

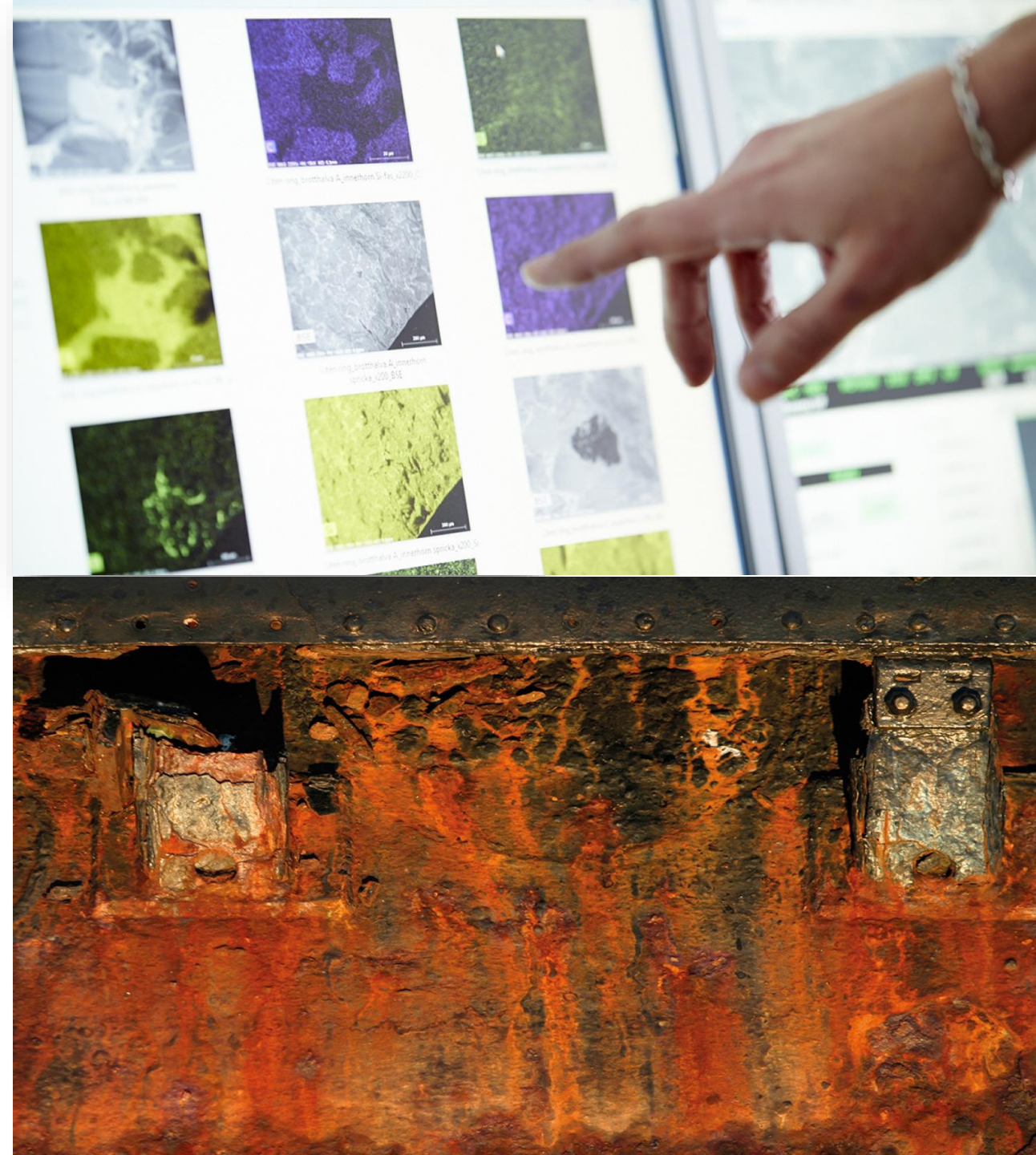


# CORROSION OF HIGH TEMPERATURE MATERIALS IN BURNERS AND BOILERS FOR SMALL-SCALE COMBUSTION OF BIOMASS

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RISE IVF



# General information

- Goal of the project :
  - Gain practical knowledge on high temperature corrosion processes in small to medium sized plants fired mainly by pellet-based bio-fuels.
  - minimize problems that lead to operational disturbances
  - increase the lifetime of critical components by a factor of 2-3 (longer term)
- Project HTC 1b followed the sub project inside HTC 1a project under the period 2014-2017

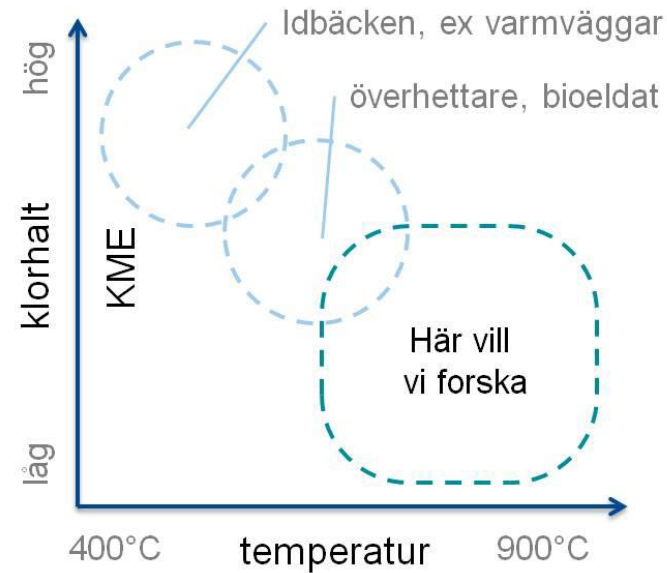


# Background

- In the combustion of bio-based fuels the critically exposed burner parts in small boilers are typically **uncooled** and are usually made of **FeCr or FeCrNi** alloys
- These materials can suffer attack from the **ashes** because of the formation of **alkali chromate**
- The reaction depletes the protective oxide in chromia, leading to accelerated corrosion
- This ultimately results in failure of the boiler unit and/or is limiting the service life of critical burner components

# Status 2018

- Determination of the project plan for the next upcoming years



- Analysis of exposed materials after field exposure at one of JanFire facility
  - 800°C for 12 hours per days for 5 and a half months
- Laboratory exposure :
  - Validation of a new test method
  - Materials' selection for the first lab exposure of the project 2018-2021



# Field exposure results

- Focus on experimental materials (base FeCrAl)

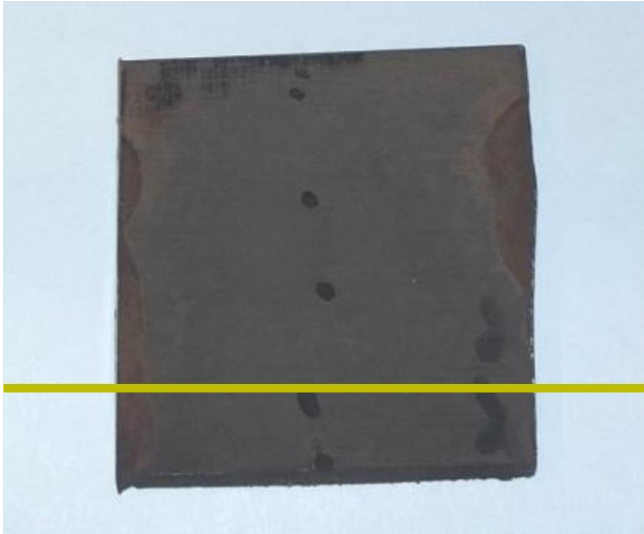
| Material   | Composition                                |
|------------|--------------------------------------------|
| 4916       | 89,9 Fe, 5,1 Cr, 3,0 Al, 2 Si, 0,03 C      |
| 4857       | 84,9 Fe, 10,1 Cr, 3,1 Al, 2 Si, 0,025 C    |
| 4800       | 80,2 Fe, 14,9 Cr, 3,0 Al, 1,9 Si, 0,022 C  |
| 4799       | 75,2 Fe, 20,1 Cr, 2,8 Al, 1,9 Si, 0,023 C  |
| 4780       | 85,9 Fe, 10,1 Cr, 4,0 Al, 0,02 Si, 0,021 C |
| 4985       | 82,4 Fe, 12,5 Cr, 3,7 Al, 1,3 Si, 0,018 C  |
| 4989       | 83,0 Fe, 12,6 Cr, 2,7 Al, 1,7 Si, 0,025 C  |
| 4942       | 85,9 Fe, 10,0 Cr, 4,0 Al, 0,14 Si, 0,005 C |
| 4929       | 86,0 Fe, 10,0 Cr, 3,9 Al, 0,15 Si, 0,025 C |
| APMT (ref) | 71 Fe, 21 Cr, 5 Al, 3 Mo                   |

- Conditions : 800 °C-12h for 5 and a half months



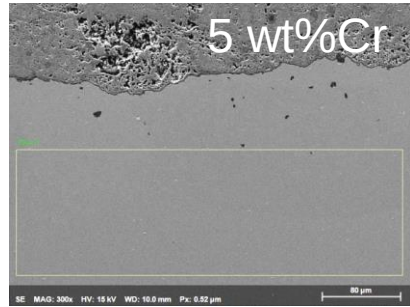
# Field exposure results : preparation of samples

- After cutting the samples from the plate (half size), the samples have then been put into epoxy resin and ground and polished

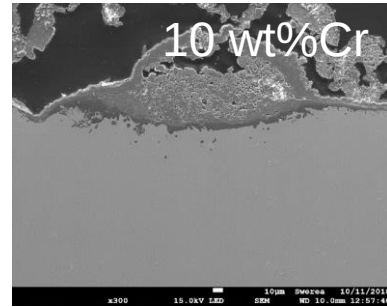


- SEM analysis have been performed as it has been in the previous HTC project
  - Images at (x80), x300, x1000 and x3000
  - Mapping at x3000

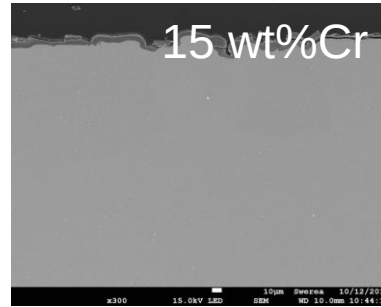
# Field exposure results : SEM overview x300



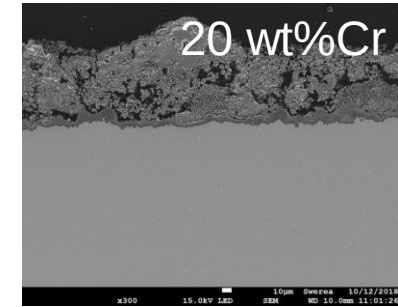
HTC 4916



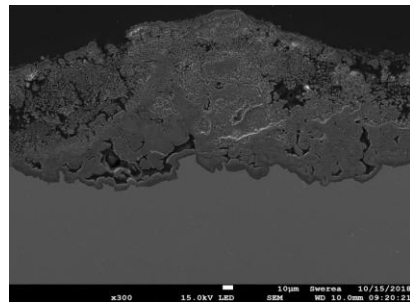
HTC 4857



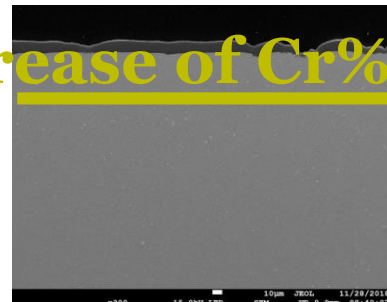
HTC 4800



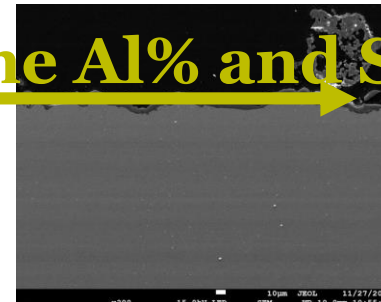
HTC 4799



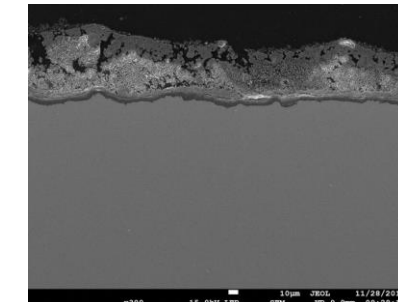
HTC 4780



KME 4985

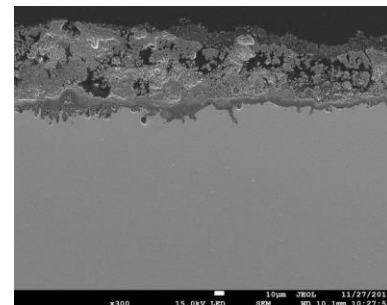


KME 4989

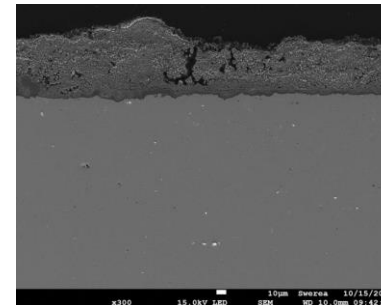


Alster 4942

**Increase of Cr% (same Al% and Si%)**

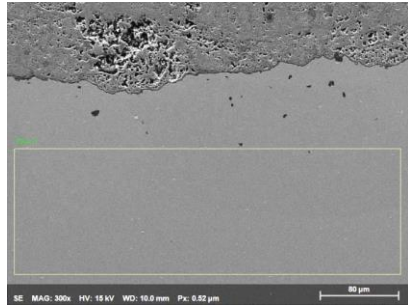


Alster 4929

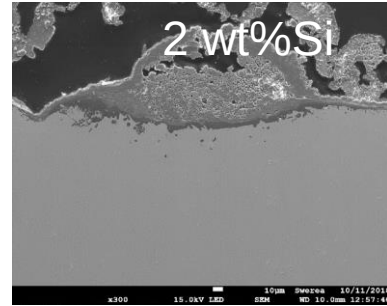


APMT

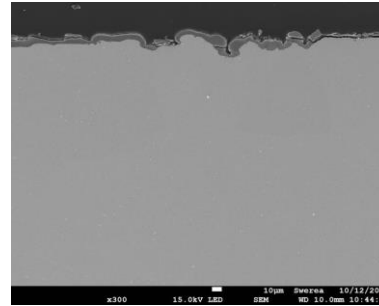
# Field exposure results : SEM overview x300



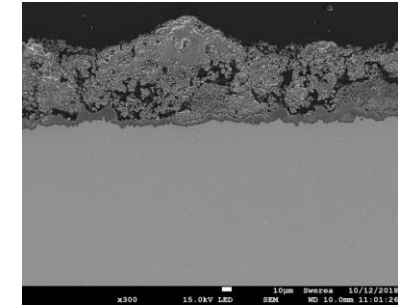
HTC 4916



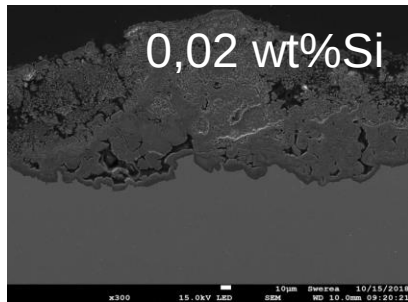
HTC 4857



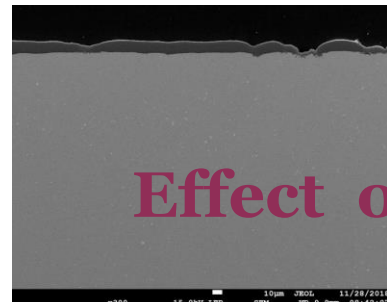
HTC 4800



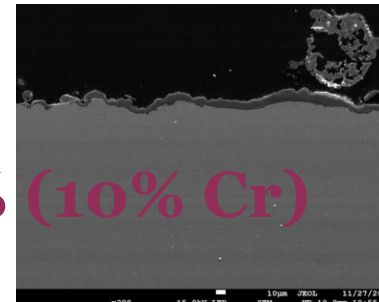
HTC 4799



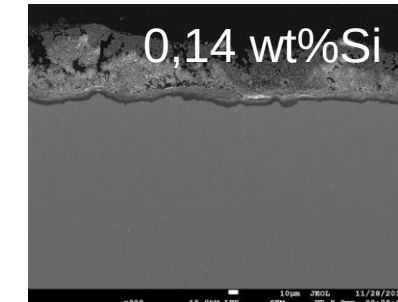
HTC 4780



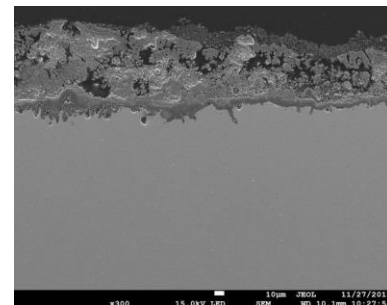
KME 4985



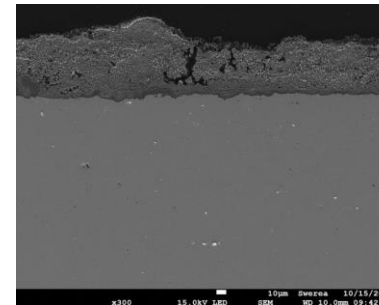
KME 4989



Alster 4942



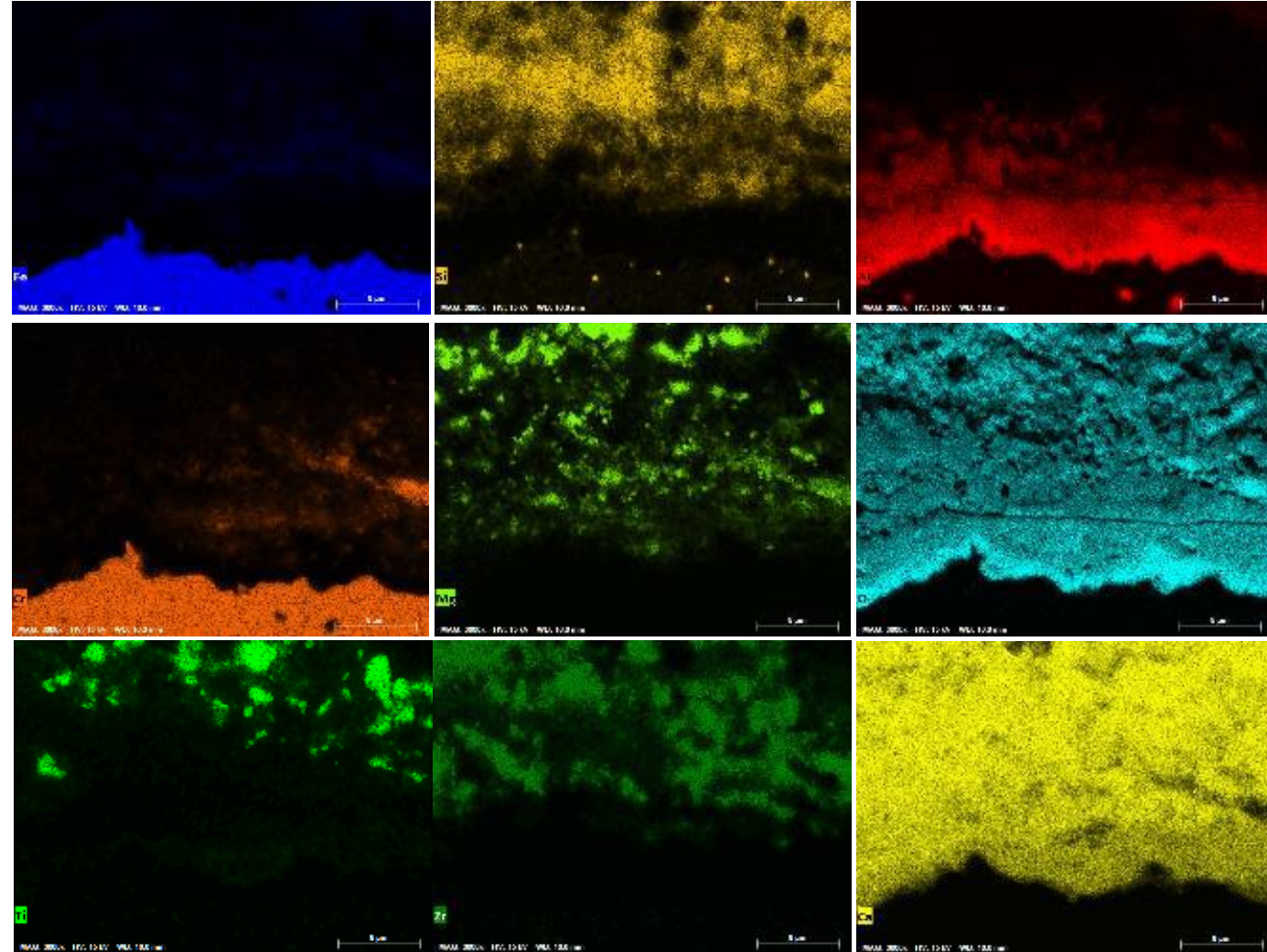
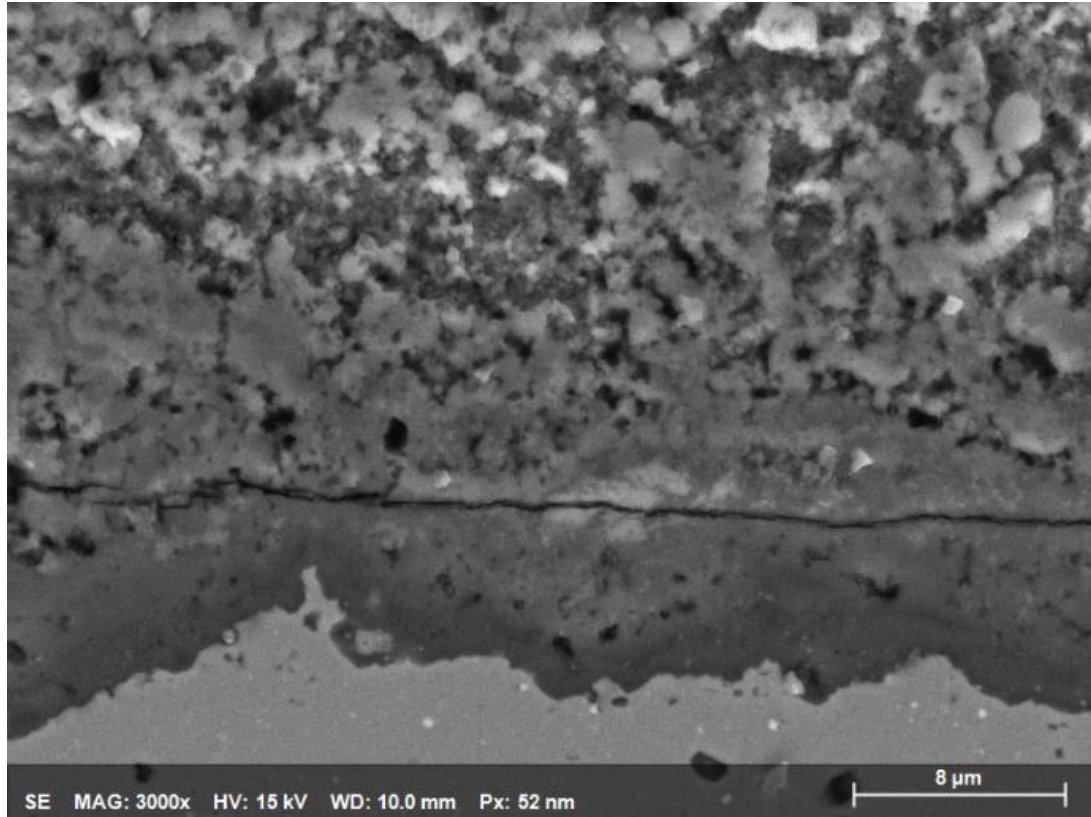
Alster 4929



APMT

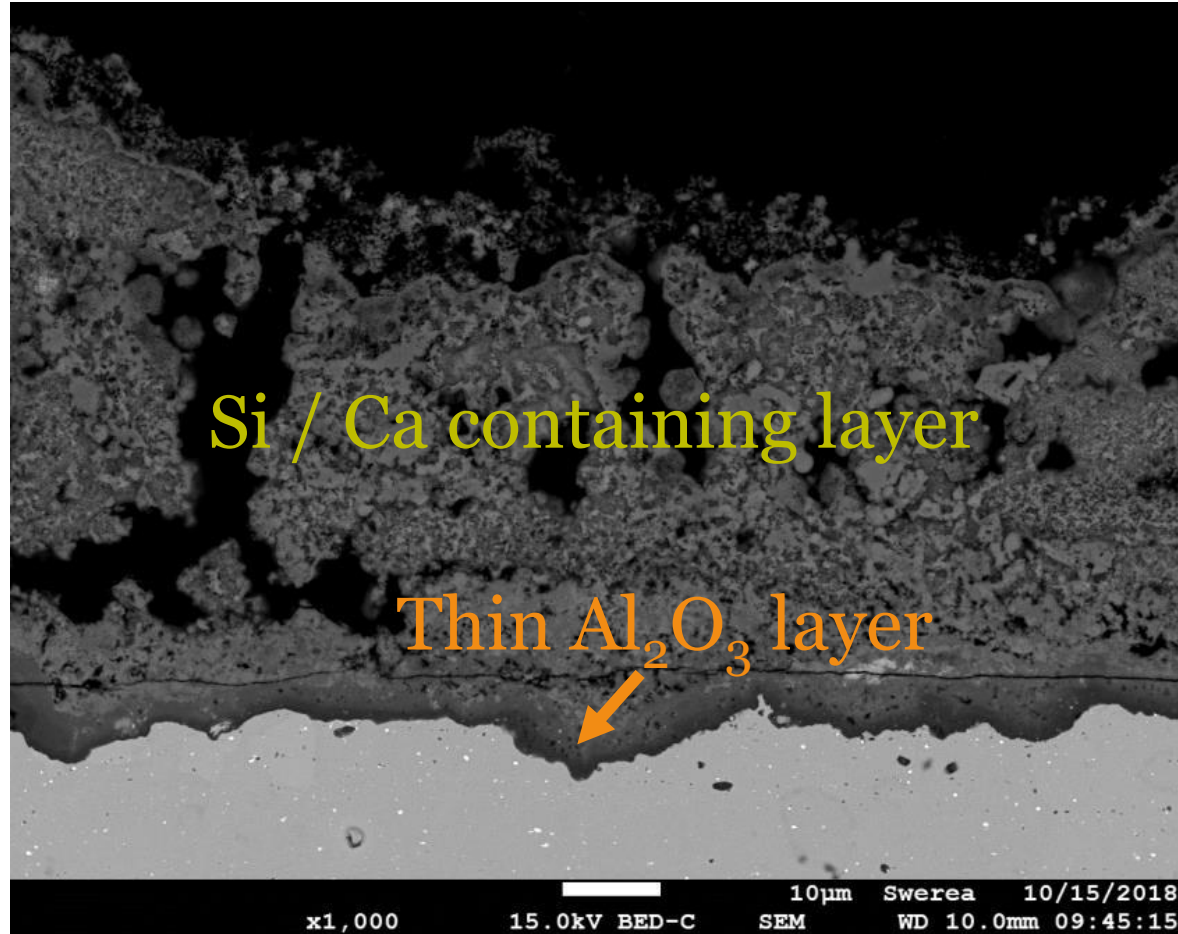


# Field exposure APMT



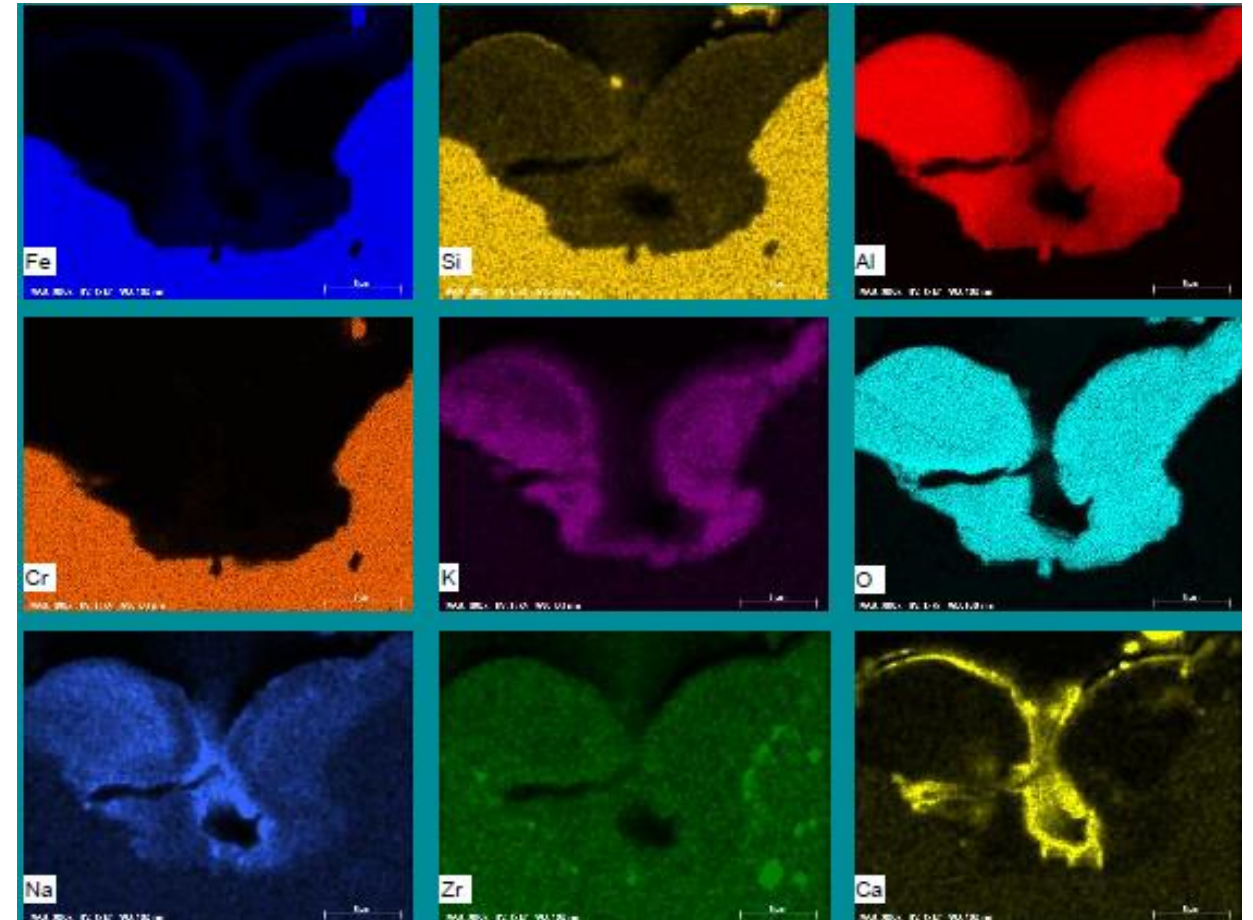
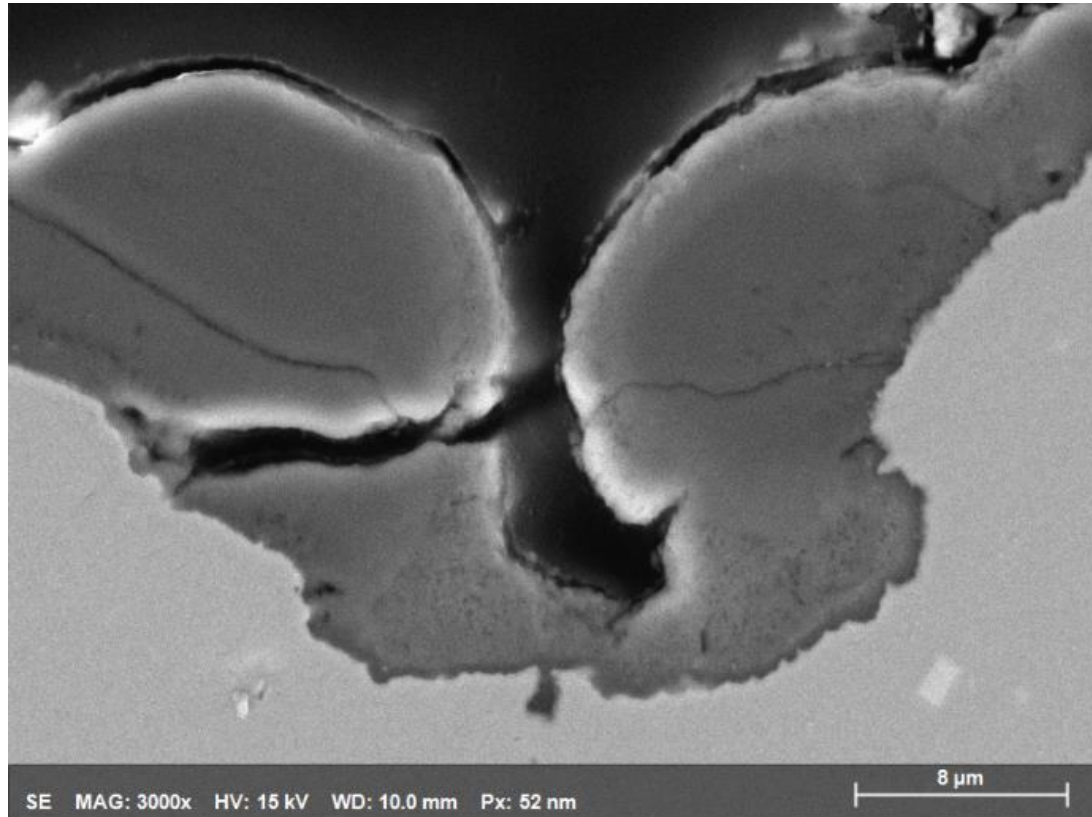
# Field exposure results : APMT

- Oxide combined with ashes : 40-70  $\mu\text{m}$  thick

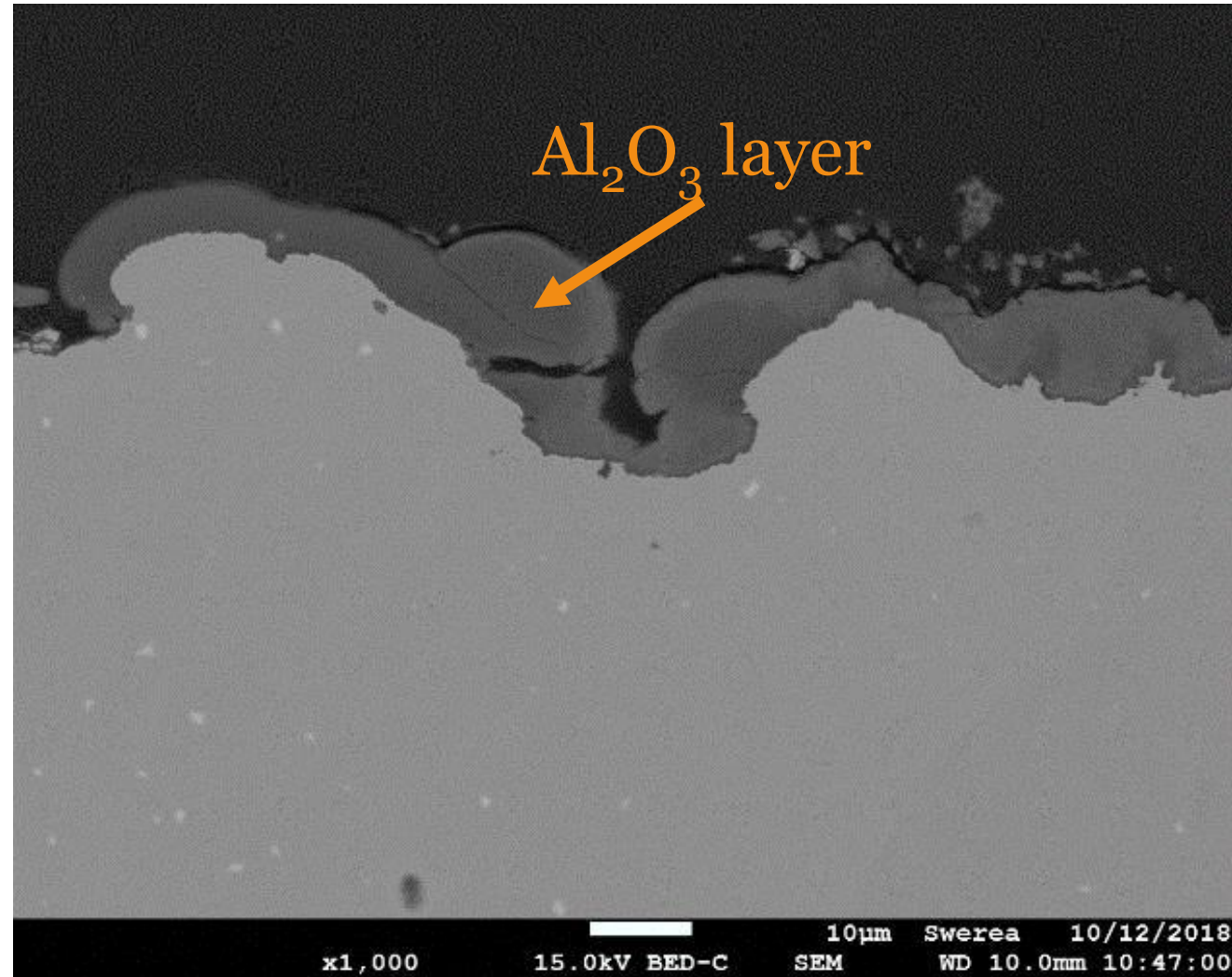




# Field exposure HTC 4800



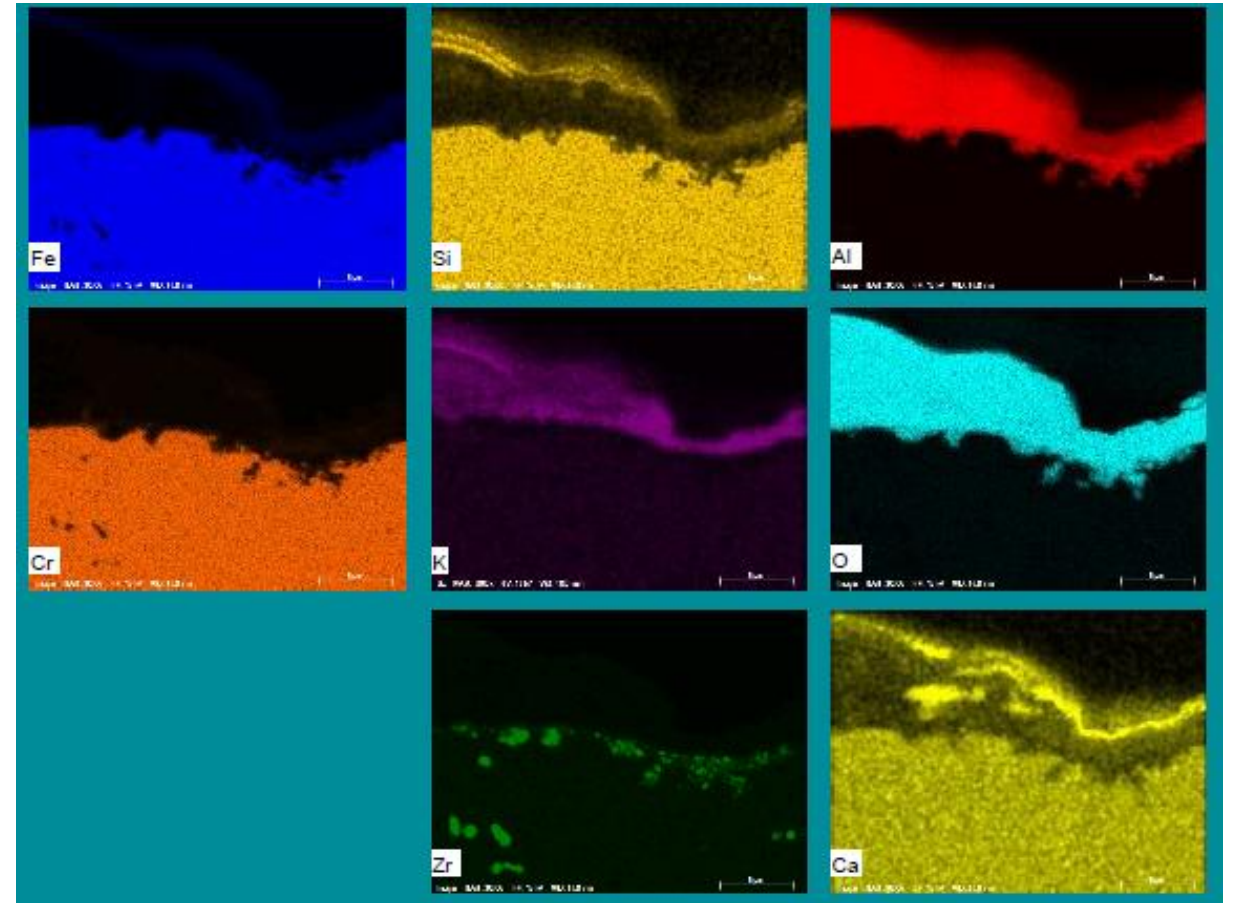
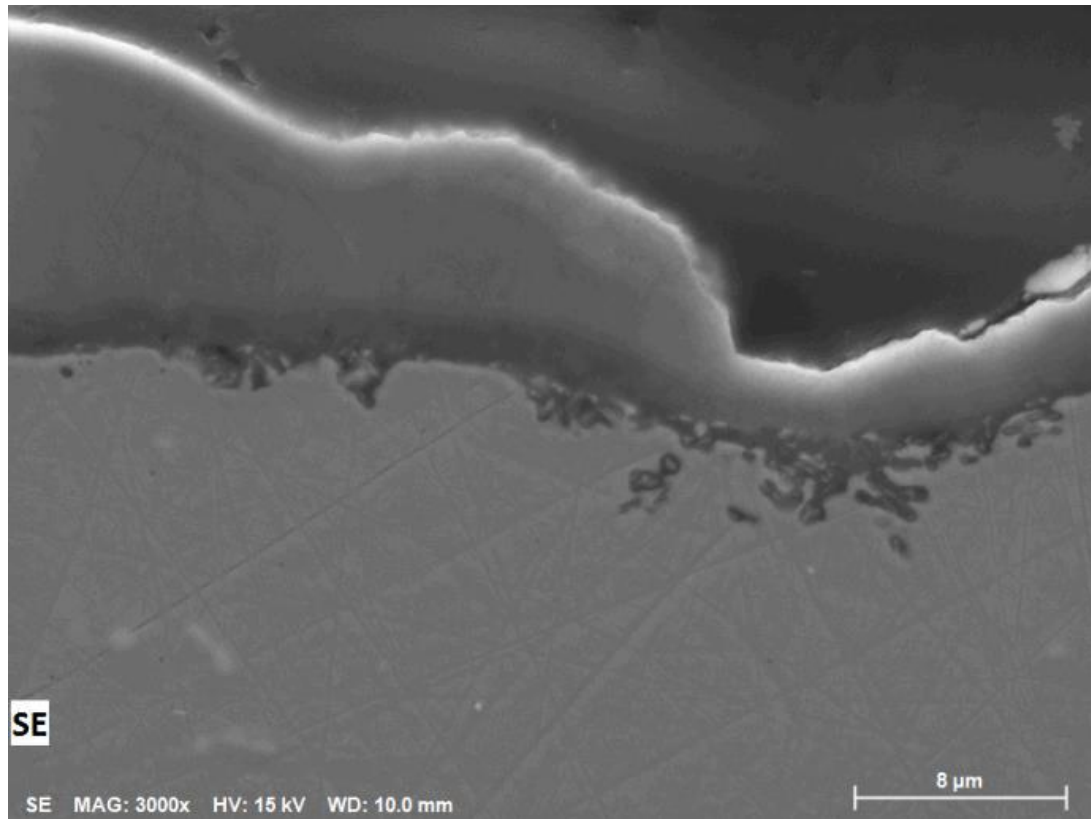
# Field exposure HTC 4800



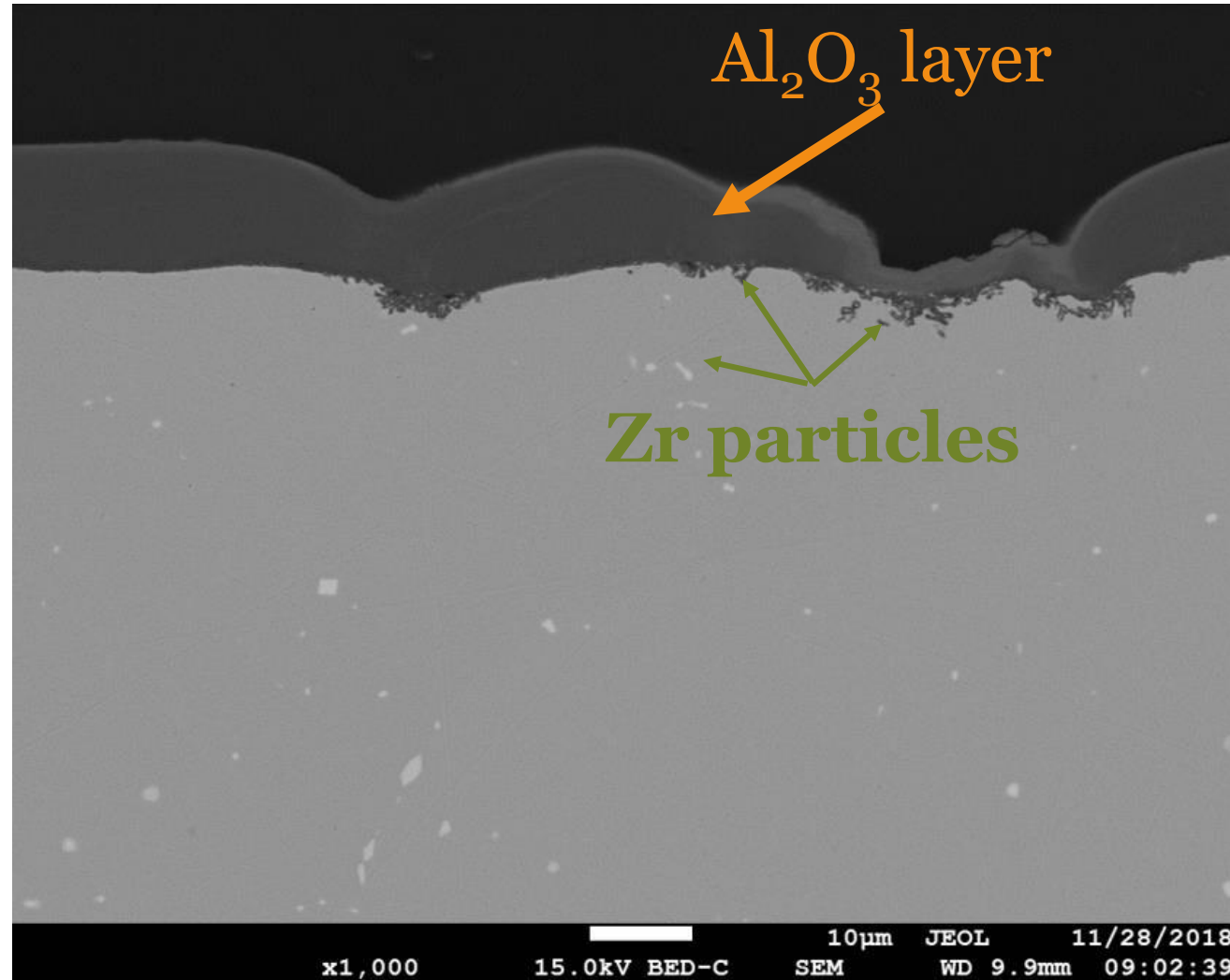
Oxide : 2-12 µm thick



# Field exposure KME 4985



# Field exposure KME 4985



Oxide : 2-15 µm thick

# Field exposure : Conclusion

| Material    | Oxide layer :<br>intern                        | Oxide layer :<br>intermediate | Oxide layer : outside                  | Total<br>oxide/ashes<br>thickness (µm) |
|-------------|------------------------------------------------|-------------------------------|----------------------------------------|----------------------------------------|
| APMT (ref)  | Al (2-3 µm)                                    | Al, Ca, Si (8-14 µm)          | Si, Ca                                 | <b>40 – 70</b>                         |
| HTC 4916    | 90 Fe, 5 Cr, 3 Al, 2 Si, 0,03 C, Na (1-1,2 mm) |                               | Si, Zr, Ca, Ti (200 µm)                | <b>1000 – 1400</b>                     |
| HTC 4857    | Al, K (2-8 µm)                                 | Mg, Ca, Si, Cr (10-100 µm)    | Glass structure                        | <b>10 – 240</b>                        |
| HTC 4800    | 80 Fe, 15 Cr, 3 Al, 2 Si, 0,022 C              |                               | /                                      | <b>2 – 12</b>                          |
| HTC 4799    | Al (6-10 µm)                                   | /                             | Si, Ca, Mg particles                   | <b>80 – 100</b>                        |
| HTC 4780    | Al (1-6 µm)                                    | /                             | Cr, Ca                                 | <b>60 – 140</b>                        |
| KME 4985    | Al, K (2-15 µm)                                | /                             | /                                      | <b>2 – 15</b>                          |
| KME 4989    | Al (1-15 µm)                                   | /                             | /                                      | <b>1 – 15</b>                          |
| Alster 4942 | Al, Ti (2-8 µm)                                | /                             | Si, Cr, Ca, Mg particles<br>(50-70 µm) | <b>50 – 70</b>                         |
| Alster 4929 | Al, Ti, Nb (2-15 µm)                           | /                             | Si, Cr, Ca, Mg particles<br>(50-60 µm) | <b>50 – 85</b>                         |

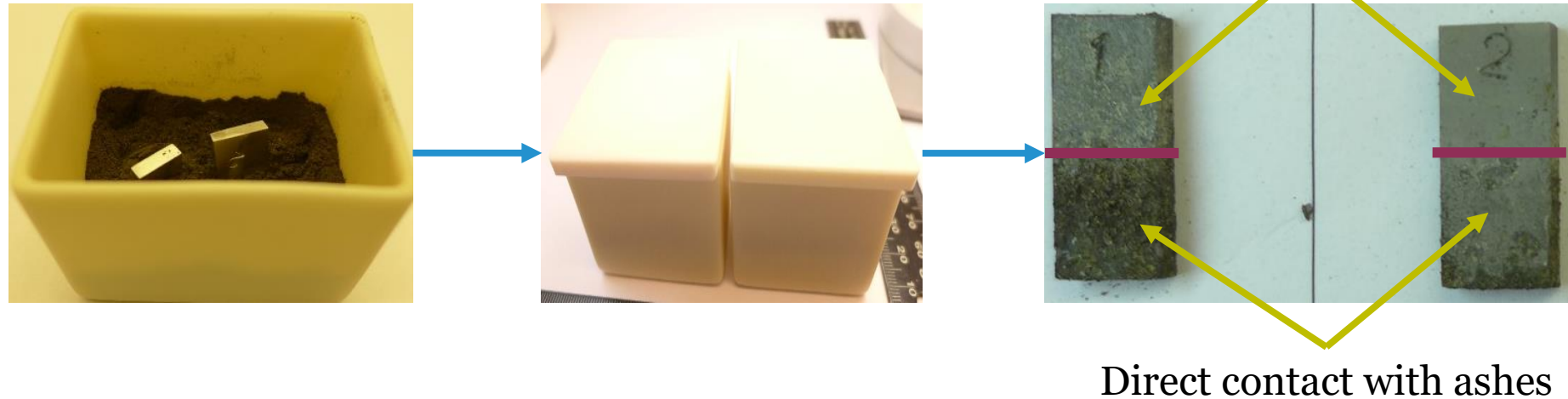


# Field exposure : Conclusion

| Material    | Oxide layer :<br>intern                                                                                                                                   | Oxide layer :<br>intermediate | Oxide layer : outside | Total<br>oxide/ashes<br>thickness (μm) |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------|----------------------------------------|
| APMT (ref)  | 90 Fe, 5 Cr, 3 Al, 2 Si, 0,03 C<br><br>80 Fe, 15 Cr, 3 Al, 2 Si, 0,022 C<br><br>82 Fe, 13 Cr, 4 Al, 1,30 Si, 0,018 C<br>83 Fe, 13 Cr, 3 Al, 2 Si, 0,025 C |                               |                       | <b>40 – 70</b>                         |
| HTC 4916    |                                                                                                                                                           |                               |                       | <b>1000 – 1400</b>                     |
| HTC 4857    |                                                                                                                                                           |                               |                       | <b>10 – 240</b>                        |
| HTC 4800    |                                                                                                                                                           |                               |                       | <b>2 – 12</b>                          |
| HTC 4799    |                                                                                                                                                           |                               |                       | <b>80 – 100</b>                        |
| HTC 4780    |                                                                                                                                                           |                               |                       | <b>60 – 140</b>                        |
| KME 4985    |                                                                                                                                                           |                               |                       | <b>2 – 15</b>                          |
| KME 4989    |                                                                                                                                                           |                               |                       | <b>1 – 15</b>                          |
| Alster 4942 |                                                                                                                                                           |                               |                       | <b>50 – 70</b>                         |
| Alster 4929 |                                                                                                                                                           |                               |                       | <b>50 – 85</b>                         |

# Laboratory exposure

- New method :
  - First test performed at 600°C for 300h and 3 x 100 h with corrosive ashes (high level of Cl) (spring 2018)



- Same method but at higher T will be used for the laboratory exposure (following the project plan)

# Laboratory exposure #1 : conditions

- Chosen method for this project :
  - 900°C
  - 3 x 100h (change of the ashes every 100h)
  - pellet ashes (same as the one used during the 2014-2017 project)
  - Lid of the alumina can slightly open
- Chosen materials : focus on commercial material for the first lab exposure

| Alumina formers  | Chromia formers | Si-rich cast materials |
|------------------|-----------------|------------------------|
| APMT (reference) | 253 MA          | SSG 9017               |
| Kanthal D        | 353 MA          | SSG 9050               |
| Kanthal AF       | Alloy 625       |                        |
| Kanthal A1       | Nikrothal 40    |                        |
| Kanthal APM      | Nikrothal 60    |                        |
| Alloy 197        | Nikrothal 70    |                        |
| Alloy 198        | Nikrothal 80    |                        |

# Laboratory exposure #1 : first results after 2x100h

## ■ Alumina formers :

| APMT<br>(ref)                                                                      | Kanthal D                                                                          | Kanthal AF                                                                         | Kanthal A1                                                                           | Kanthal APM                                                                          | Alloy 197                                                                            | Alloy 198                                                                            |
|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| 71 Fe, 21 Cr,<br><b>5 Al</b> , 3 Mo                                                | 74 Fe, 21 Cr,<br><b>4,9 Al</b> , 0,3 Si                                            | 73 Fe, 21 Cr,<br><b>5,2 Al</b> , 0,4 Si                                            | 73 Fe, 21 Cr,<br><b>5,5 Al</b> , 0,2 Si                                              | 73 Fe, 21 Cr,<br><b>5,6 Al</b> , 0,3 Si                                              | 83 Fe, 12 Cr, <b>3,7 Al</b> , <b>1,3 Si</b>                                          | 86 Fe, 10 Cr, <b>4 Al</b> , 0,3 Si                                                   |
|  |  |  |  |  |  |  |

➡ 197 > (APMT, D, AF, A1, APM) > 198



# Laboratory exposure #1 : first results after 2x100h

- Chromia formers:

| 253 MA                                                                           | 353 MA                                                                            | Alloy 625                                                                         | Nikrothal 40                                                                        | Nikrothal 60                                                                        | Nikrothal 70                                                                        | Nikrothal 80                                                                        |
|----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| 66 Fe, 11 Ni,<br>21 Cr, 2 Si                                                     | 38 Fe, 35 Ni,<br>25 Cr, 2 Si                                                      | 58 Ni, 21 Cr,<br>0,4 Al, 0,5 Si,<br>9 Mo, 3-4 Nb                                  | 43 Fe, 35 Ni, 20<br>Cr, 2 Si                                                        | 27 Fe, 56 Ni, 16<br>Cr, 2 Si                                                        | 69 Ni, 30 Cr, 1<br>Si                                                               | 79 Ni, 20 Cr, 1<br>Si                                                               |
|  |  |  |  |  |  |  |

➡ Nikrothal serie > 353 MA > Alloy 625 > 253 MA

# Laboratory exposure #1 : first results after 2x100h

- Cast alloys:

| 9017 SSG                                                                           | 9050 SSG                                                                           |
|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| 53 Fe, 20 Ni,<br>25 Cr, 1,3 Si,<br>1,8 Mn                                          | 61 Fe, 15 Ni,<br>15 Cr, 5,1 Si,3<br>Mo, 0,8 Mn                                     |
|  |  |

- Exposition of SSG 9017 was stopped after 100 h due to poor aspect

# Laboratory exposure #1 : first results after 300h

- First conclusions:
  - Alumina former materials (FeCrAl based) :
    - hard to distinguish corrosion resistance between commercial alloy
    - Alloy 197 seems to be the best
  - Chromia former materials :
    - 253 MA worst behaviour in these conditions
    - Hard to distinguish between the others
  - Cast materials :
    - Not as good as the powder metallurgy materials
- Next step : SEM analysis will be performed during spring 2019
- Next materials : alloys with sprayed materials on the surface -> test the surface properties as it is difficult to manufacture components with some of the selected alloys



## CONTACTS

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