SUNRISE Reactor Material Breakthroughs

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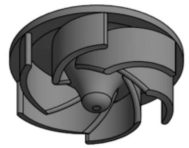
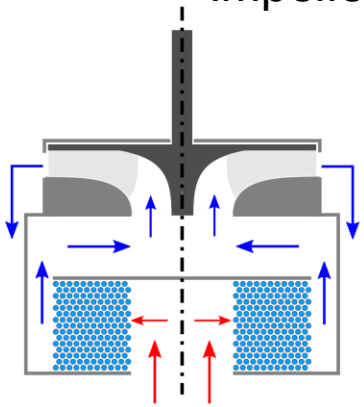
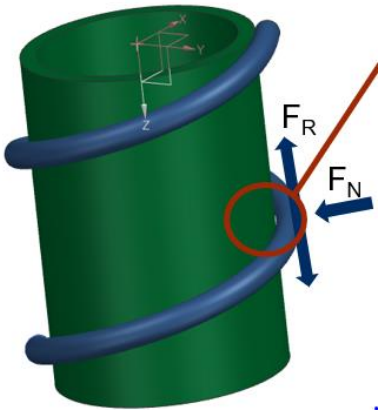
Material questions

- How does coolant liquid lead affect the material?
  - High temperature
  - Erosion / Corrosion / Wear behaviour
- What material is best for the impeller?
- How to protect the fuel rods?

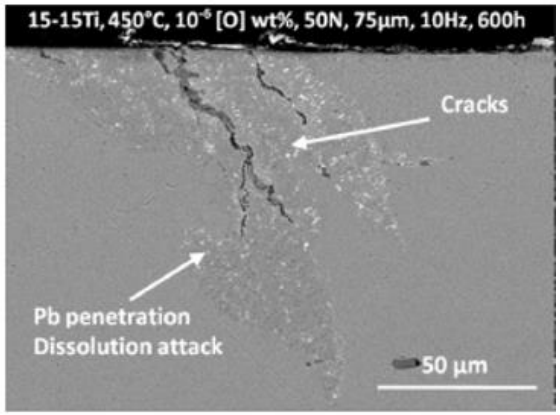


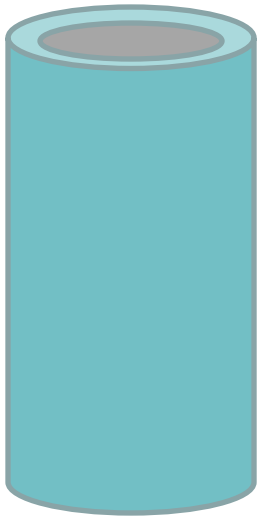
Impeller



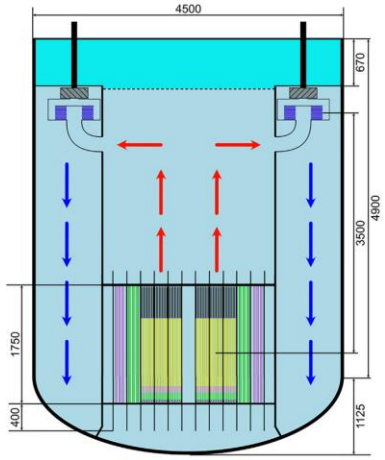


Spacer wire



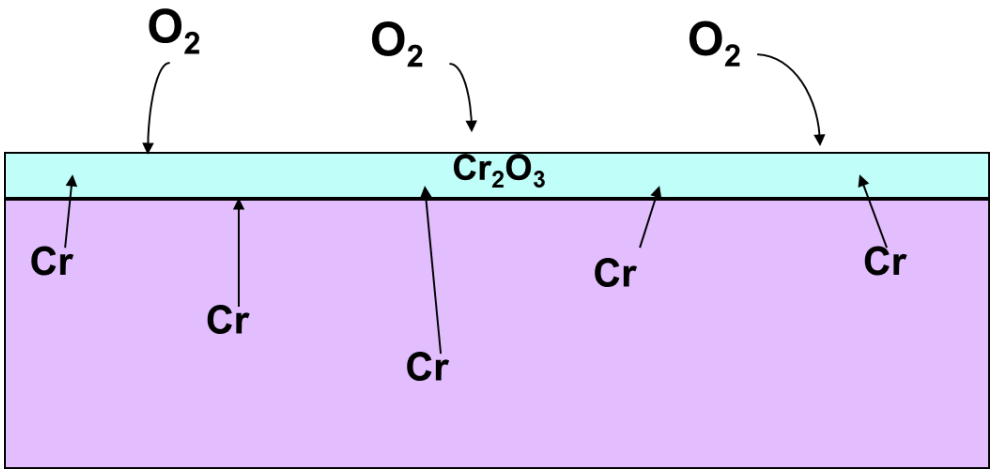


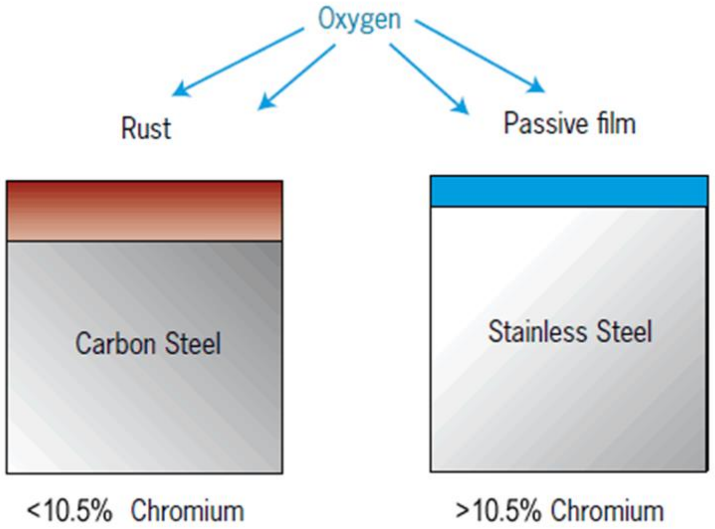
Fuel rod



Stainless steels

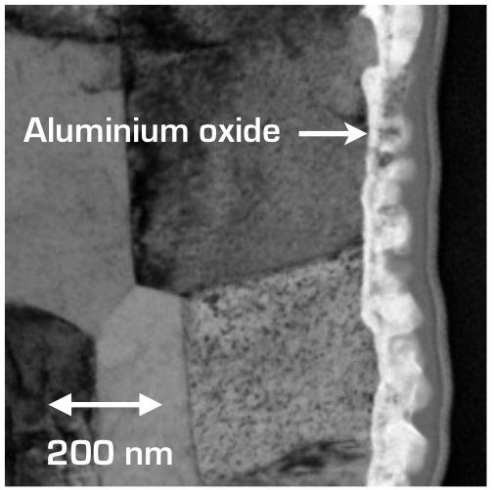
- Alloy 316L qualified for nuclear applications.
- Surface oxide layer protects from corrosion.
- Chromium-oxide not good enough for liquid lead.

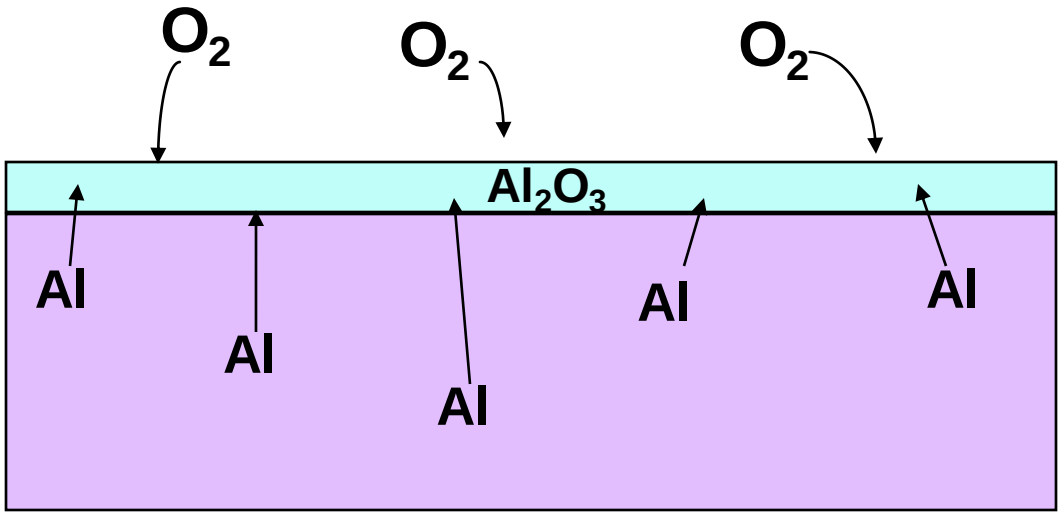




Material breakthrough

- A new aluminum-oxide forming steel (AFA – alumina forming austenite) has been developed within SUNRISE
- Excellent weldability.
- Excellent ductility.
- Self healing effect, alumina formed already at 400°C.





Aluminium oxide layer

Exposure with AFA in liquid lead, 1 year @ 550°C

Excellent corrosion properties in lead!

New FeCrAl developed by KTH
(10Cr-4Al-RE)

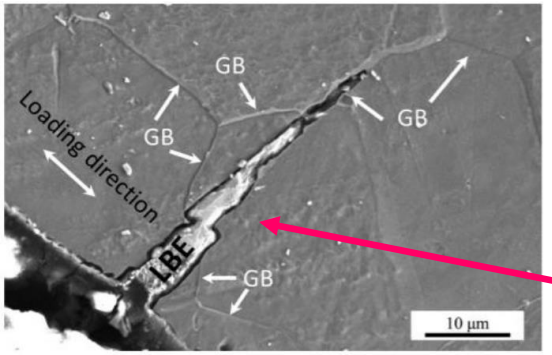
AFA, improved compositions
(15-20)Ni-(10-14)Cr-3Al-Fe

Conventional 316L
(Chromium-oxide forming stainless steel)

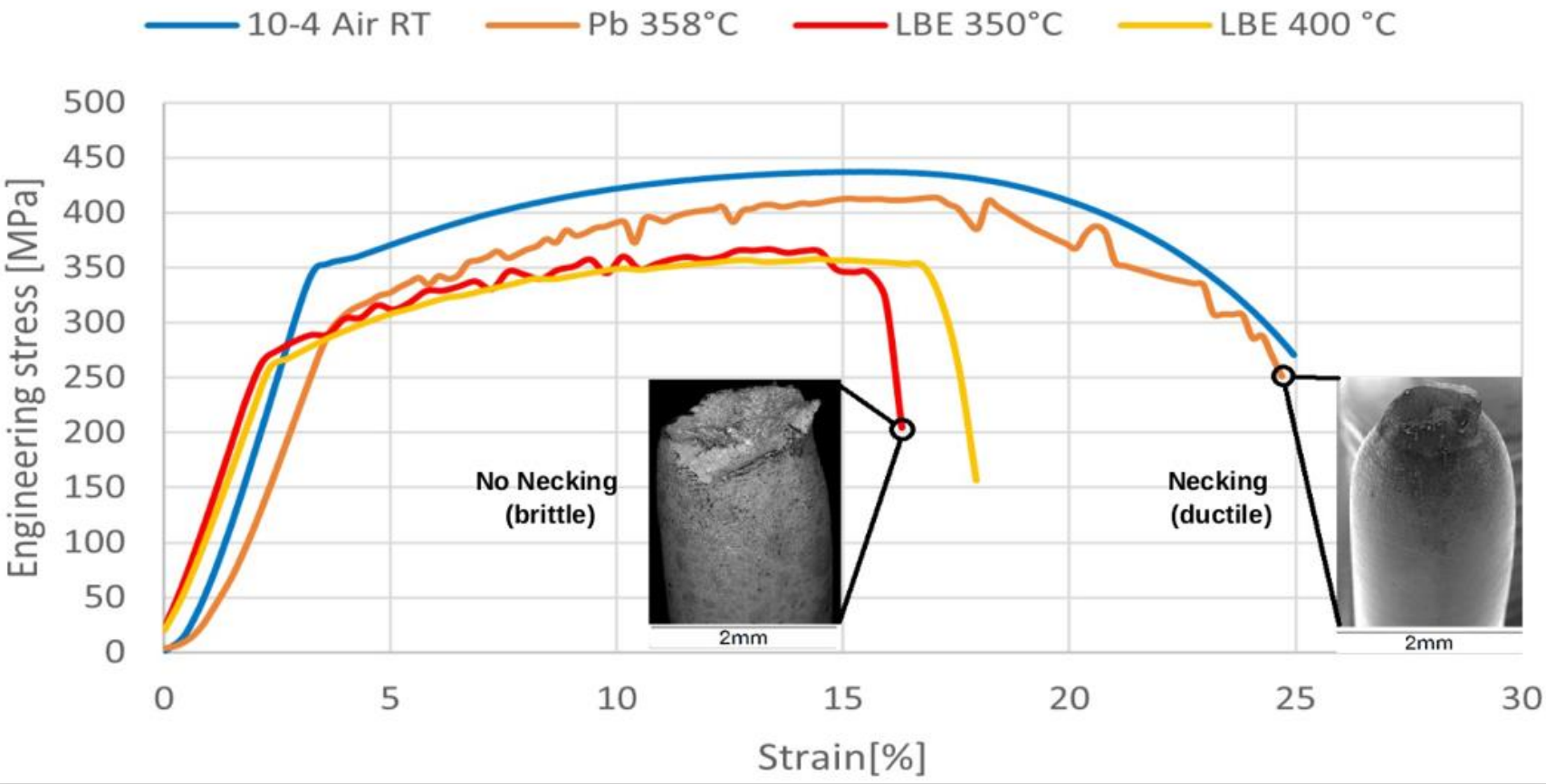
AFA = alumina forming austenite

Liquid metal embrittlement (LME)

- LME a problem in coolant liquid lead bismut eutectic (LBE).
- New Fe-10Cr-4Al showed no brittleness in Pb, 340-500°C!

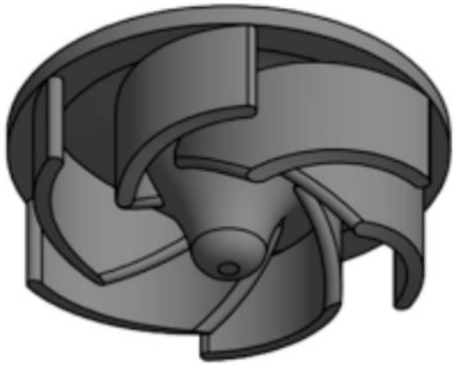


Crack!



The pump impeller

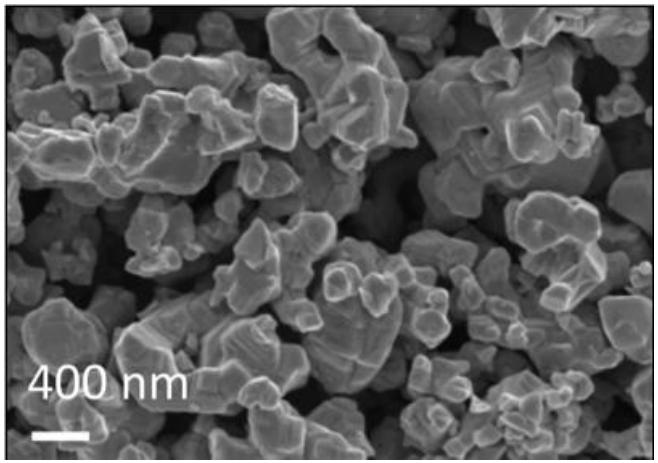
- Harsh environment, circulate the lead.
- Erosion and corrosion expected.
- Cemented carbides, binder phase Ni.
- High hardness and chemically inert.
- WC- NbC- Ni.
- Surface layer of alumina under development.

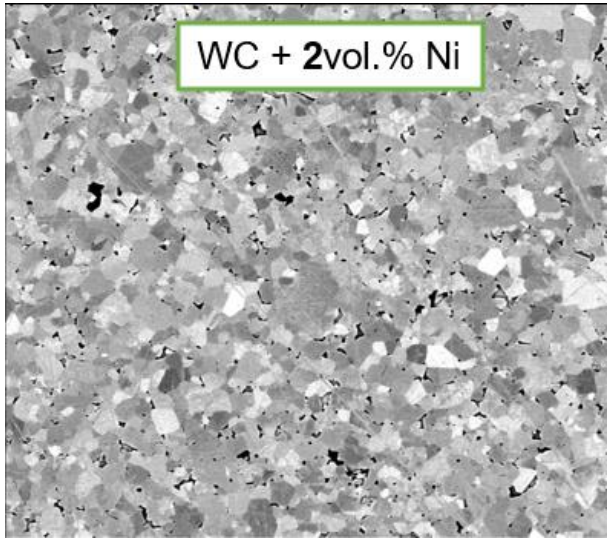


Breakthrough

- Novel powder coating method, dot coating. Salt-based solution route with low-cost chemicals and equipment. Ni dots <100nm.

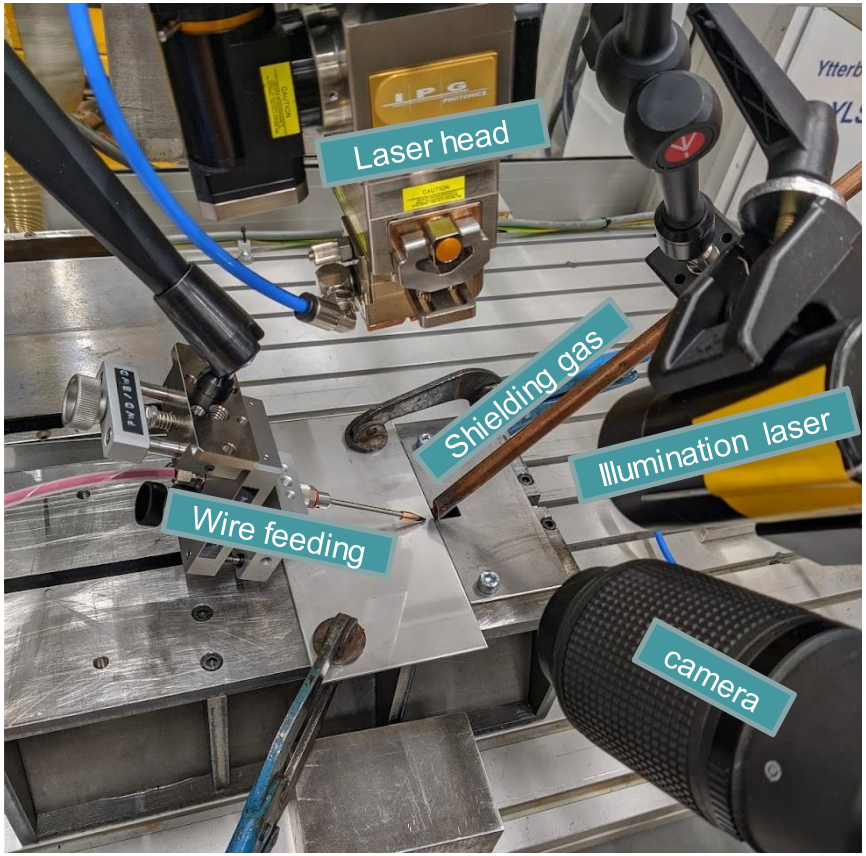
  - Enhances sintering (>99% density)
  - Improves microstructure
  - Less binder (Ni) needed (2 vol%)
  - Good mechanical properties
  - Very high hardness
  - Acceptable toughness





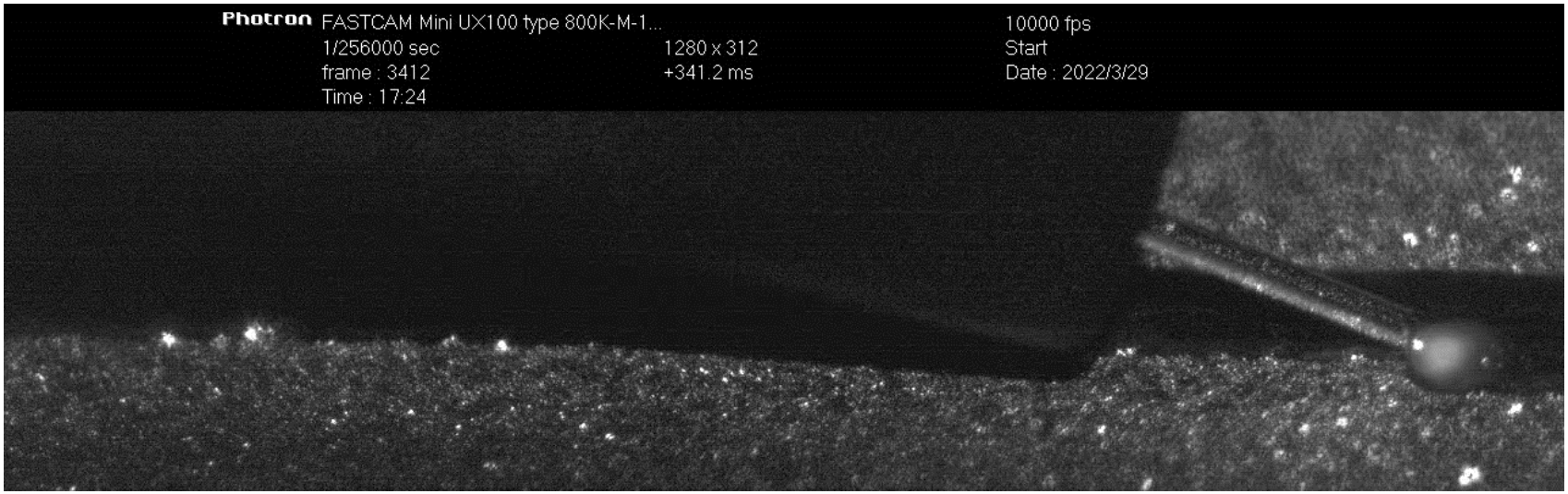
Protecting fuel rods

- Nuclear fuel tubes must be protected from corrosive liquid lead environment.
- New steel (FeCrAl+RE) used as coating.
- Must be **thin enough** to not impair efficiency of reactor.
- Must be **thick enough** for self healing oxide layer on surface when eroded.



Breakthrough

- A laser cladding process developed for ultra thin wire (0.2mm). Thinner than the average tooth brush bristle and about only three times thicker than a human hair.
- This way layers of 0.1-0.2 mm can be deposited.
- Process parameters found that give 10 times faster process than previous attempts in literature. With no porosity!
- Unique high-speed imaging helps understand the process.



Thank you for your attention!