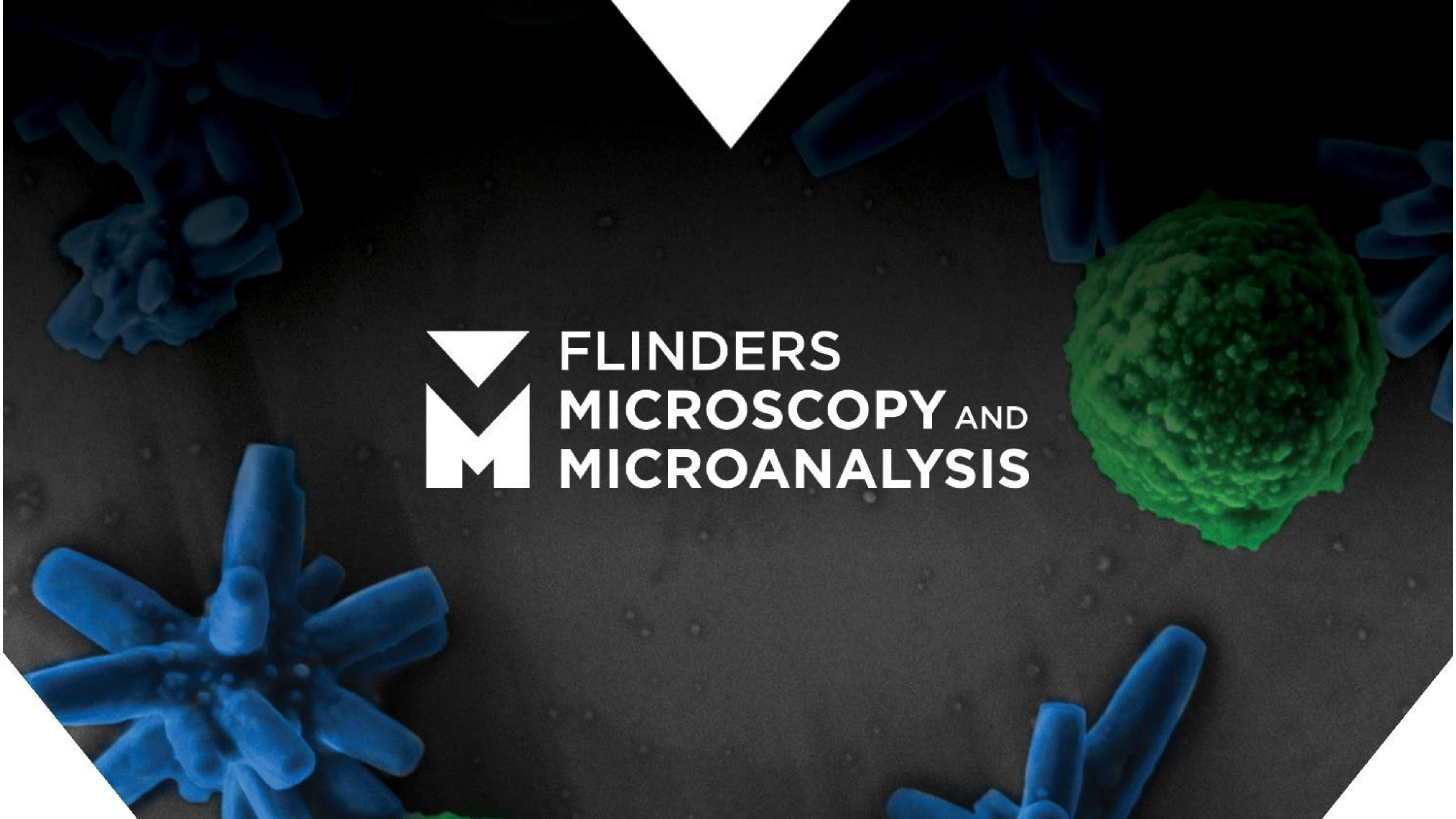

FLINDERS
MICROSCOPY AND
MICROANALYSIS

Microbial Induced Corrosion of 3D printed 316L Stainless Steel by *ferrooxidans*

Presented by Brianna Young

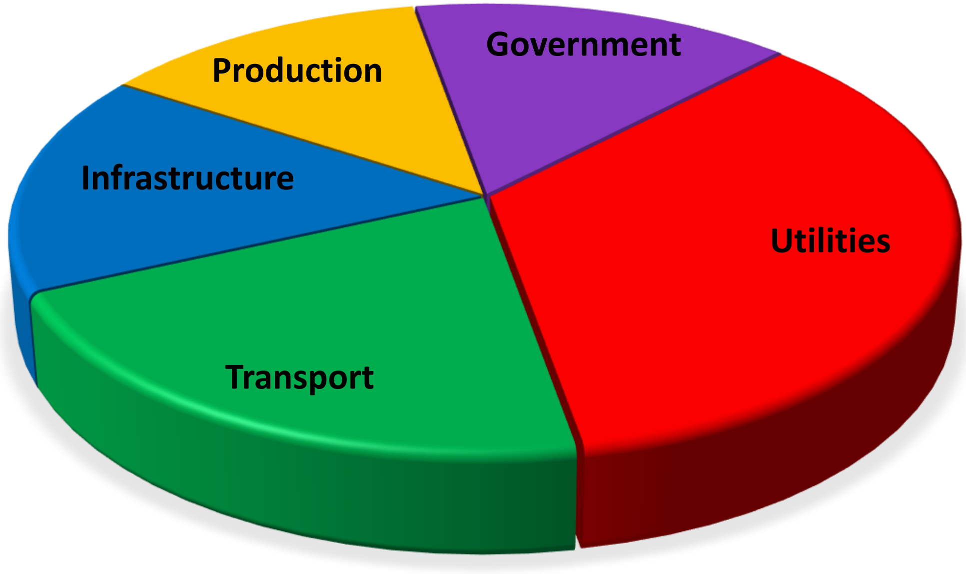
Supervisors: Professor Sarah Harmer & Professor Jamie Quinton

Flinders University | Flinders Microscopy and Microanalysis

The Problem

- Global costs of corrosion ≈$3.4 trillion annually
- Australia spends $32 billion a year

CORROSION DAMAGE BY AREA



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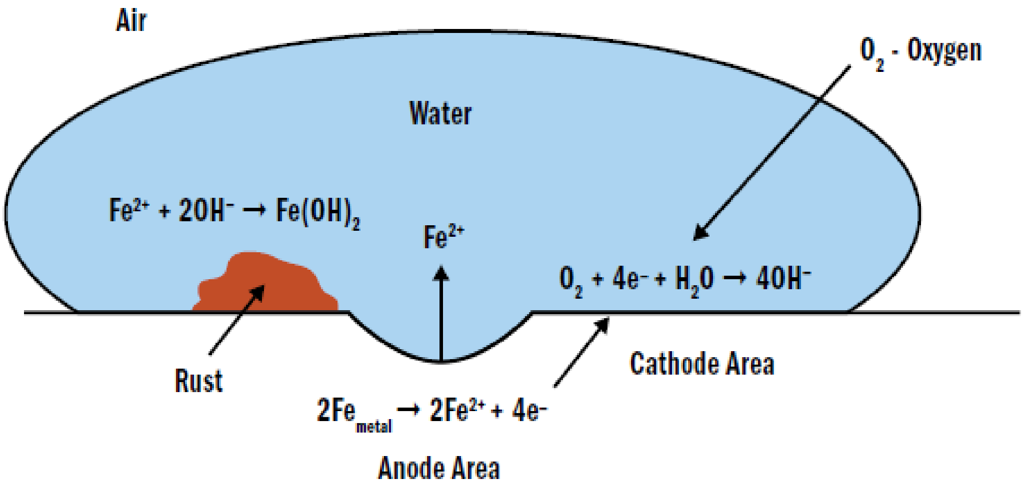
What Is Corrosion?

- Deterioration of a material and its properties by a chemical or electrochemical reaction between the material and its environment



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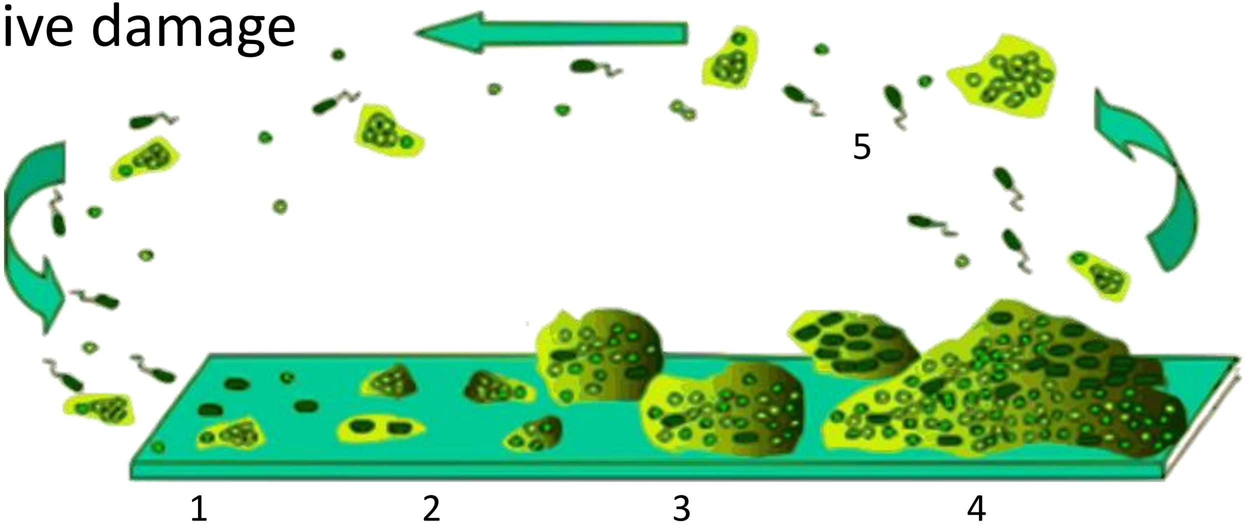
Microbial Induced Corrosion

- Microorganisms modify the environment
- Electrochemical processes associated with microorganisms
- 20% of total corrosive damage



Inaba, Y., Xu, S., Vardner, J., West, A., & Banta, S. (2019). Microbially Influenced Corrosion of Stainless Steel by Acidithiobacillus ferrooxidans Supplemented with Pyrite: Importance of Thiosulfate. *Applied and Environmental Microbiology, 85*(21). doi:10.1128/AEM.01381-19

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Bacteria

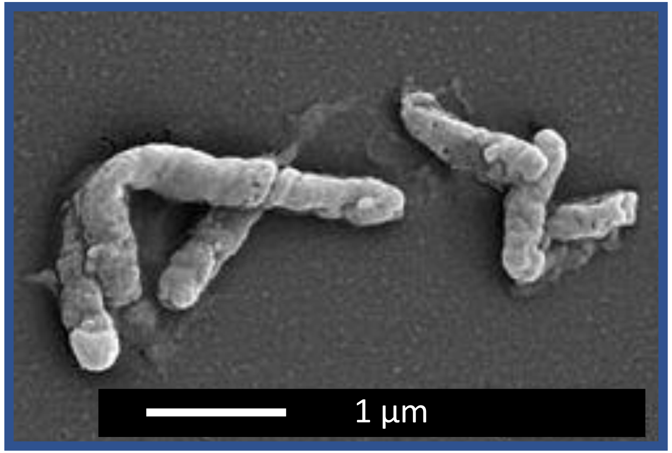
Acidithiobacillus ferrooxidans (A.f)

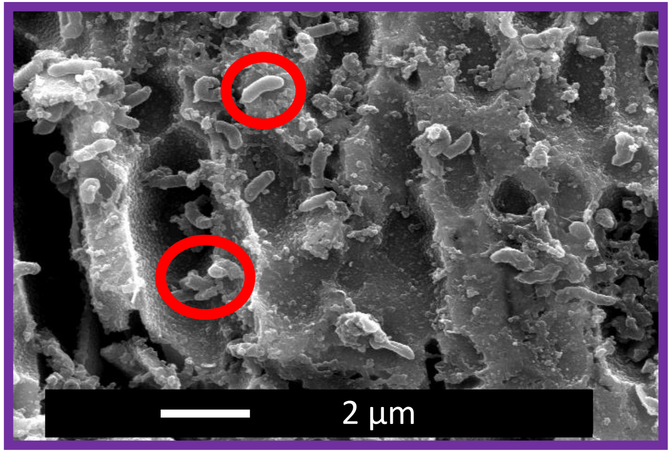
- Iron and Sulfur Oxidising
- Acidophilic
- Mesophilic

Leptospirillum ferrooxidans (L.f)

- Iron Oxidising
- Acidophilic
- Mesophilic

$$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O$$





SEM images provided by the Harmer research group

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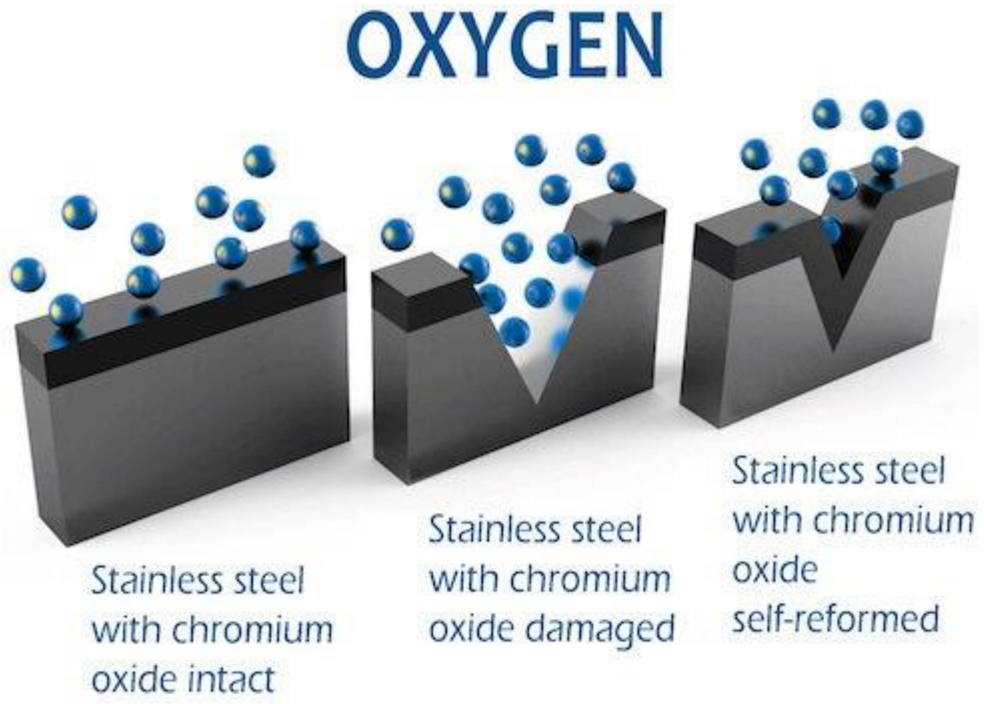
Could additively manufactured stainless steel reduce the costs seen due to corrosion damage?

- Layer by layer production
- Gives more control over design
- Reduces waste
- Physical properties can be similar
- Limited research into corrosive properties

Type 316 Stainless Steel

- Iron alloy, $FeCr_{18}Ni_{10}Mo_3$
- Austenitic stainless steel
- Resistant to corrosion
    - Cr_2O_3 passive layer



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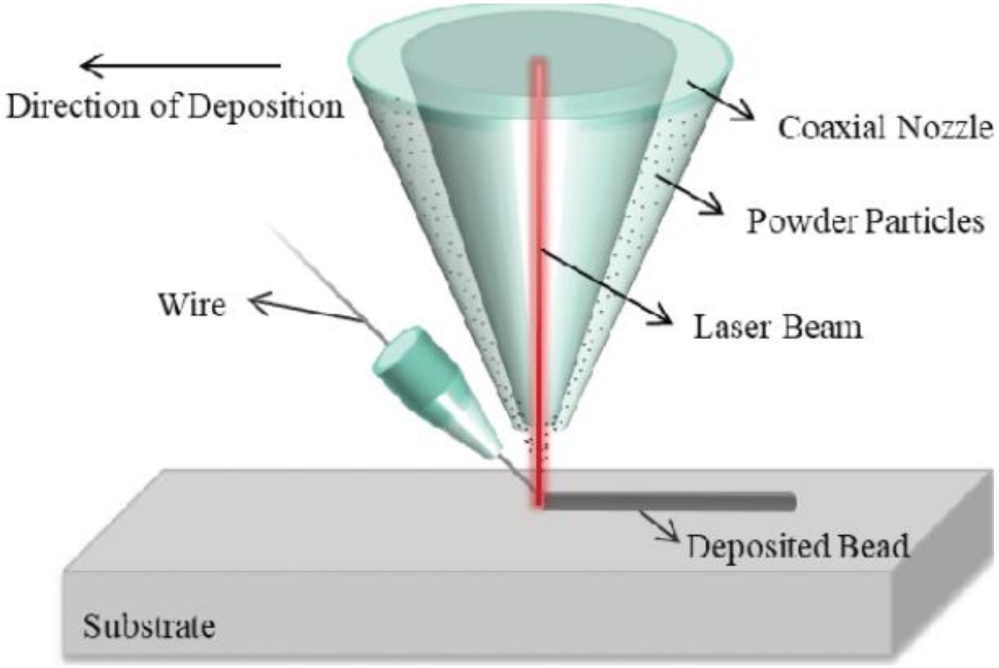
Laser Metal Deposition

- Material is deposited coaxially with laser beam
- Creates melt pool on substrate
- Solidifies to create layer
- Can create corner parts without bolts or welding



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Project Aims

- Investigate microbial induced corrosion by *A.f* and *L.f* on the surface of 3D printed 316L stainless steel

- Determine if 3D printed 316L stainless steel could be used in conjunction with other materials for underground pipes in acidic soils

Experimental Design

1. Sample preparation

- Cut – 10mm x 10mm x 0.5mm
- Polish – Rz < 1µm
- Clean

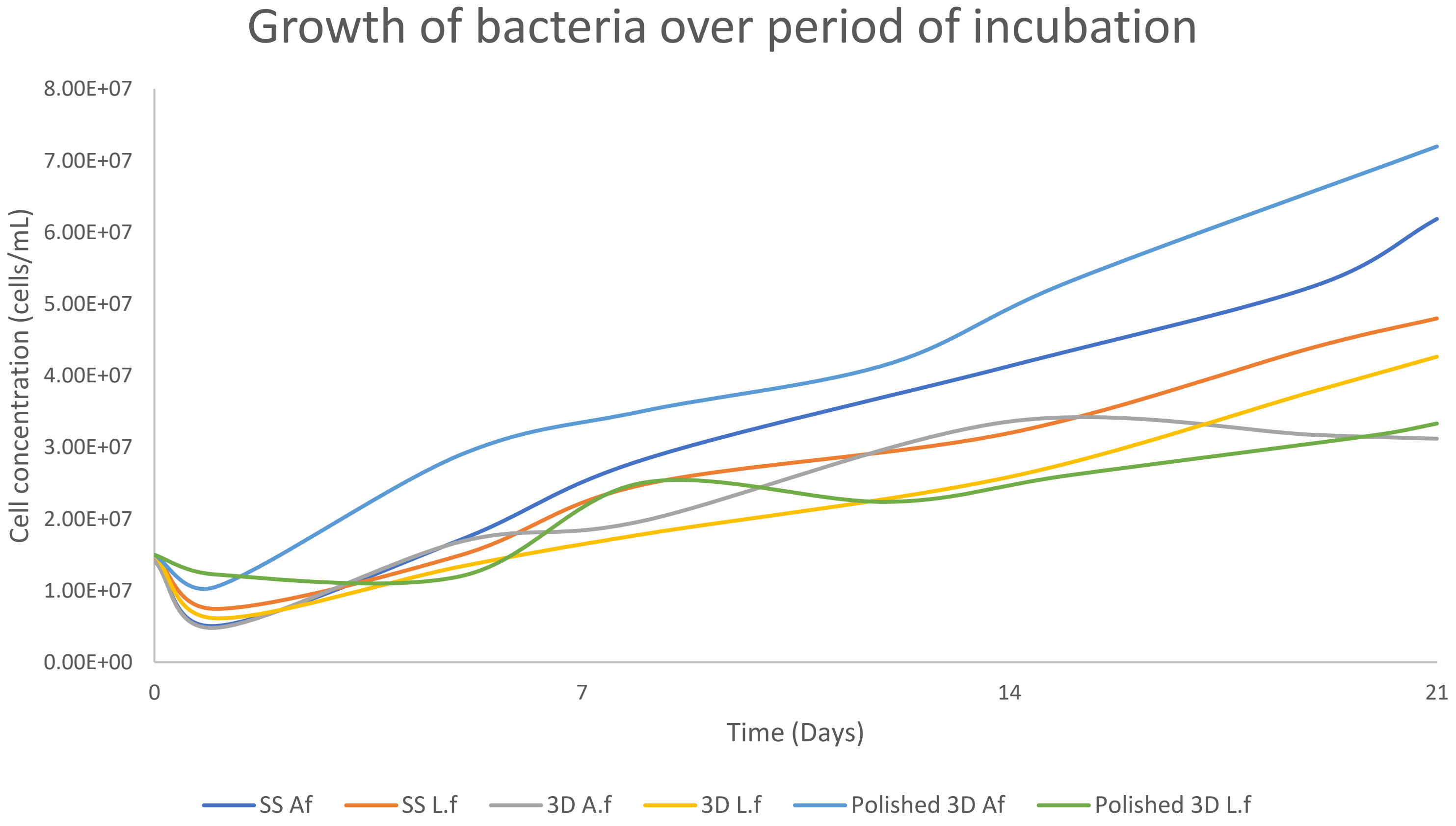
2. Sample incubation

- Temperature 30°C
- pH 1.8
- Cell concentration $1.5 \times 10^7\ cells/mL$

3. Sample analysis

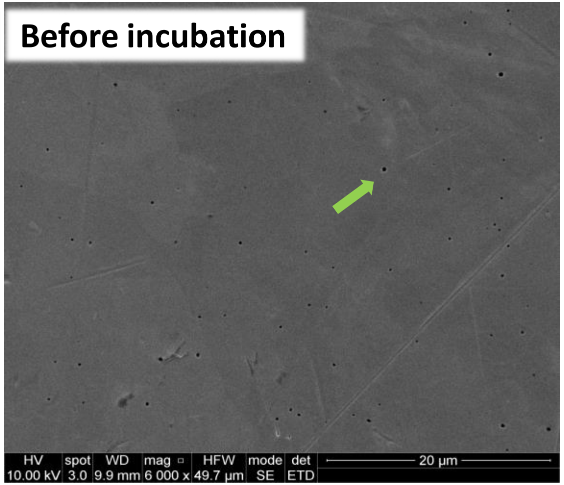
- Scanning Electron Microscopy
- Auger Electron Microscopy
- Surface roughness
  - AFM
  - Profilometer

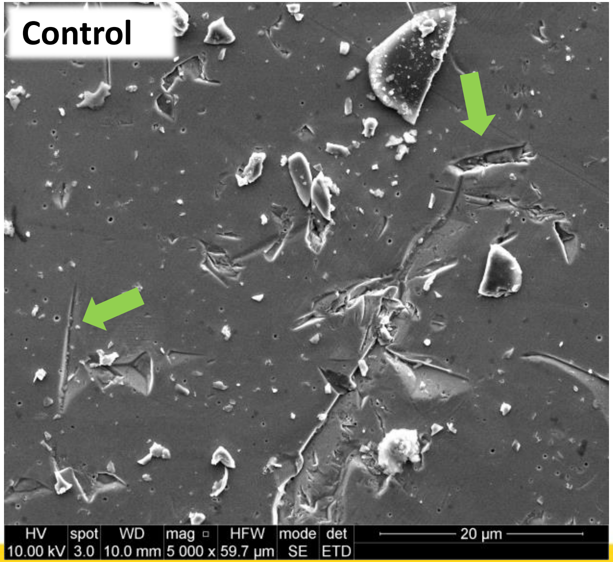
Results

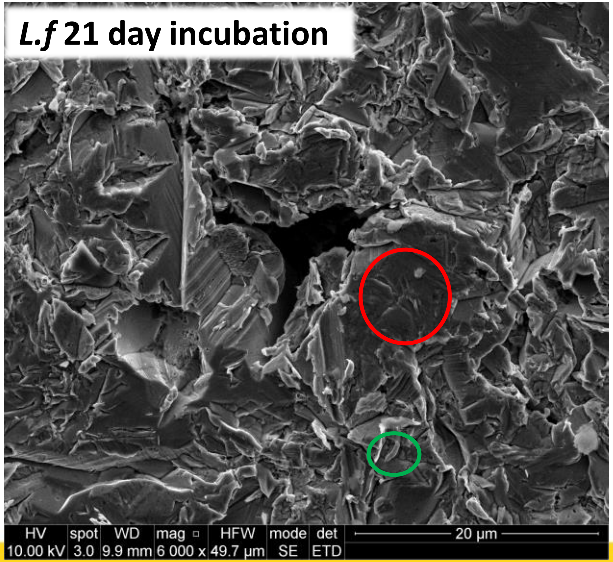


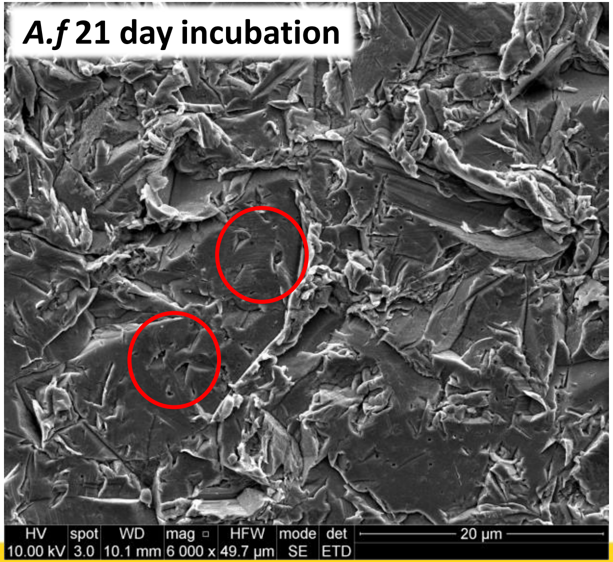
Growth of bacteria over period of incubation
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
Cell concentration (cells/mL)
0
7
14
21
Time (Days)
SS Af
SS L.f
3D A.f
3D L.f
Polished 3D Af
Polished 3D L.f

Polished 3D Printed Stainless Steel



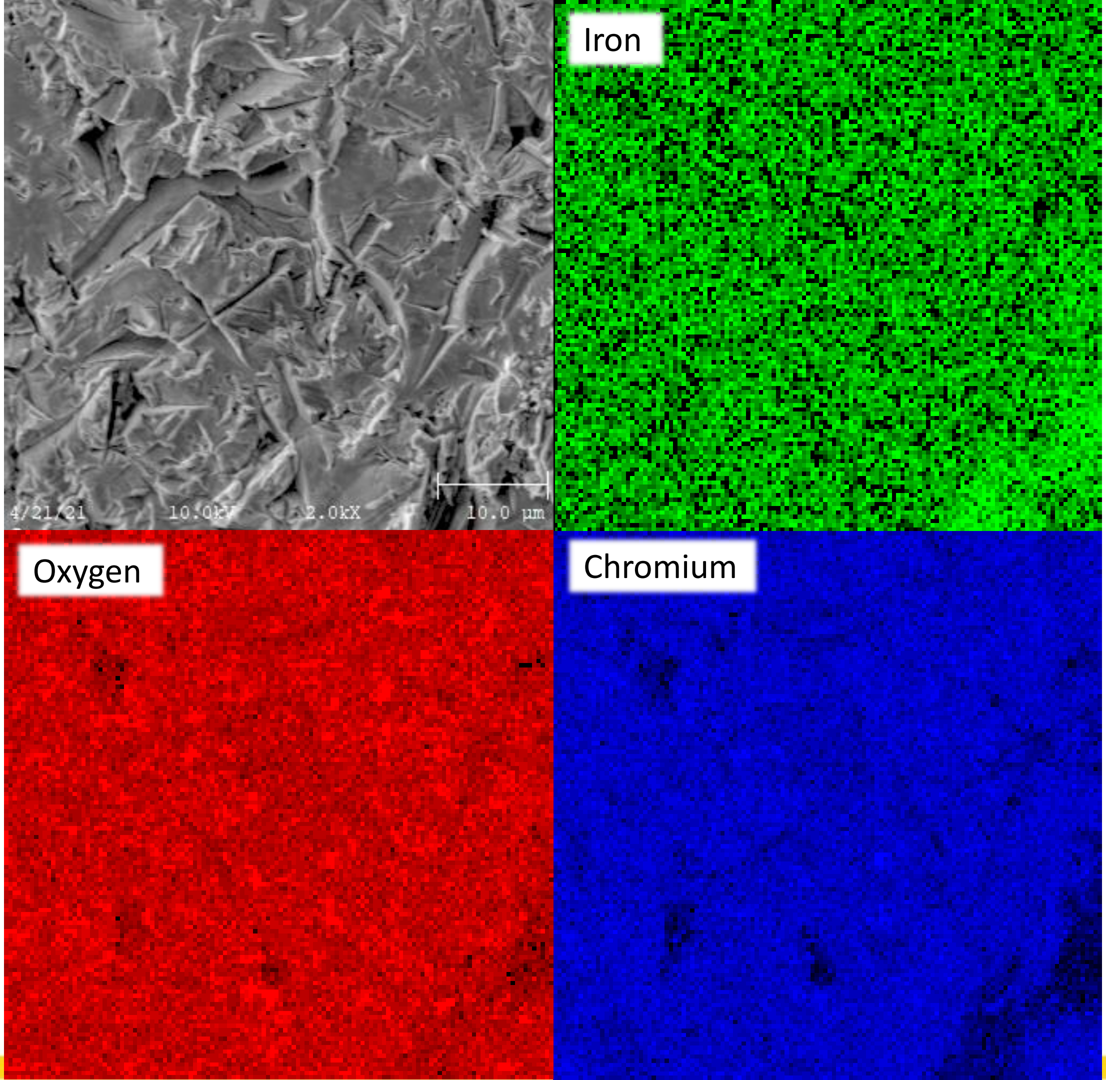




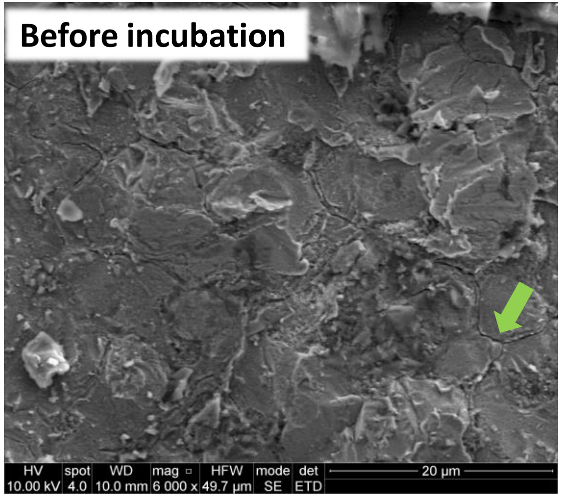


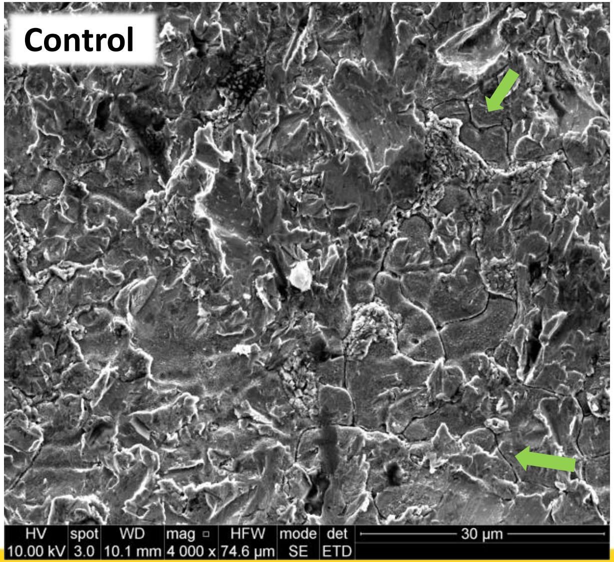
Polished 3D Printed Stainless Steel – 21 day incubation

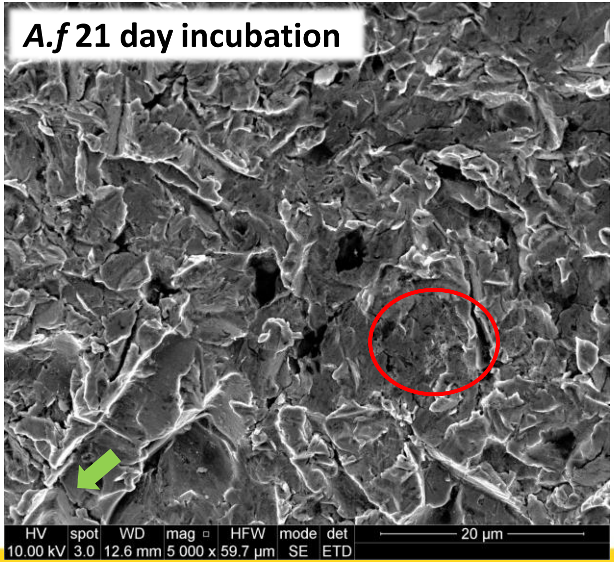
- Uniform spread of iron
- Lower intensity of chromium indicates weakness in chromium oxide passive layer



Unpolished 3D Printed Stainless Steel

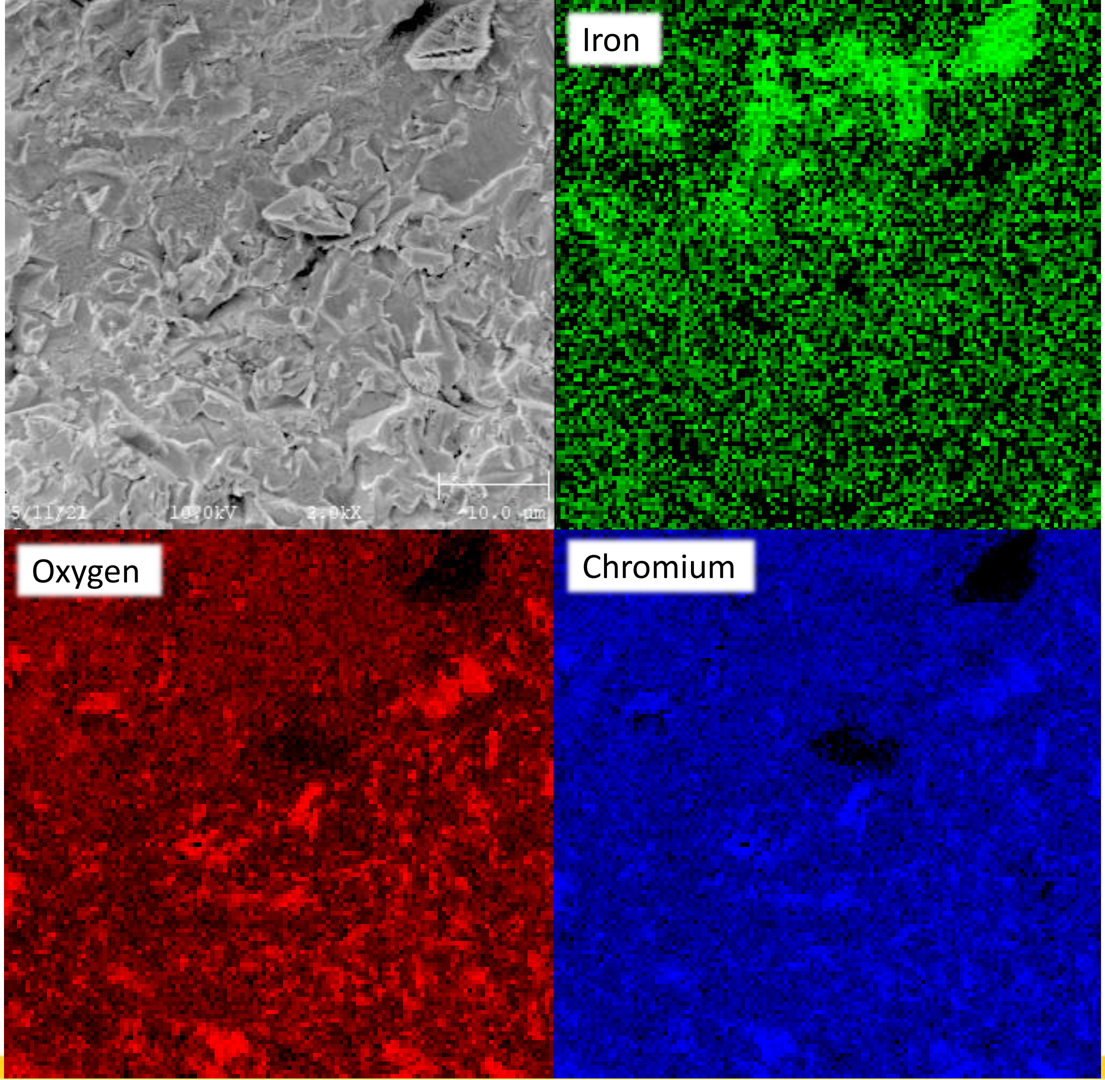




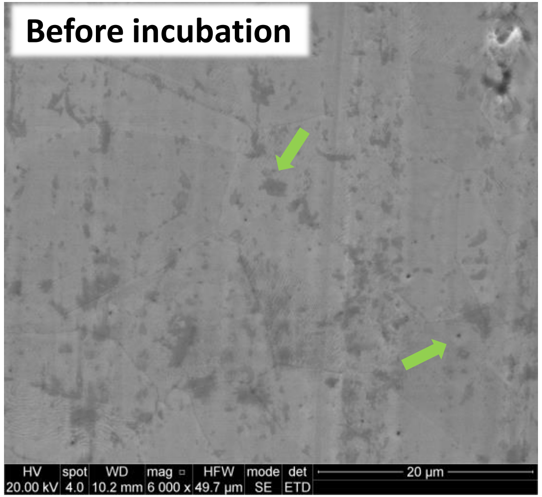


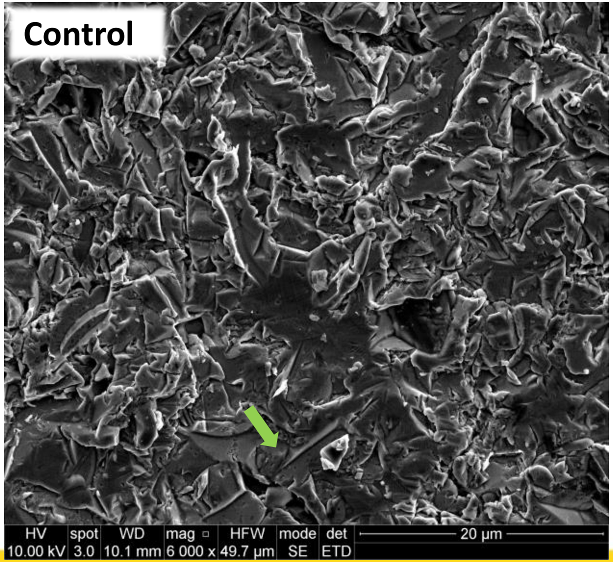
Unpolished 3D Printed Stainless Steel – 21 day incubation

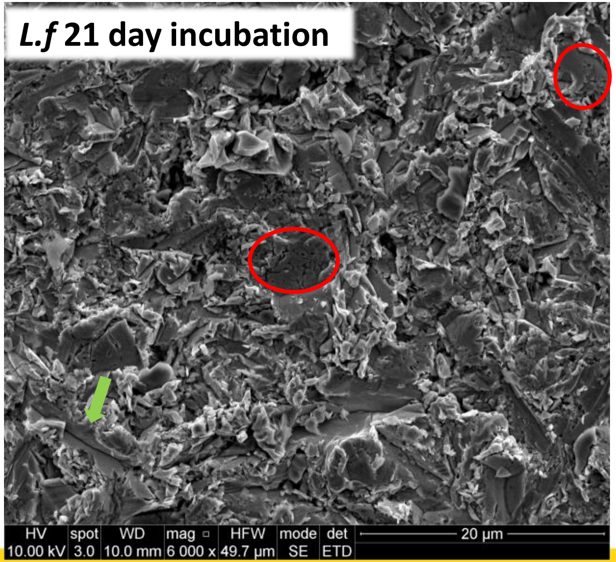
- Uneven distribution of chromium oxide layer
- Dark spots in oxygen and chromium due to pyrite particles

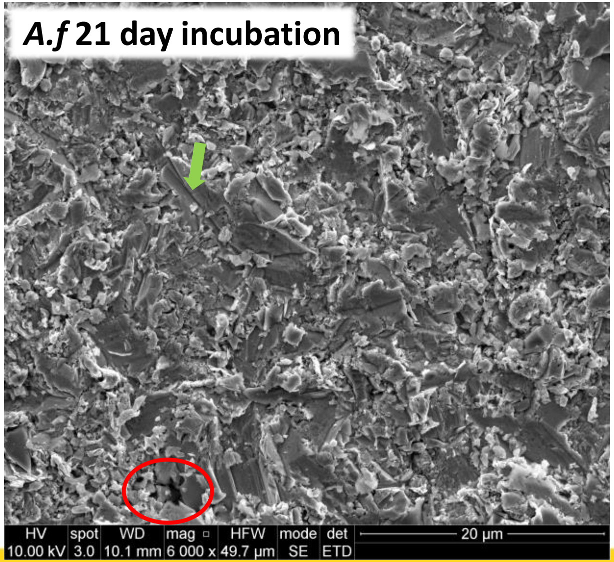


Traditionally Manufactured Stainless Steel





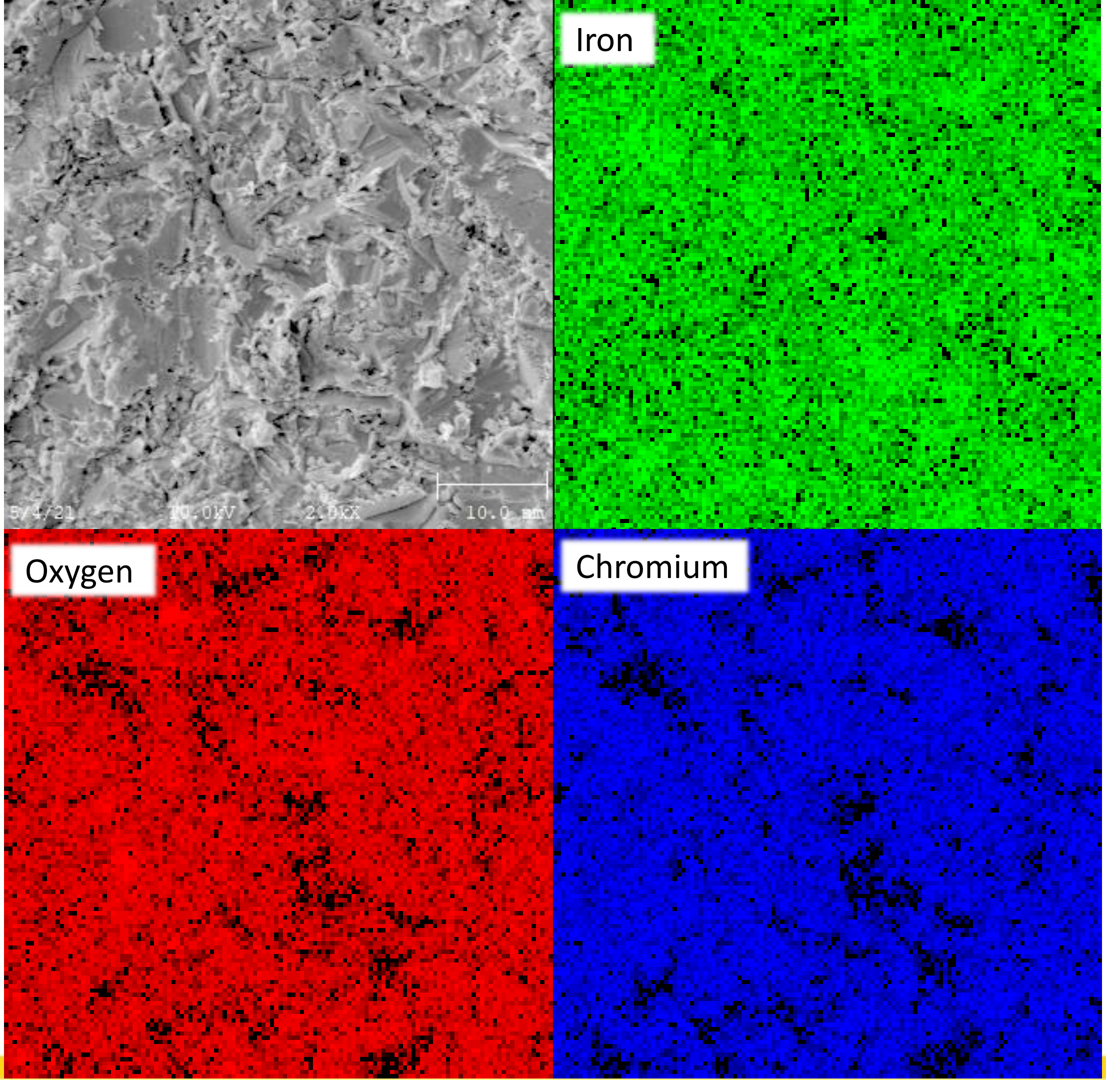




Traditionally Manufactured Stainless Steel – 21 day incubation

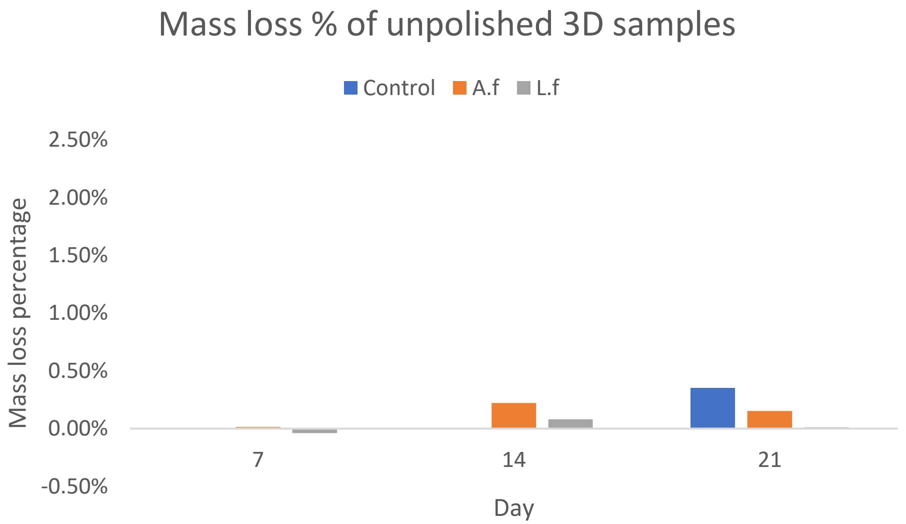
- Potential damage to chromium oxide passive layer

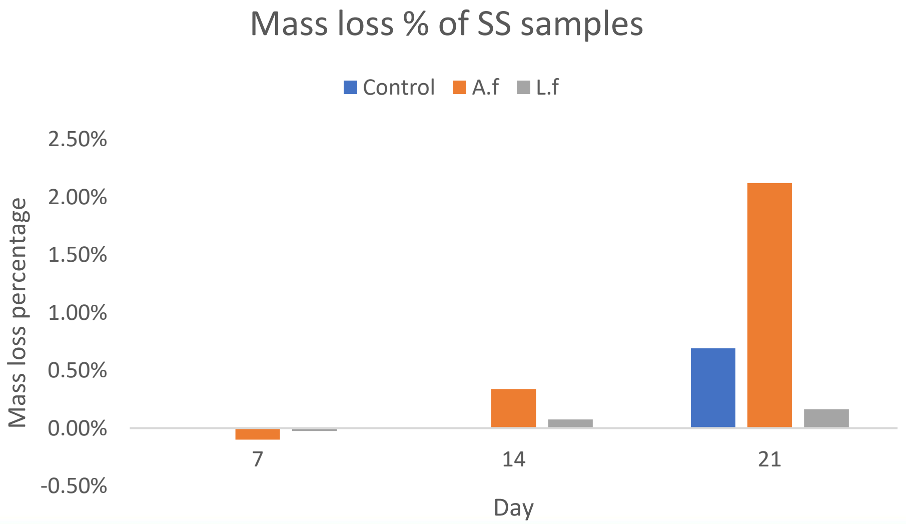
- Higher intensity of iron corresponds to lower intensity of chromium and oxygen

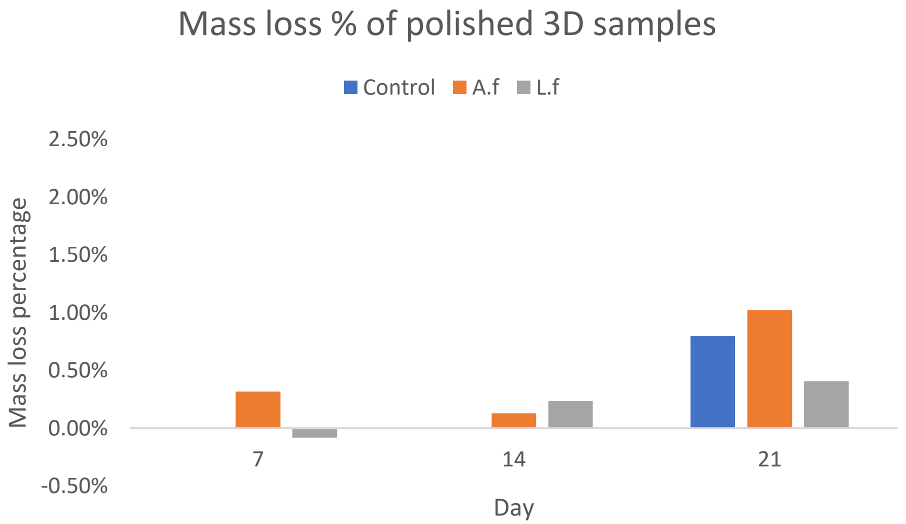


Mass Loss Analysis

- Complex system affects mass analysis
- Addition of biofilm, bacteria or pyrite could alter mass loss measurements







Conclusions

- Increased growth of *Acidithiobacillus ferrooxidans* and *Leptospirillum ferrooxidans* in all conditions
- Visual change to surface after incubation
- Possible damage to chromium oxide passive layer in traditionally manufactured and polished 3D printed stainless steel

Future Research

- Repeated experiments with longer periods of incubation
- Expand type of bacteria used
- Explore different additive manufacturing techniques

Acknowledgements

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Thank you for listening