Cathodic protection of aluminium in seawater

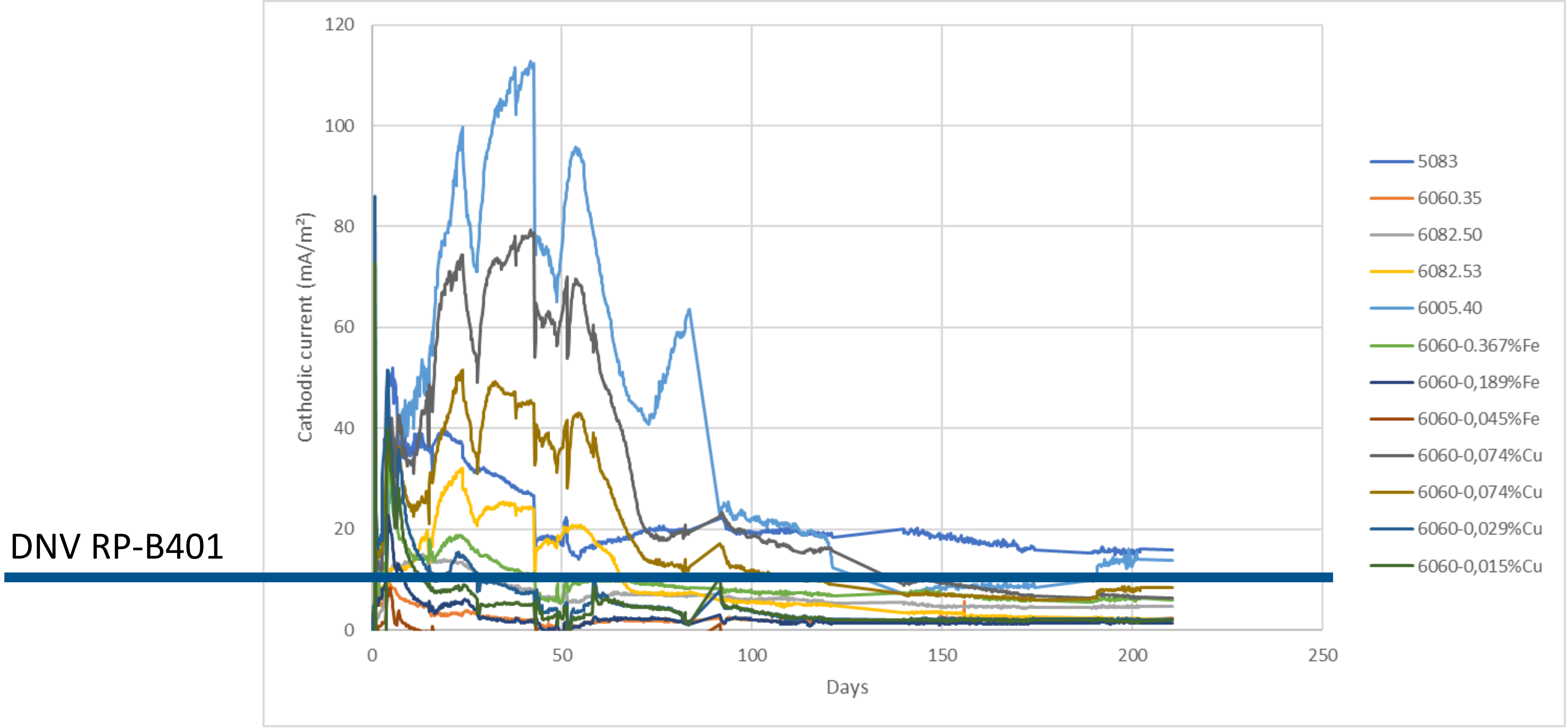
Background and objectives

- Cathodic current density
  - DNV RP-B-401 recommends to use 10 mA/m² for designing CP of aluminium
  - Based on experiences with thermally sprayed aluminium
- Coating of submerged aluminium
  - We do not know how coatings behave and degrade on submerged aluminium
  - No recommendations about coatings
  - No coating breakdown factors for CP design
- Objectives
  - Investigate cathodic current density on varous aluminum alloys
  - Investigate coating performance on submerged aluminium with CP

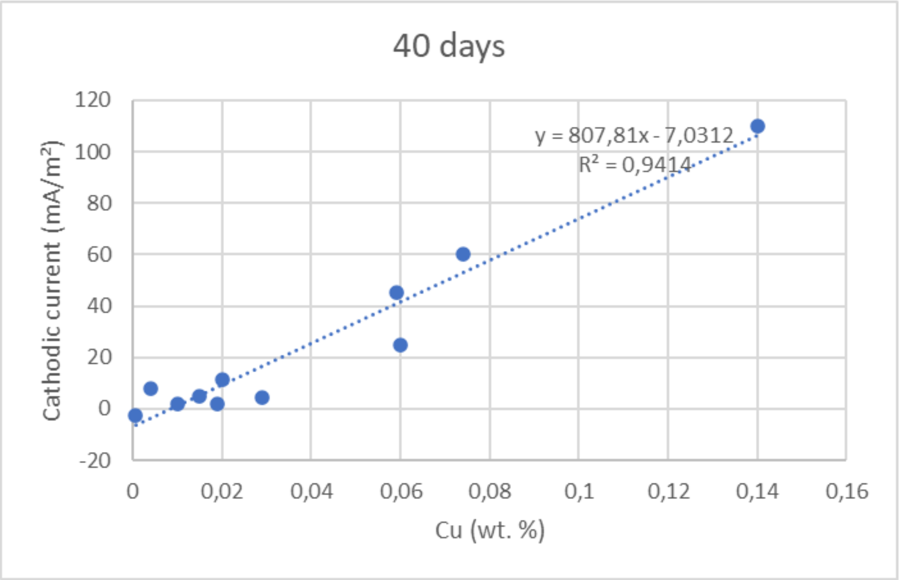
Test matrix

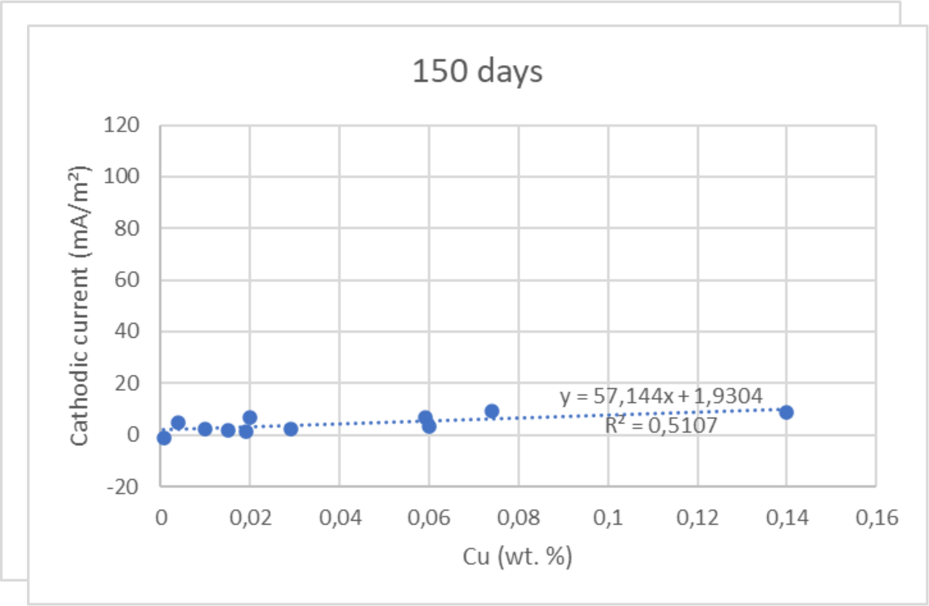
		Composition (wt%)						
Alloy	Temper	Si	Mg	Fe	Cu	Mn	Cr	Zn
6060.34	T6	0.43	0.47	0.23	< 0.001	0.06	< 0.01	0.03
6060.34	T6	0.43	0.47	0.23	0.015	0.06	< 0.01	0.03
6060.34	T6	0.43	0.47	0.23	0.029	0.06	< 0.01	0.03
6060.34	T6	0.43	0.47	0.23	0.044	0.06	< 0.01	0.03
6060.34	T6	0.43	0.47	0.23	0.059	0.06	< 0.01	0.03
6060.34	T6	0.43	0.47	0.23	0.074	0.06	< 0.01	0.03
6060.34	T6	0.43	0.47	0.23	0.090	0.06	< 0.01	0.03
6060	T6	0.48	0.38	0.20	0.034	0.05	< 0.01	0.03
6082.50	T6	1.01	0.65	0.17	0.002	0.52	< 0.01	
6060		0.40	0.35	0.045	0.0006	0.04	< 0.001	0.005
6060		0.39	0.38	0.189	0.019	0.04	0.004	0.017
6060		0.39	0.38	0.367	0.020	0.05	0.004	0.017
6005.40	T6	0.62	0.53	0.19	0.134	0.18	0.036	0.004
6082.53	T6	1.06	0.81	0.21	0.059	0.56	0.204	0.004
6082.50	T6	1.08	0.69	0.19	0.004	0.56	0.004	0.004
6060.35	T6	0.46	0.48	0.20	0.010	0.015	0.005	0.004
5083	H11	0.08	4.4	0.22	0.011	0.57	0.06	0.01

Current density for cathodic protection in seawater



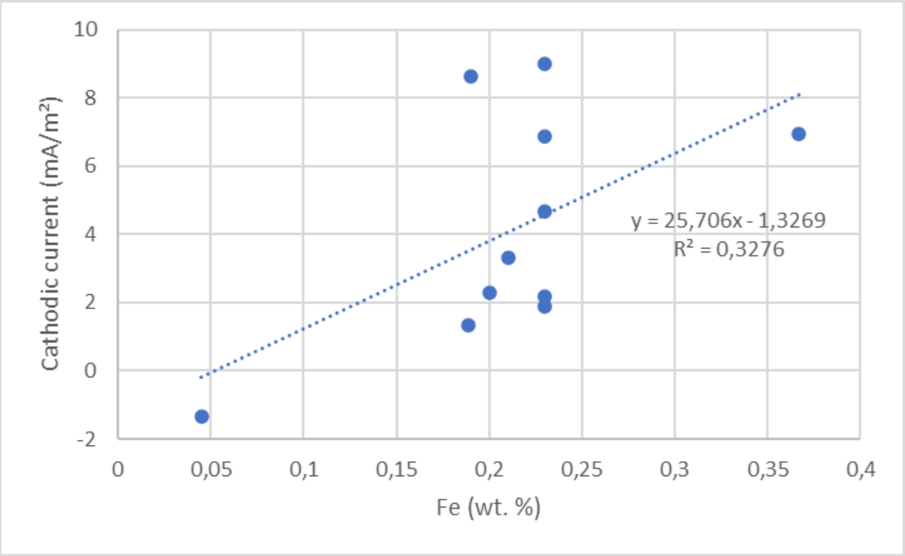
Cathodic current vs Cu content (6000 alloys)



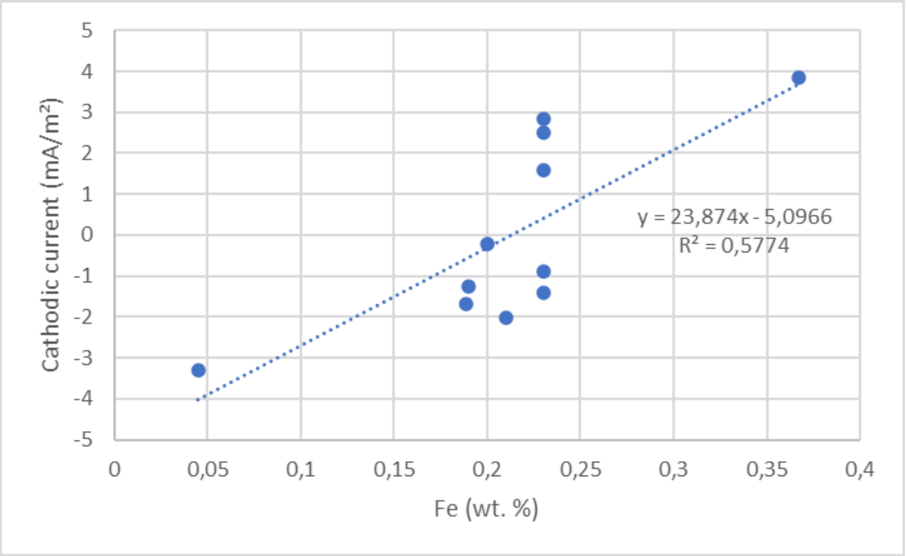


Cathodic current vs Fe content

After 150 days



Subtracting the Cu effect



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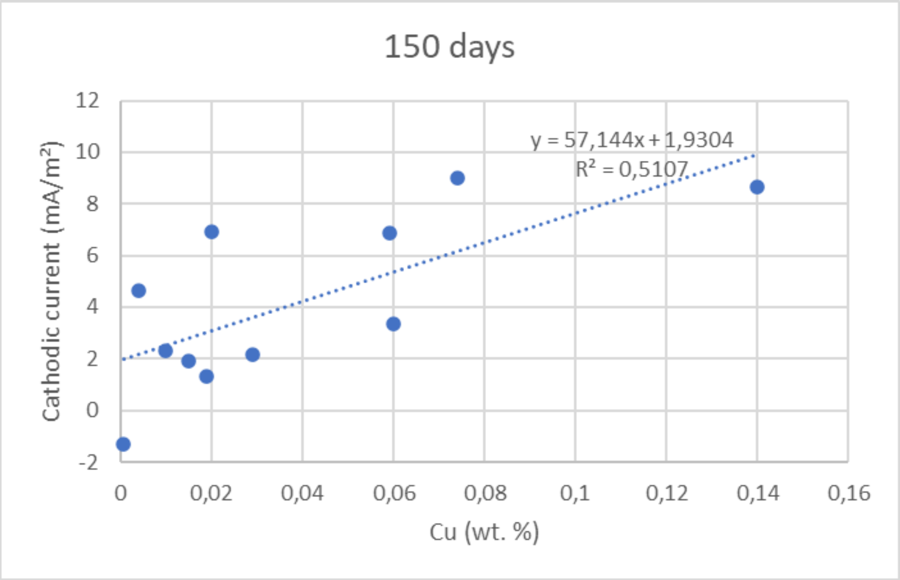
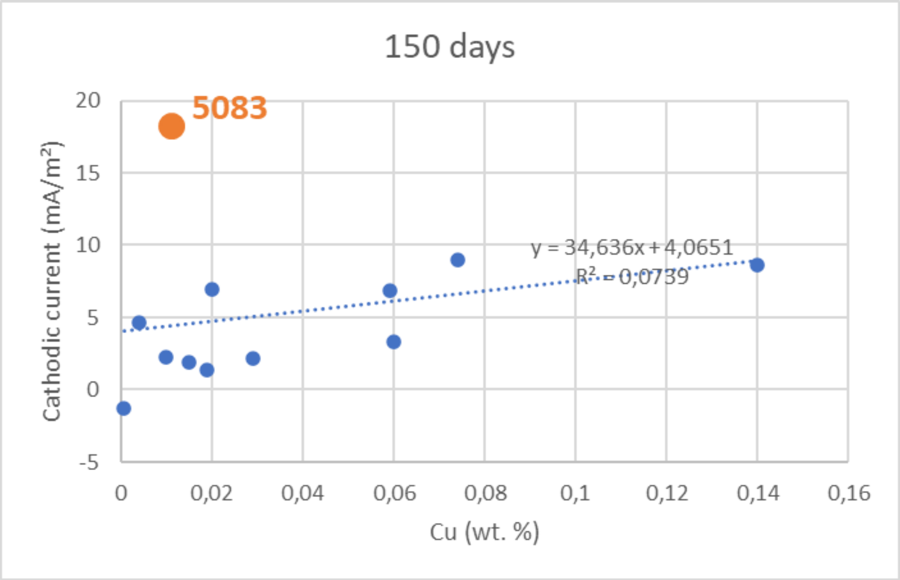
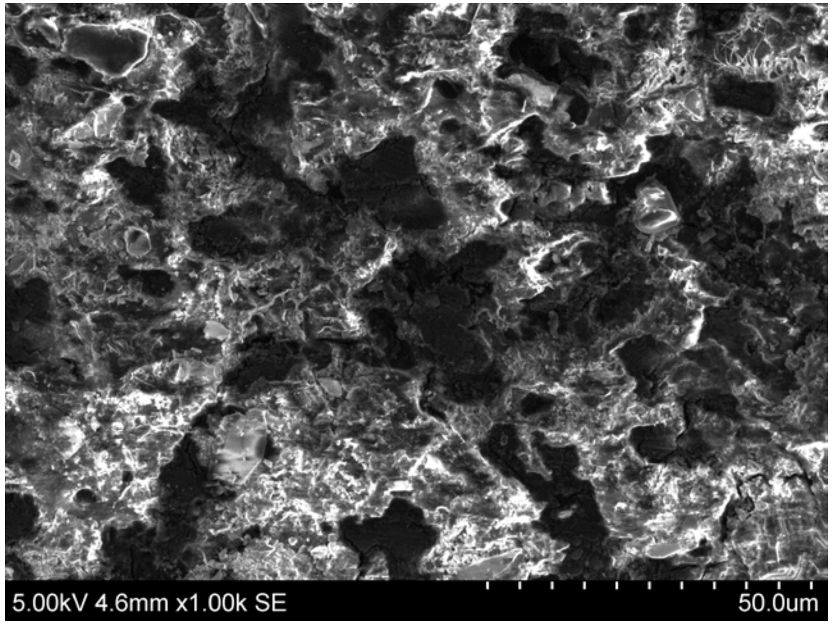
EN-AW 5083





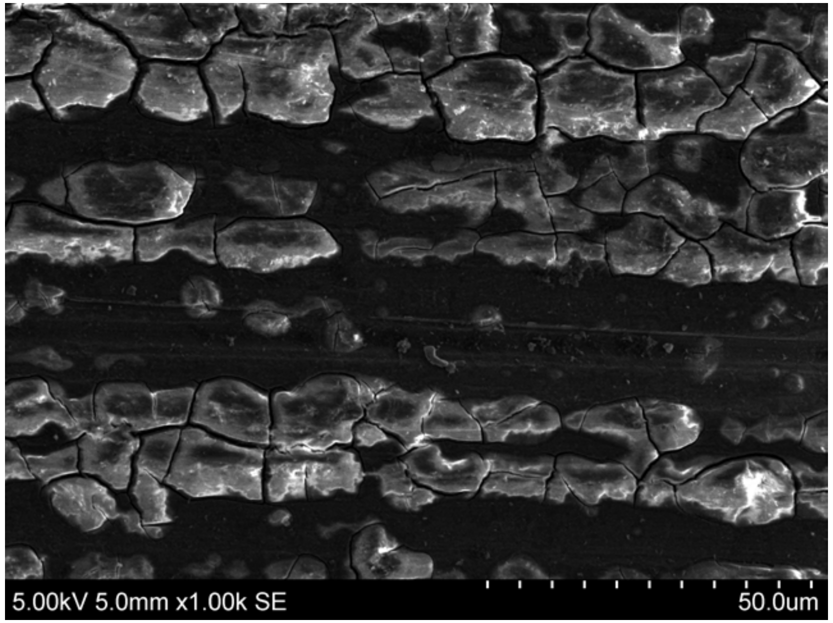
Higher cathodic current density on 5083 – why?

5083



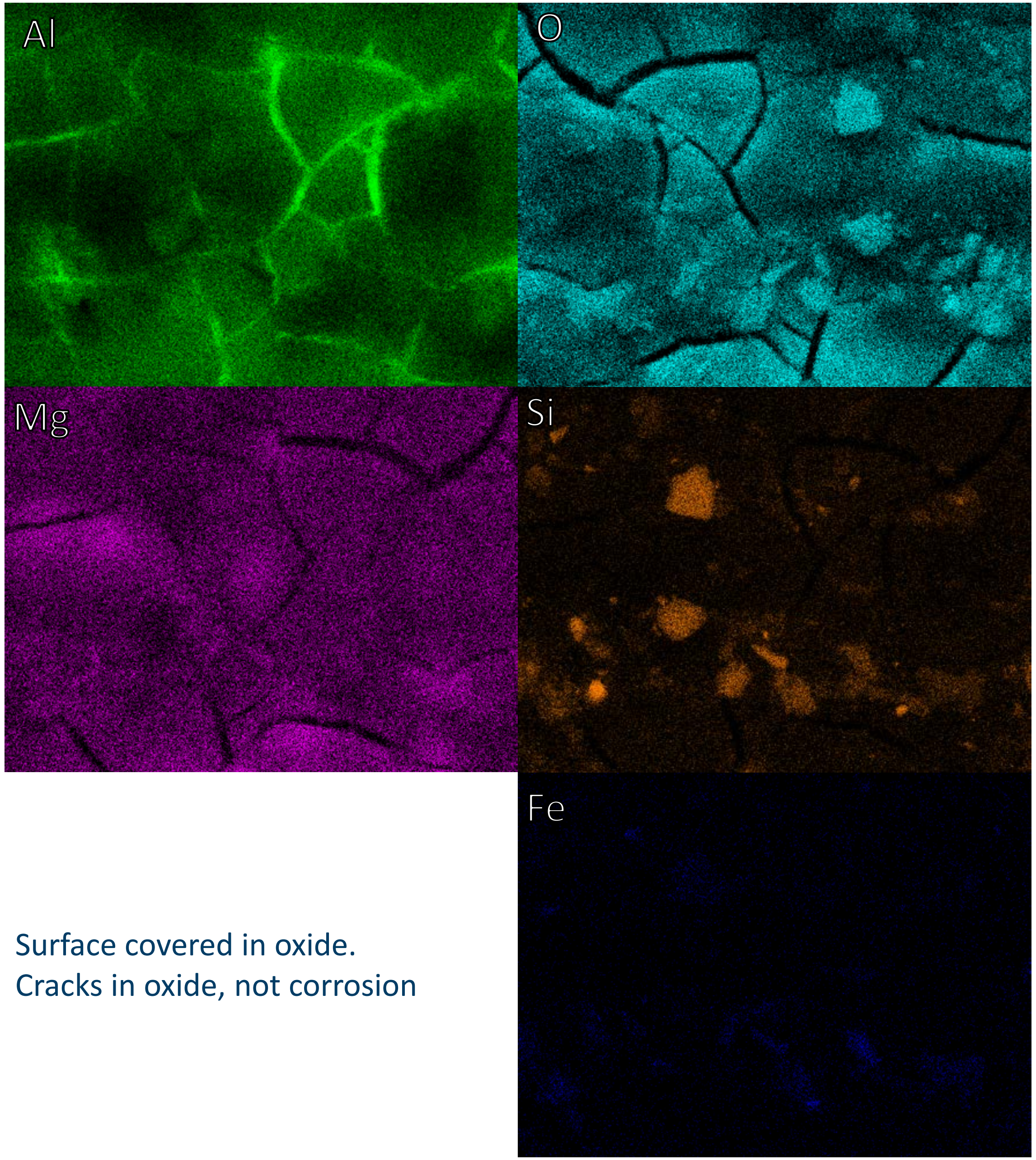
Oxide covering the entire surface

6082

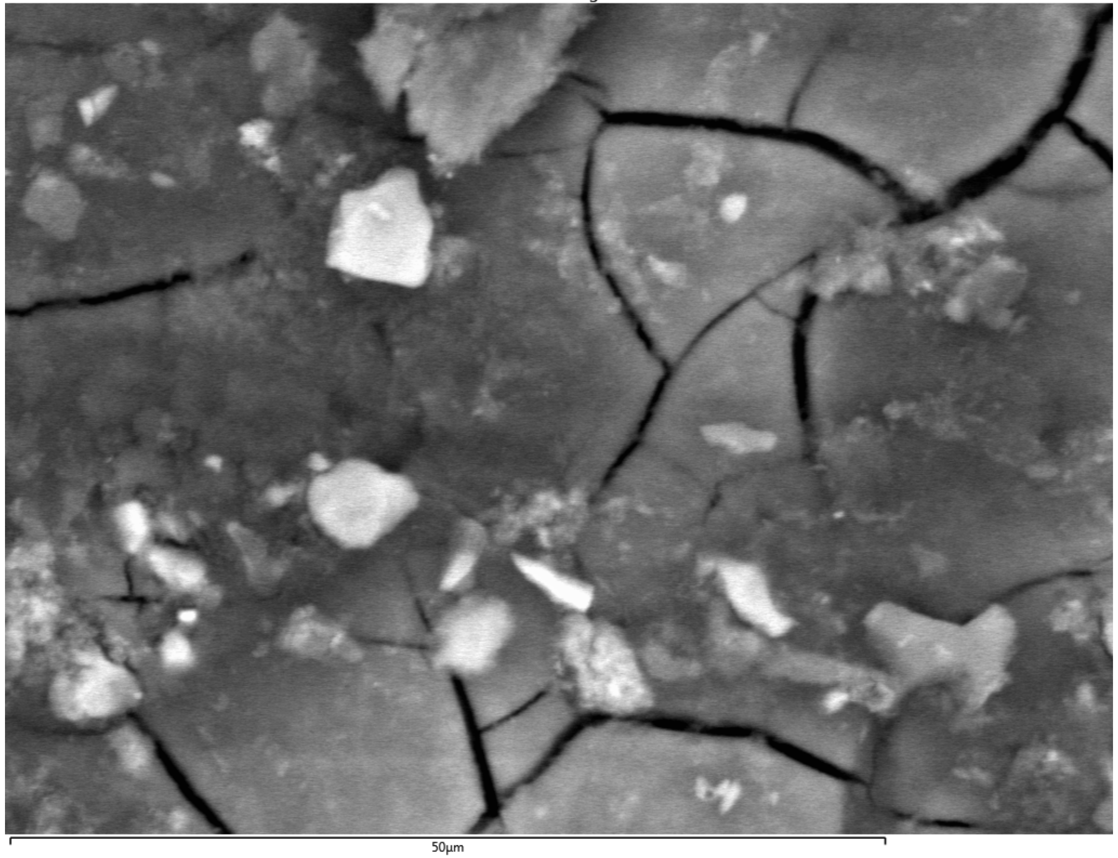


Oxide covering the peaks in the extrusion lines
Cracks in the oxide

5083-EDS

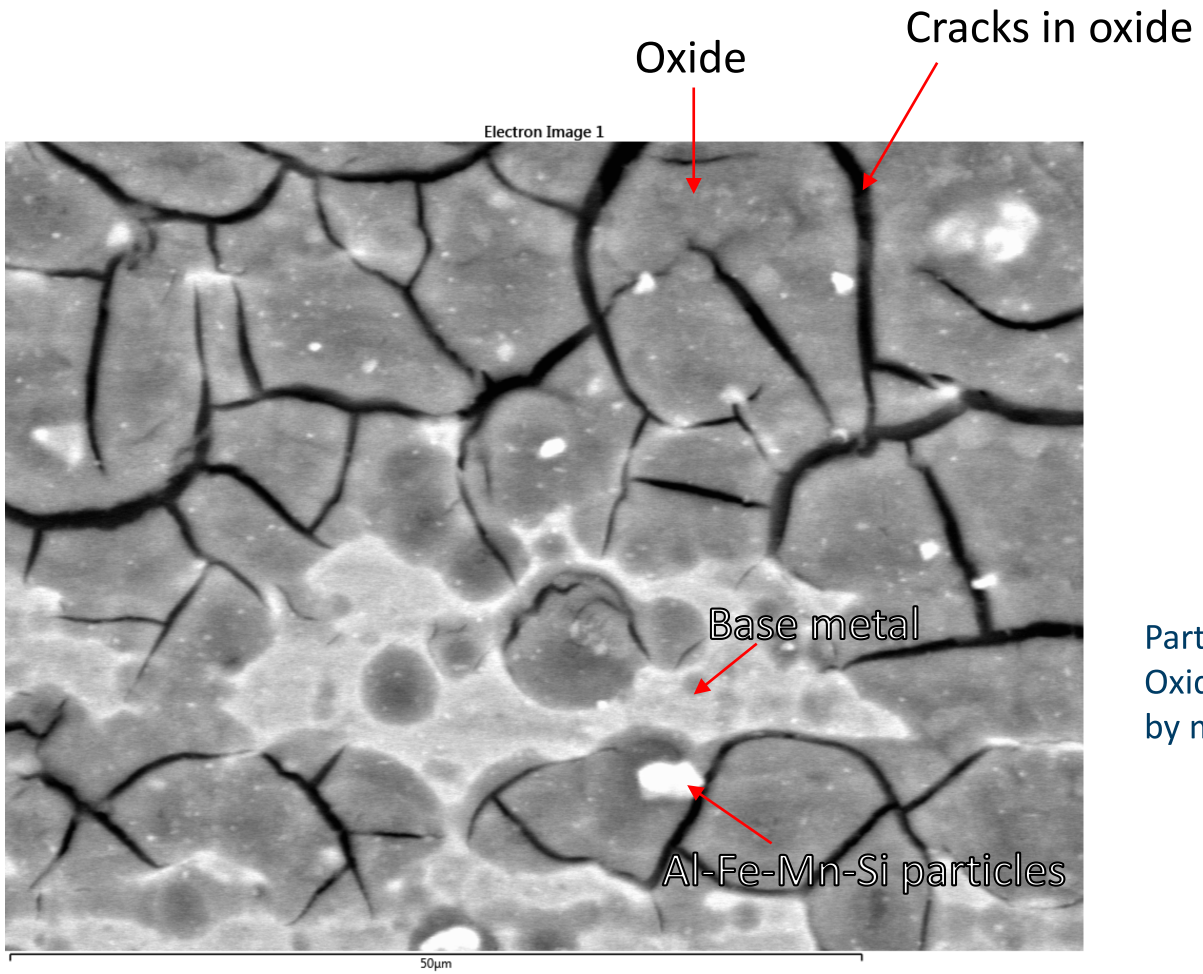


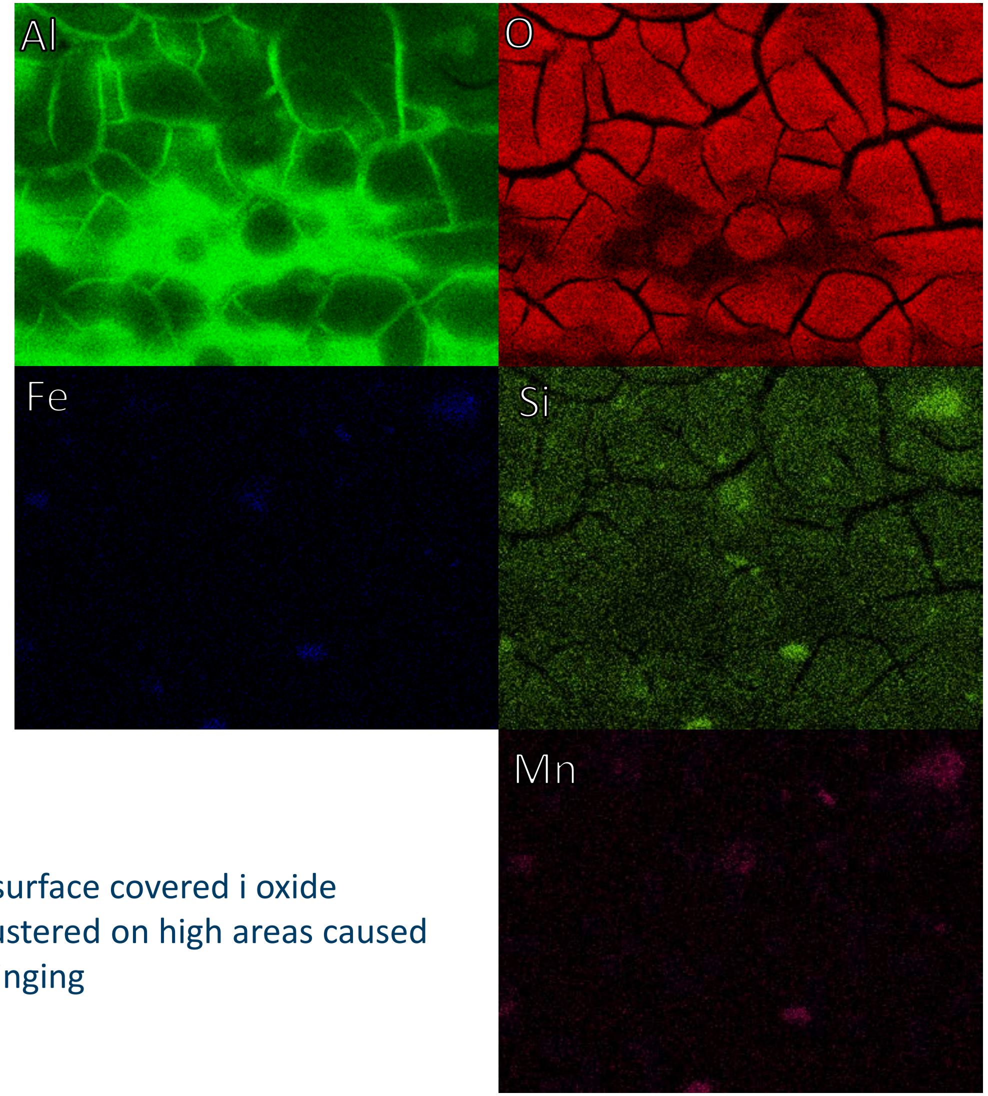
Electron Image 2



Surface covered in oxide.
Cracks in oxide, not corrosion

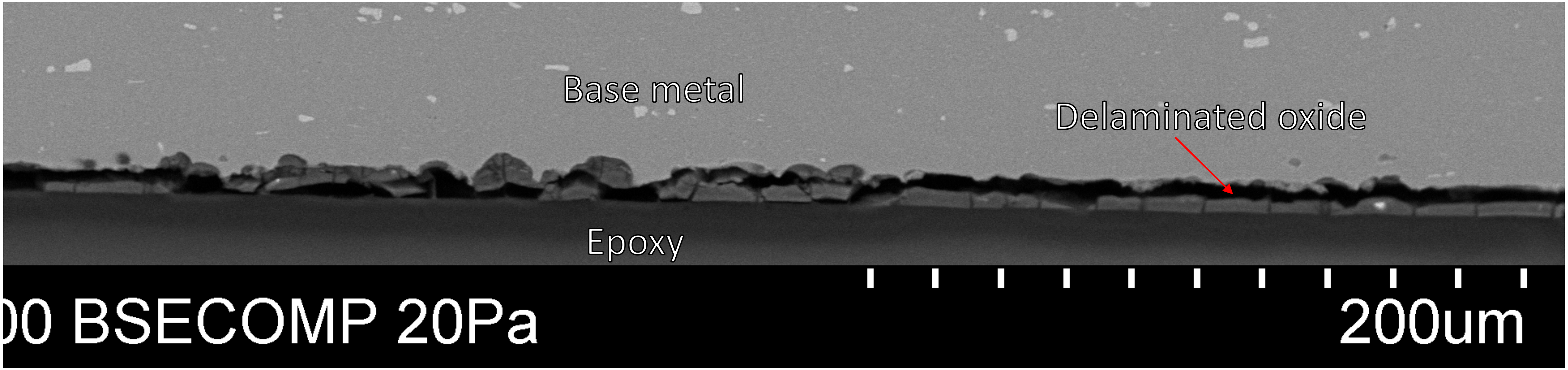
6082-EDS





Parts of surface covered i oxide
Oxide clustered on high areas caused by machinging

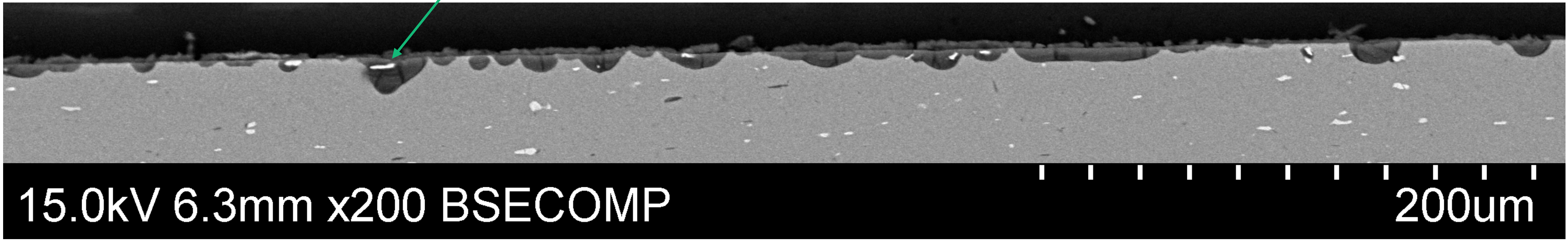
5083 - cross section



Average oxide thickness 8±3 µm

6082 - cross section

Intermetallic particles trapped in oxide



Average oxide thickness 5±1 µm

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Higher cathodic current density on 5083 – why?

- Thicker and more covering oxide on 5083 than 6082
  - Should have been opposite, higher current on 6082?
  - Causality is probably the other way: High cathodic current density causes more oxidation
- Uniform oxide
  - Cathodic reaction not only occurring on the noble intermetallic particles but also on the matrix

Degradation of paint on submerged Al

No.	Alloy	Geometry	Pre-treatment	Coating	Washer material	CP	Parallels	Sintef/Hereon
1-3	EN AW-6082	flat	Garnet	DNV category II		Yes	3	SINTEF
4-6	EN AW-6082	flat	Garnet	DNV category II		-	3	SINTEF
7-9	EN AW-6082	flat	Glas-Grit	DNV category II		Yes	3	SINTEF
10-12	EN AW-6082	flat	Glas-Grit	DNV category II		-	3	SINTEF
13-15	EN AW-6082	flat	Bristle Blaster	DNV category II		Yes	3	SINTEF
16-18	EN AW-6082	flat	Bristle Blaster	DNV category II		-	3	SINTEF
19-21	EN AW-6082	flat	as recieved	DNV category II		Yes	3	SINTEF
22-24	EN AW-6082	flat	as recieved	DNV category II		-	3	SINTEF
25-27	EN AW-6082	flat	Garnet	DNV category I		Yes	3	SINTEF
28-30	EN AW-6082	flat	Garnet	DNV category I		-	3	SINTEF
31-33	EN AW-6082	flat	Garnet	DNV category III		Yes	3	SINTEF
34-36	EN AW-6082	flat	Garnet	DNV category III		-	3	SINTEF
151-153	EN AW-5083	flat	Garnet	DNV category II		Yes	3	SINTEF
154-156	EN AW-5083	flat	Garnet	DNV category II		-	3	SINTEF
157-159	EN AW-5083	flat	Glas-Grit	DNV category II		Yes	3	SINTEF
160-162	EN AW-5083	flat	Glas-Grit	DNV category II		-	3	SINTEF
163-165	EN AW-5083	flat	Bristle Blaster	DNV category II		Yes	3	SINTEF
166-168	EN AW-5083	flat	Bristle Blaster	DNV category II		-	3	SINTEF
169-171	EN AW-5083	flat	as recieved	DNV category II		Yes	3	SINTEF
172-174	EN AW-5083	flat	as recieved	DNV category II		-	3	SINTEF
175-177	EN AW-5083	flat	Garnet	DNV category I		Yes	3	SINTEF
178-180	EN AW-5083	flat	Garnet	DNV category I		-	3	SINTEF
181-183	EN AW-5083	flat	Garnet	DNV category III		Yes	3	SINTEF
184-186	EN AW-5083	flat	Garnet	DNV category III		-	3	SINTEF

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Coating systems

Category I

- Epoxy
- 1 coat
- > 20 µm nominal DFT

Coating system applied

- 50 µm epoxy primer

Category II

- Marine paint
- 1 or more layers
- > 250 µm nominal DFT

Coating system applied:

- 250 µm epoxy mastic

Category III

- Epoxy based
- 2 or more layers
- > 350 µm nominal DFT

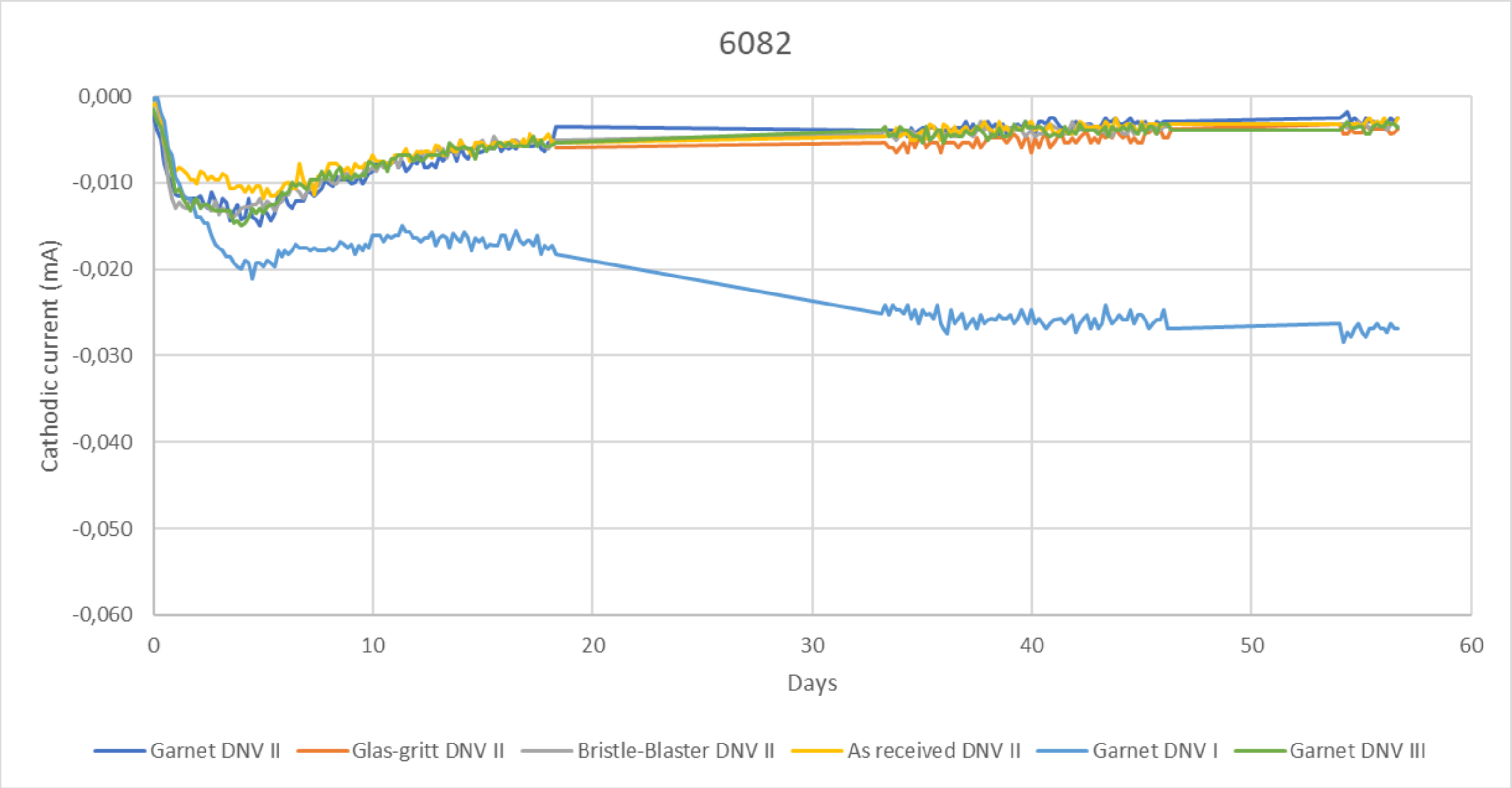
Coating system applied

- 175 µm epoxy mastic
- 175 µm epoxy mastic

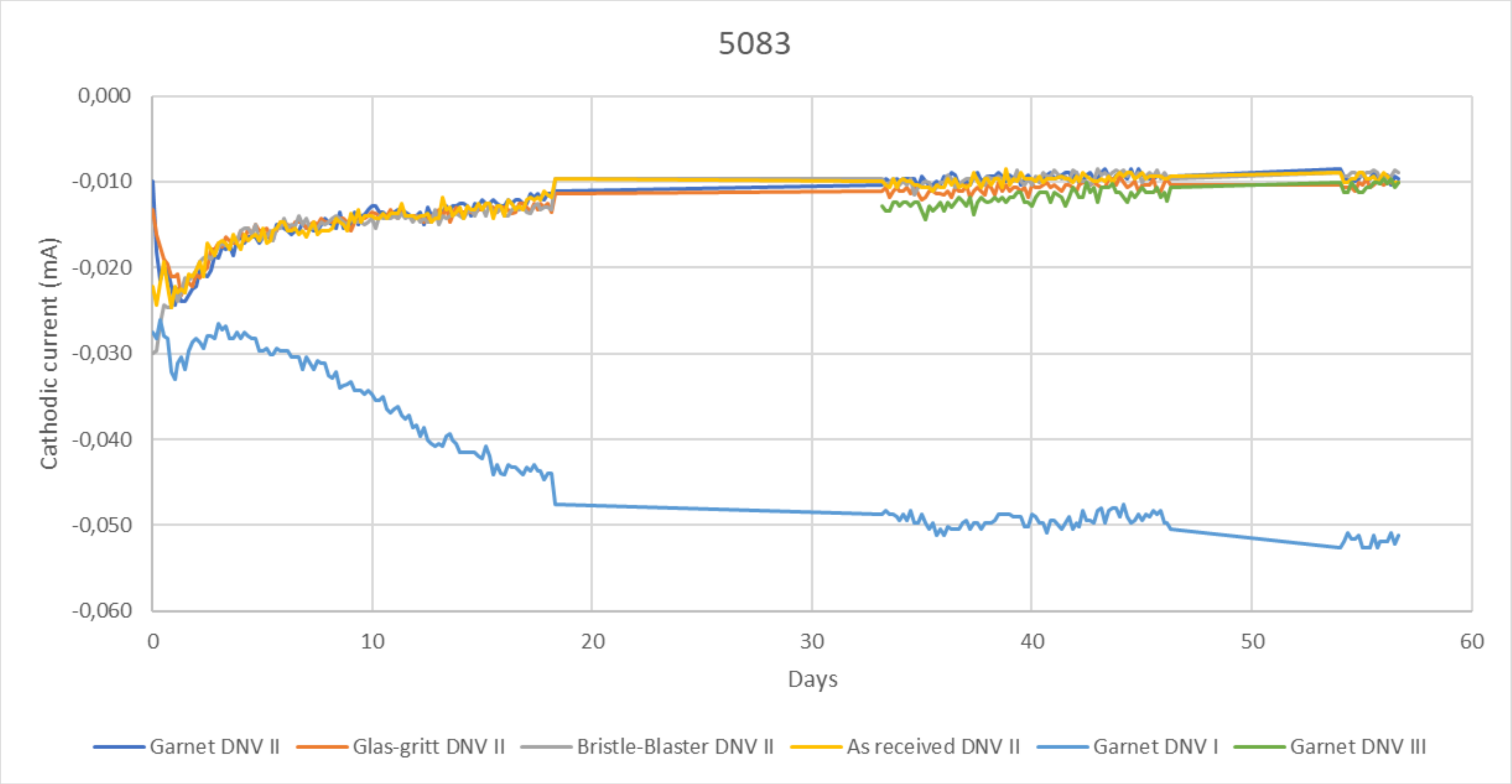
Category IV

- NORSOK M-501 qualified
- 2 or more layers
- > 350 µm nominal DFT

Coating degradation on 6082 with CP



Coating degradation on 5083 with CP



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Summary

- Cathodic current density on aluminium depends on the alloy composition
- For the most relevant alloys, the current density is quite near the recommended design value
- Coatings on submerged aluminium alloys seem very stable and little susceptible to degradation