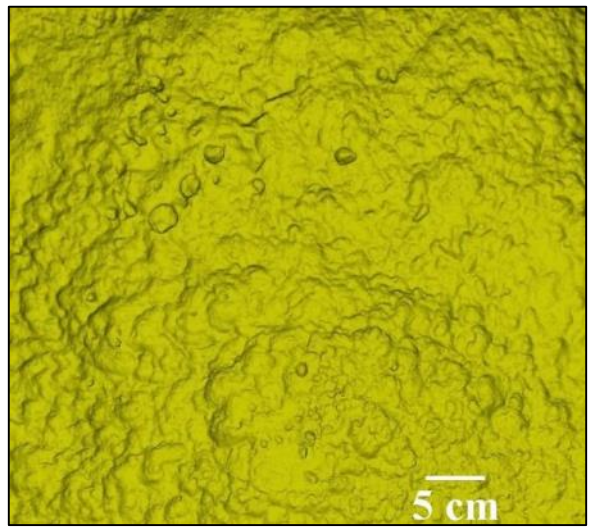
Pothole location characterized by pitting

Pitting

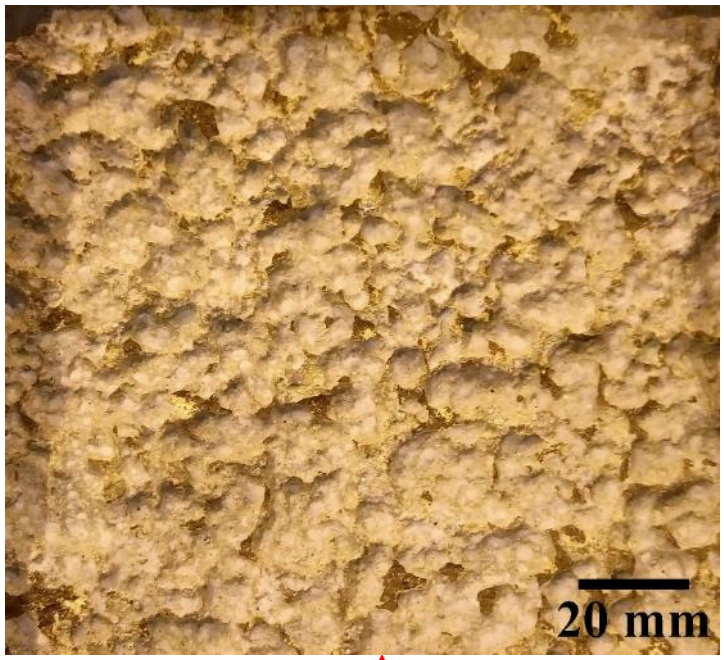
Pitting is a term adopted from pitting corrosion of steel which is a highly localized form of corrosion that produces sharply defined cavities

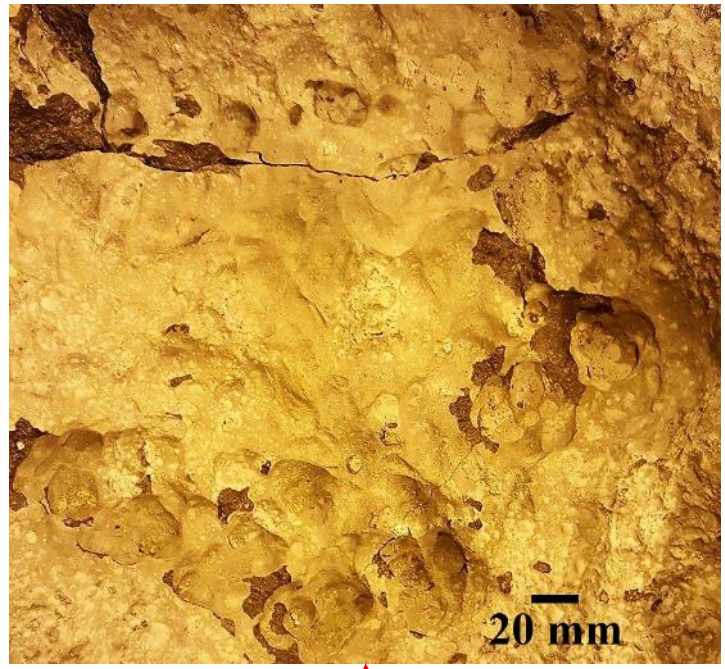


Ref: J.R. Davis, *Corrosion:*

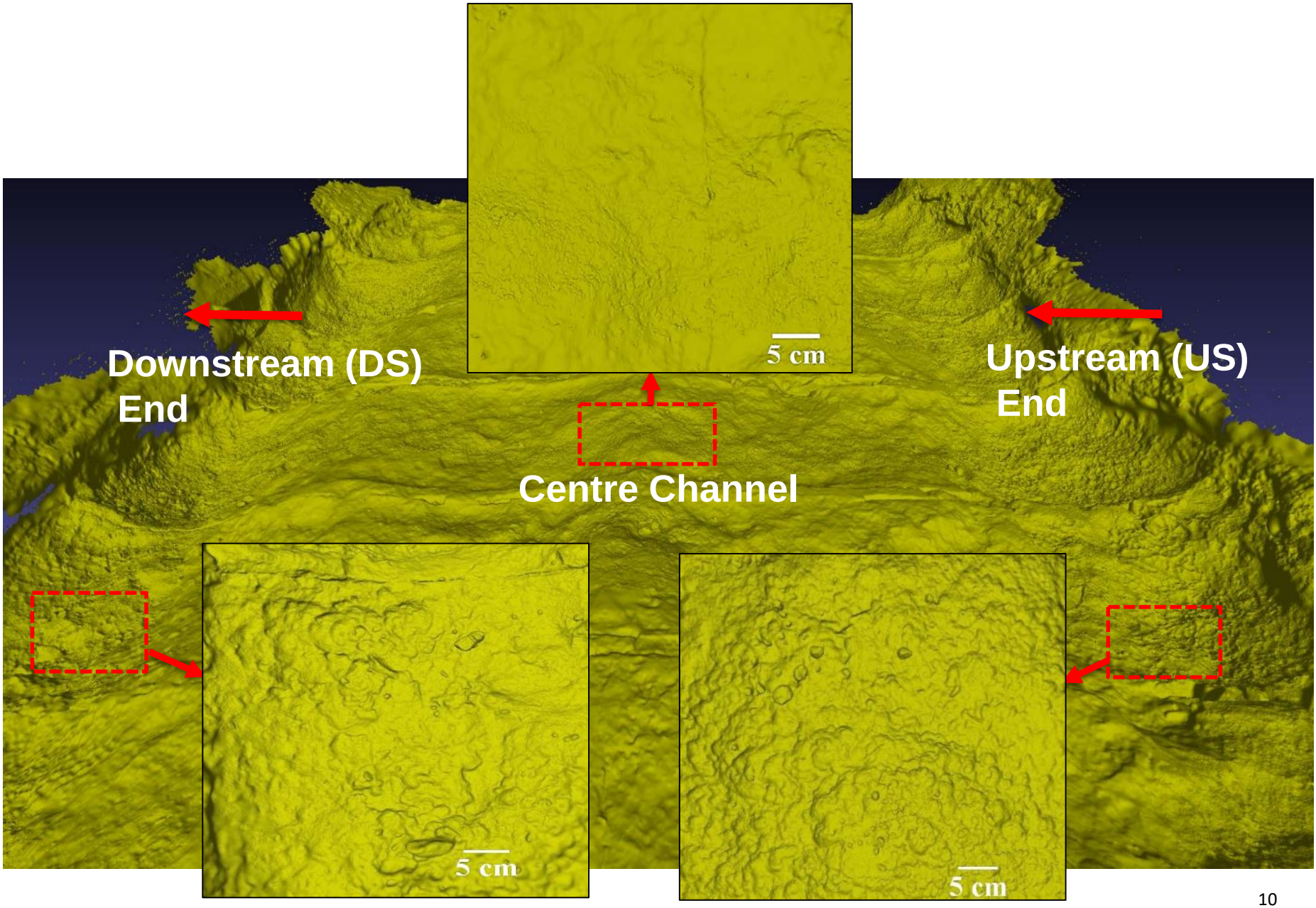


Pitting on Spent Potlining

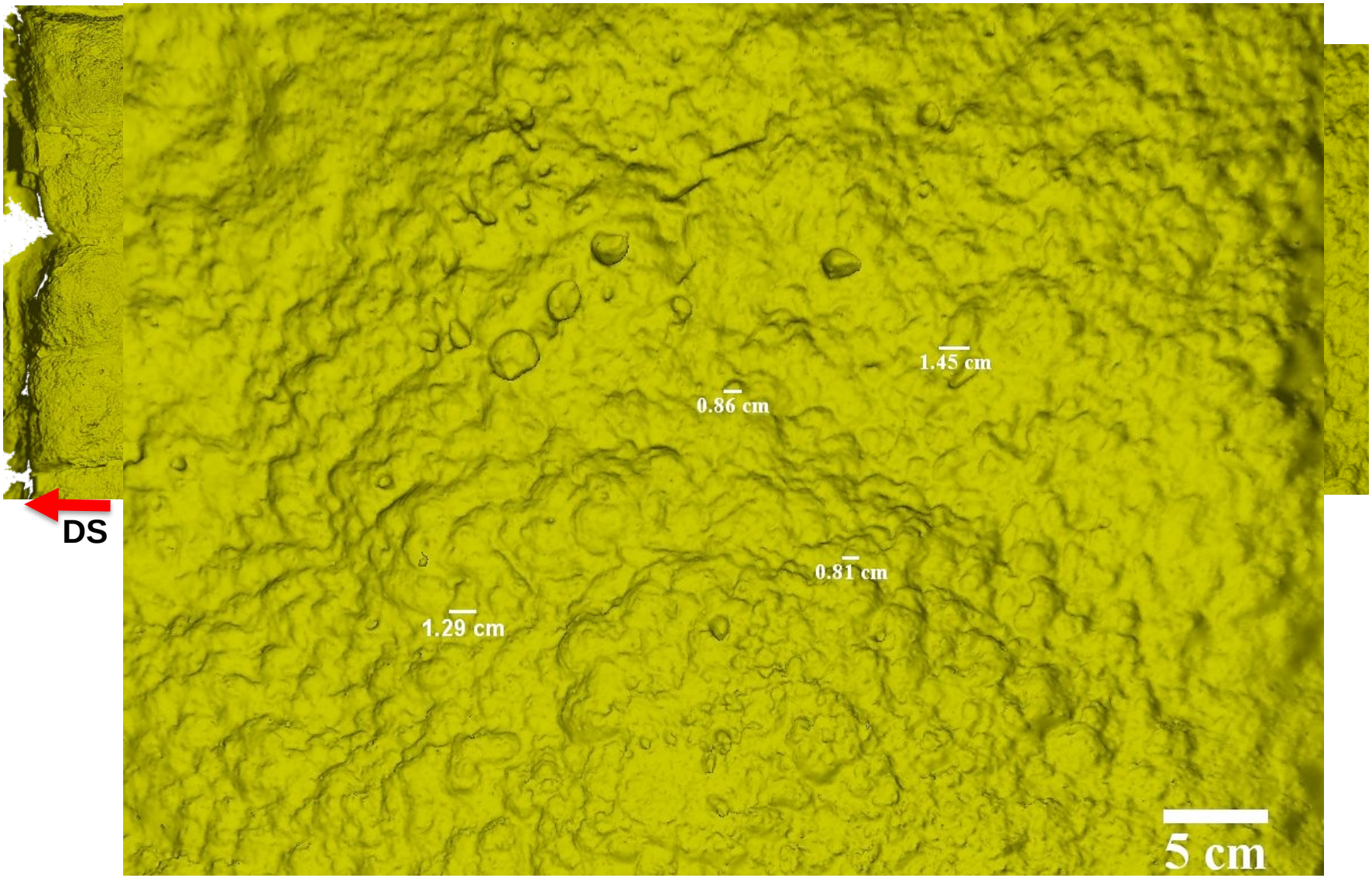




Pitting on Spent Potlining (3D scanning)



Characterization of Pitting



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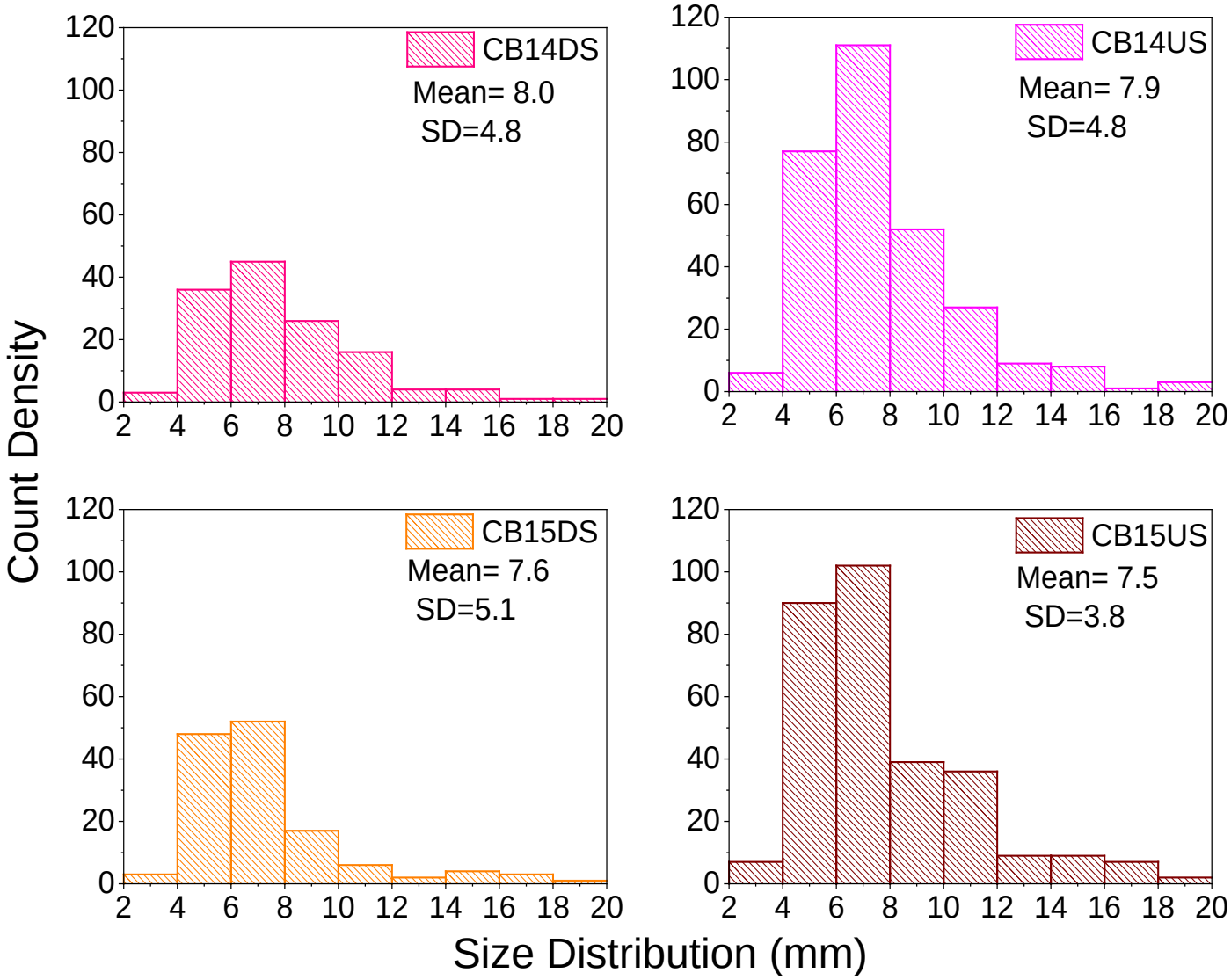
Characterization of Pitting



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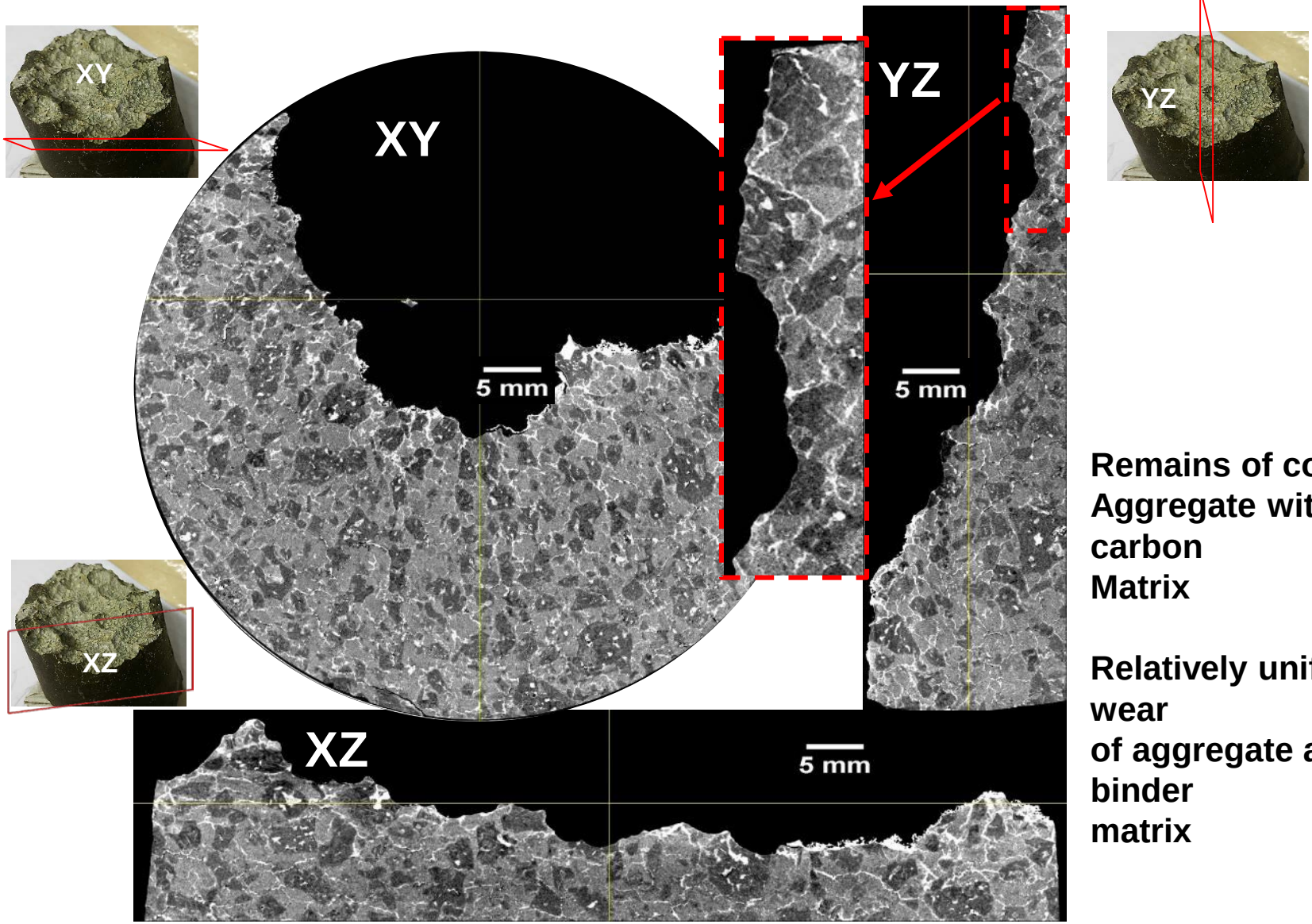
Microstructure Analysis

Samples for CT analysis

Samples for Microscopy analysis

Microstructure Analysis (CT)

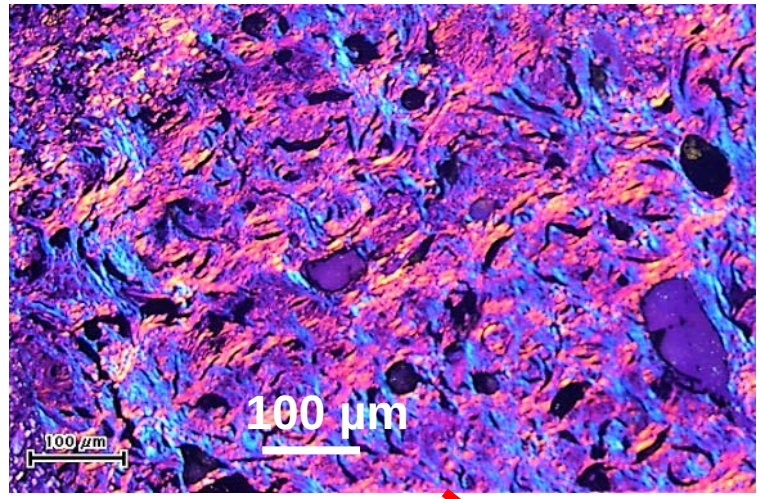


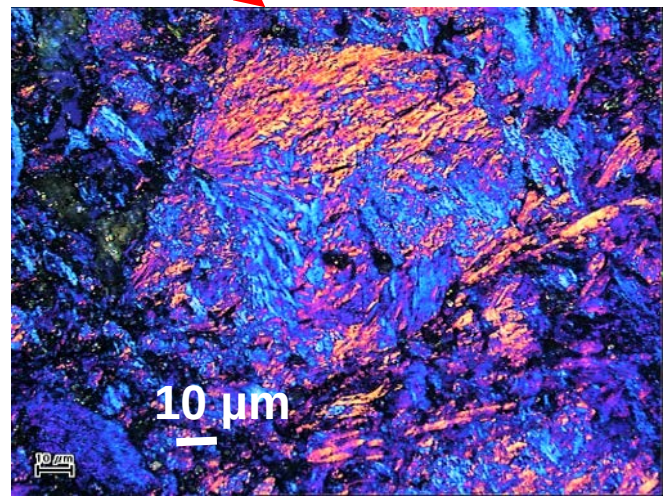
Remains of coke
Aggregate within carbon
Matrix

Relatively uniform wear
of aggregate and binder
matrix

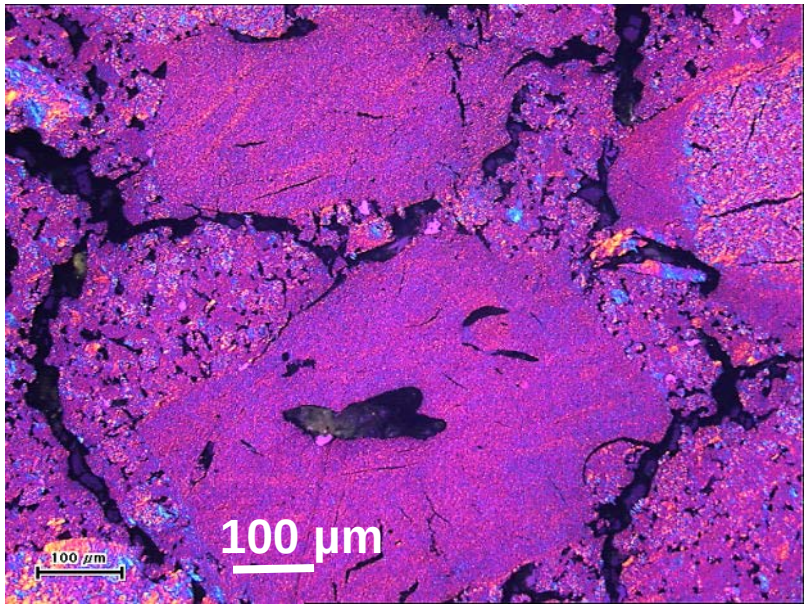
Microstructure Analysis

Graphitic Cathode block





Graphitized Cathode block



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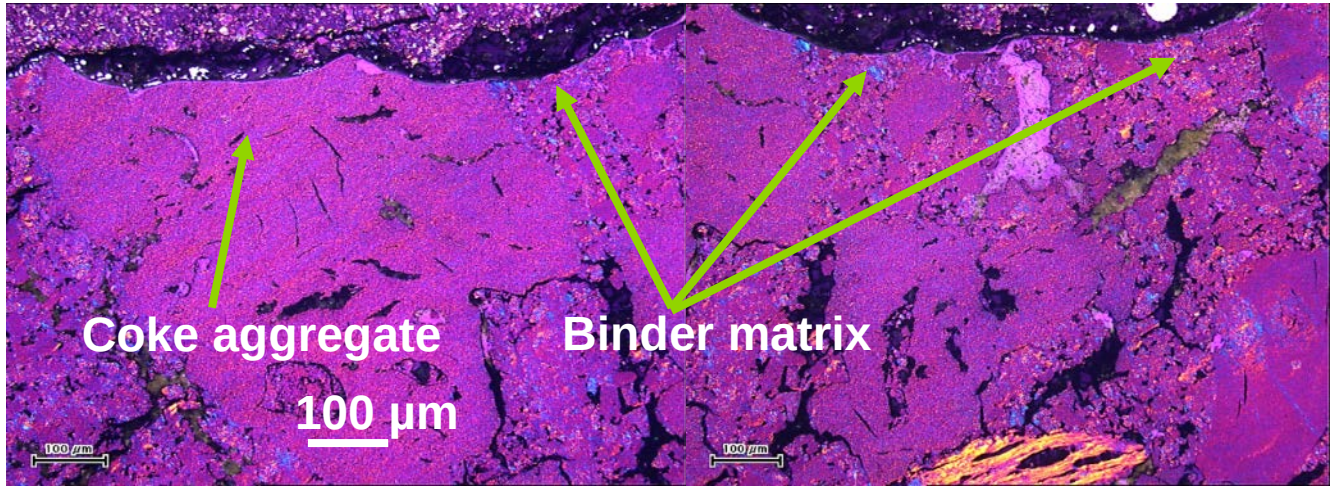
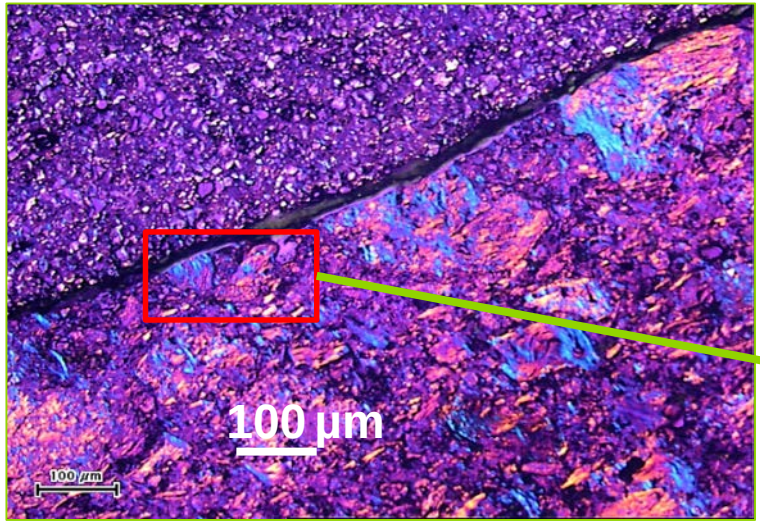
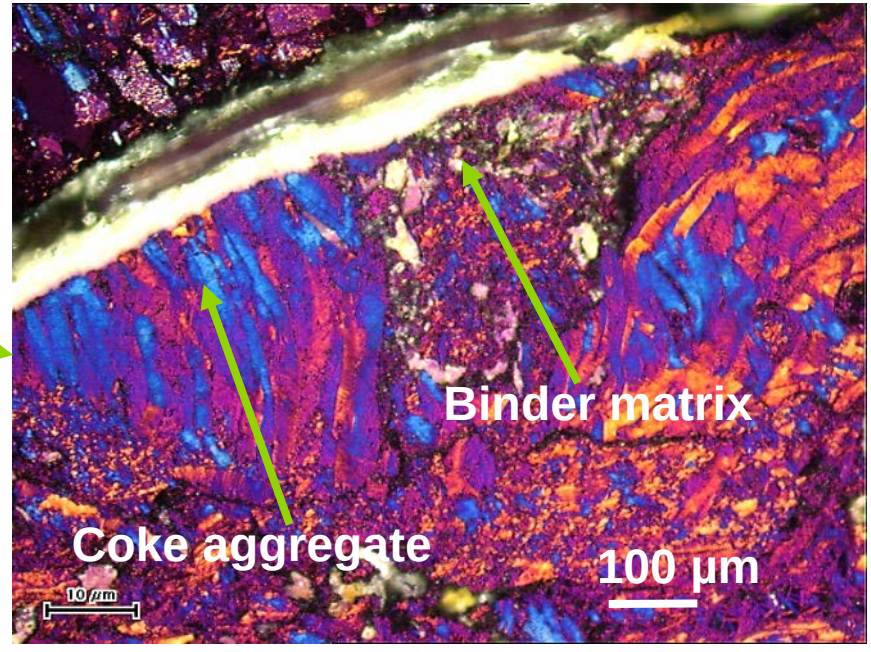
Microstructure Analysis of Pitting

Graphitized Cathode block



Graphitic Cathode block





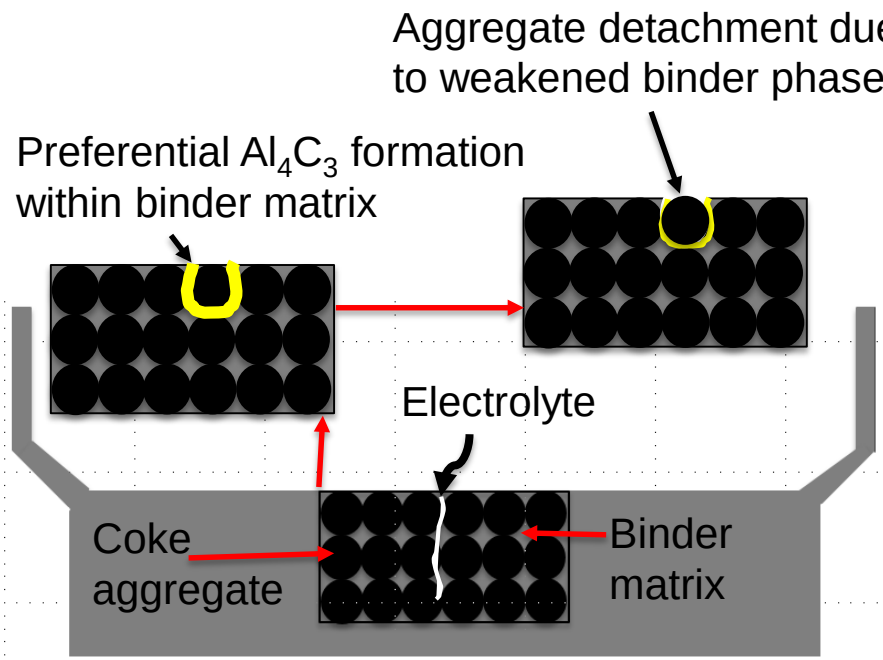
Summary of Autopsy Results

- **Highest wear at side ends of carbon cathode blocks**
- **Locations with highest wear characterized by high degree of distinct pitting**
- **Graphitized cathode blocks with very low degree of pitting at centre canal**
- **Pitting observed all over graphitic cathode block surface**
- **Variations in size of pitting from centre canal to side end of cathode blocks**
- **Remains of worn out coke aggregate observed in carbon matrix**

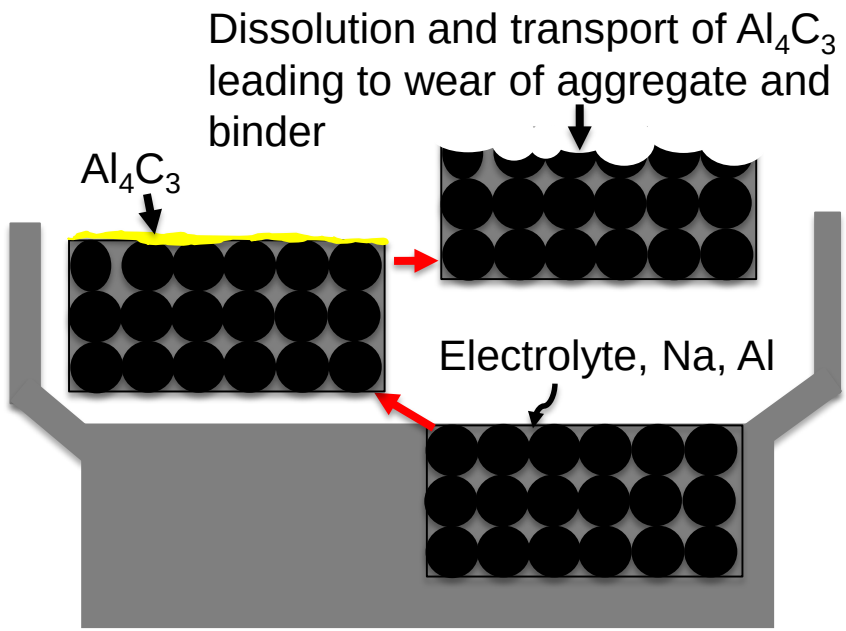
Discussions

What is the mechanism behind pitting formation on carbon cathode blocks?

- **Aggregate grain detachment due to weakened binder matrix**

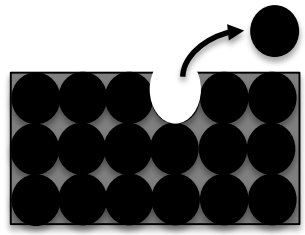


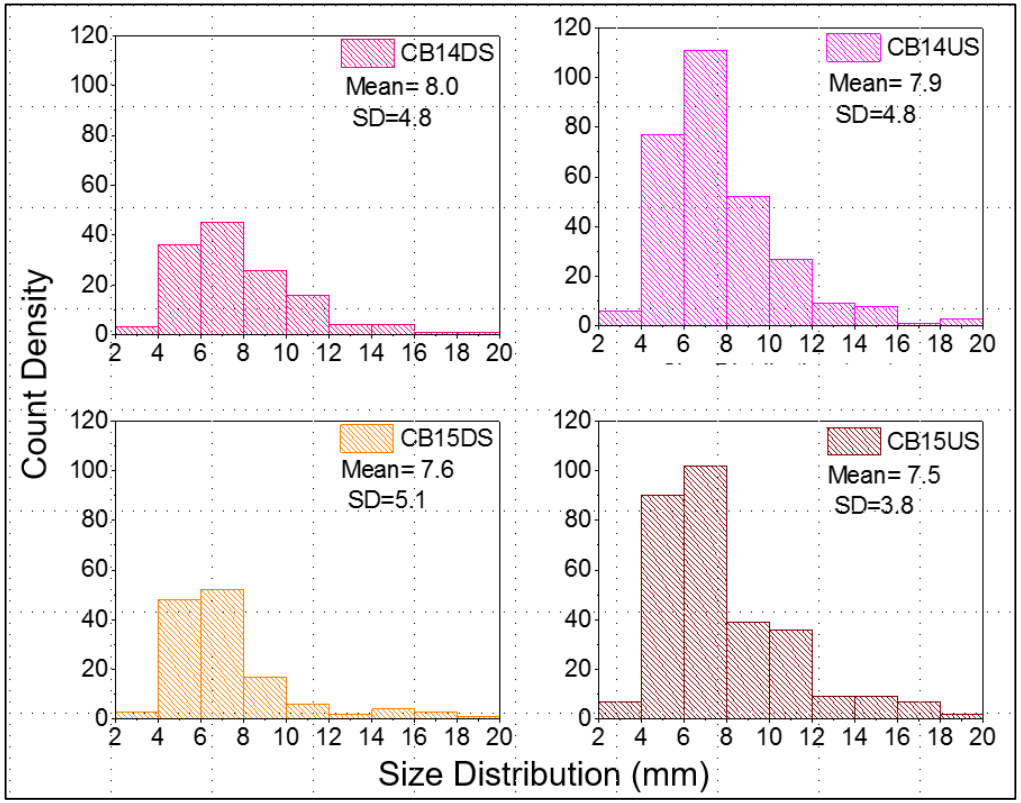
- **Electrochemical / Chemical wear of carbon cathode (binder and aggregate)**



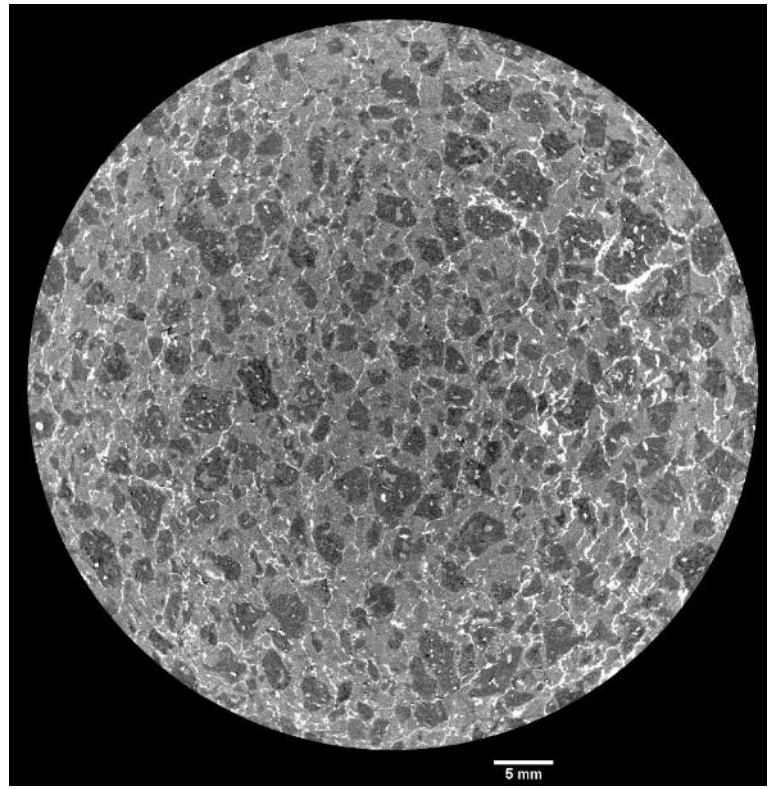
Discussions

Verify grain detachment mechanism





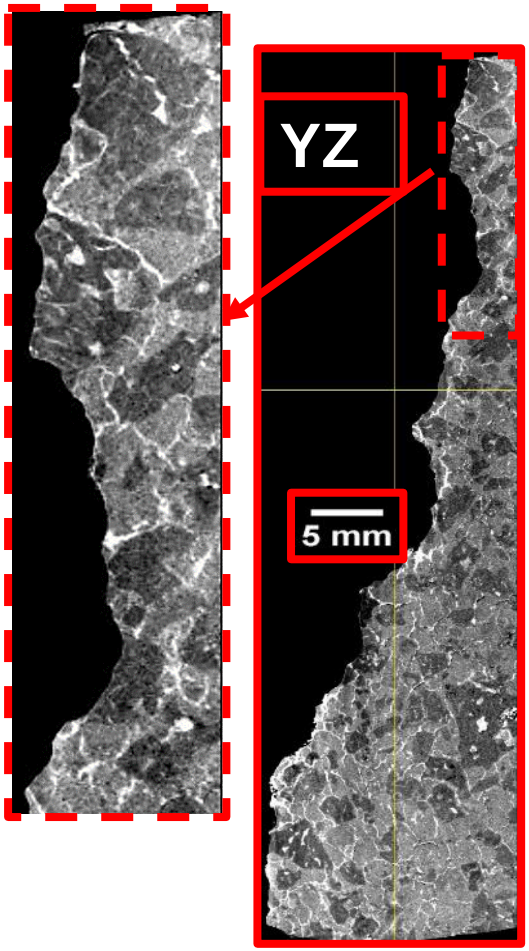
Average pitting size = 7.4 mm

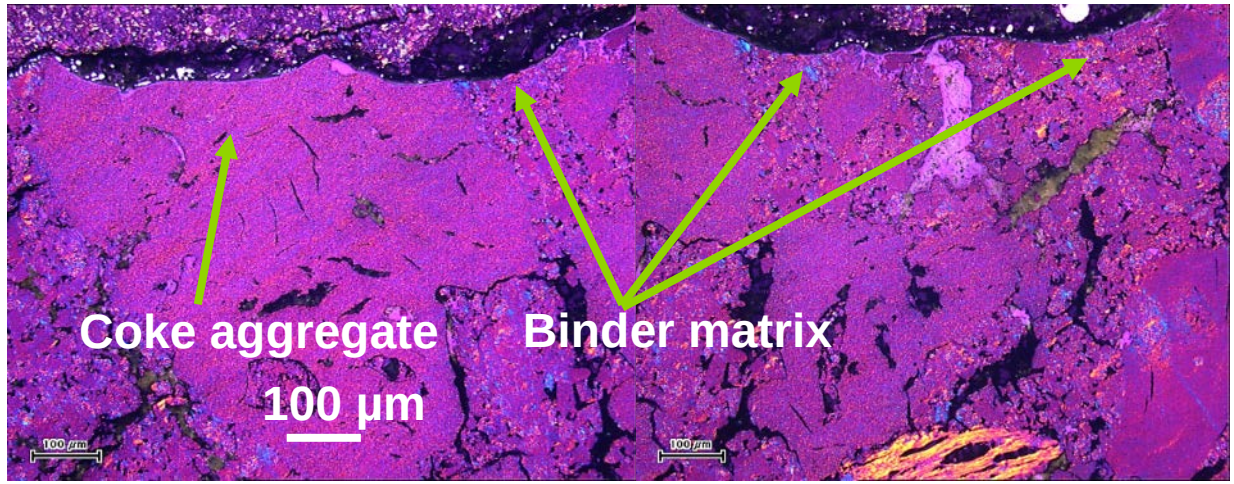


Average aggregate grain size = 3 mm

No correlation beten aggregate grain and pitting size ⇒ No grain detachment

Discussions





Remains of coke aggregate within carbon matrix as shown by CT image and optical micrographs questions particle detachment as a possible mechanism

A relatively uniform wear front suggest a chemical or electrochemical mechanism

Conclusions

- **Pitting occurs on all carbon cathode types**
- **Current density and faster transport rates might be important for pitting formation and development**
- **Occurrence of pitting at locations with highest wear might suggest it as a precursor for cathode wear**
- **Non-correlation between pitting and aggregate size and presence of aggregate remains with carbon matrix questions particle detachment as possible mechanism for pitting formation**
- **A relatively uniform wear front suggest chemical or electrochemical mechanism**

Acknowledgement

Financial support from the Norwegian Research Council and the partners Hydro, Alcoa, Elkem Carbon and Skamol through the project ”Reactivity of Carbon and Refractory Materials used in Metal Production Technology” (CARMA) is acknowledged.