Additive manufacturing of nuclear component

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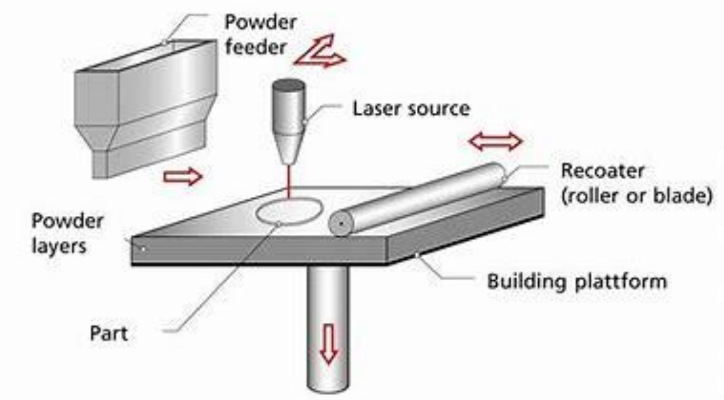
CONTEXT :

- In 2018, Framatome CERCATM launched a 3D printing initiative in order to produce metallic Uranium fuels and Uranium targets for Mo-99 production
- The developments works are performed in partnership with Université de Technologie de Belfort Montbeliard (UTBM)
- Preliminary fuel and target developments have been successfully achieved using surrogates materials (see B. Stepnik et al. in RRFM2019)
- This work present the world first 3D printing development with Uranium material
- The samples were produced by laser based additive manufacturing technology using U_3Si_2 and UMo powder

1. Laser Beam Melting

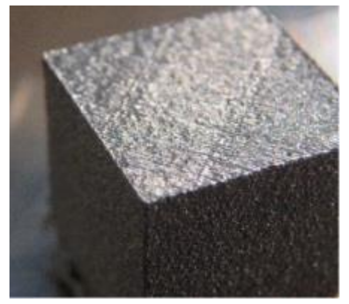
Laser Beam Melting is one of the most promising additive manufacturing process. Very small spot size coupling to the high scanning speed and the incredible parameters flexibility allow us to freely design and manufacture parts with any metals. The laser beam is focalized on a 50µm thick powder bed to melt only the right amount of powder to built one layer. The final part is thus build layer by layer.



Laser Beam Melting process. [Mueller et all. (2013)

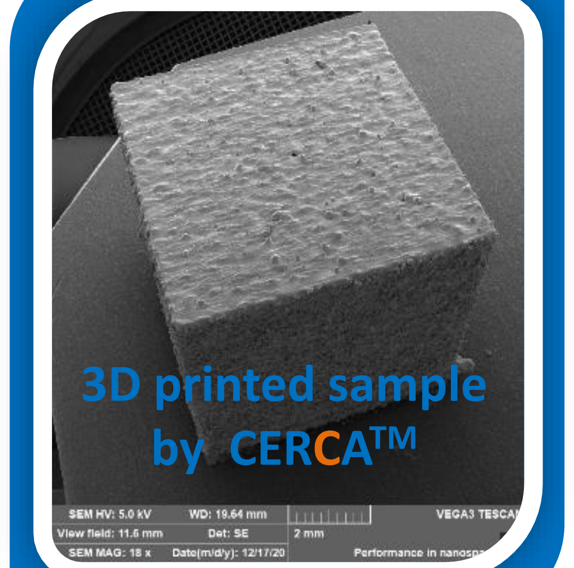
2. Studies on surrogate materials

- ❑ The first step of the study was to select the metallic 3D printer suitable for nuclear use and uranium alloys
- ❑ Then experiments plans were conducted to identify the optimized process parameters range for surrogate materials
- ❑ Finally, fuel core were produced and assembled with Al sheets to produce monolithic fuel plate



3D printed 8x8x8mm cubes

Fuel core manufactured by Laser Beam melting and X-Ray analysis of Fuel plate



3. 3D printer nuclear adaptation

- ❑ Concept Laser Mlab 200R commercial 3D printer deeply modify to suit for Nuclear use
  - 200W ND-YAG fiber laser
- ❑ Custom glove box specially developed for the device and the uranium use
- ❑ Two different building modules available:
  - Module 50x50x80mm
  - Module 100x100x100mm

Mlab Cusing 200R device

Laser Beam Melting in glovebox

4. Additive manufacturing on Uranium alloy samples

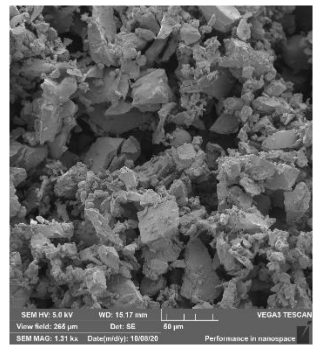
❑ Objectives: Build a 8x8x8 mm cube samples with porosities <5%

Optimize process parameters to enhance the manufacturing process and build part properties

4.1 U_3Si_2

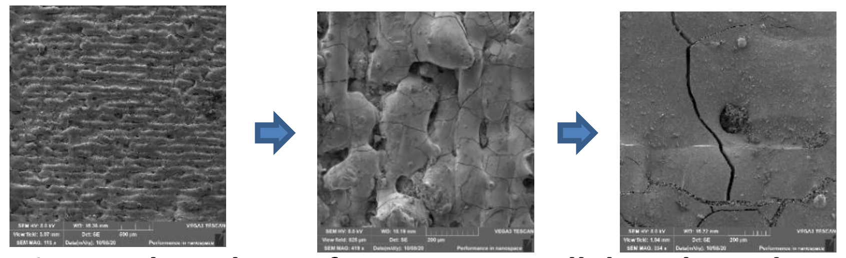
❑ Use of a 0-40µm ground U_3Si_2 powder

U_3Si_2 powder bed



U_3Si_2 powder

- ❑ Melt pool quenching during Laser based additive manufacturing are very fast; U_3Si_2 parts break under this high thermal strain
- ❑ Laser tracks are too spaced, recovery ratio need to be improved in order to melt all the building part
- ❑ Laser additive manufacturing is suitable for U3Si2 alloys with process parameters adjustments



U_3Si_2 sample: cube surface; Laser parallel tracks and cracks

❑ Laser additive manufacturing is suitable for U3Si2 alloys with process parameters adjustments

4.2 UMo

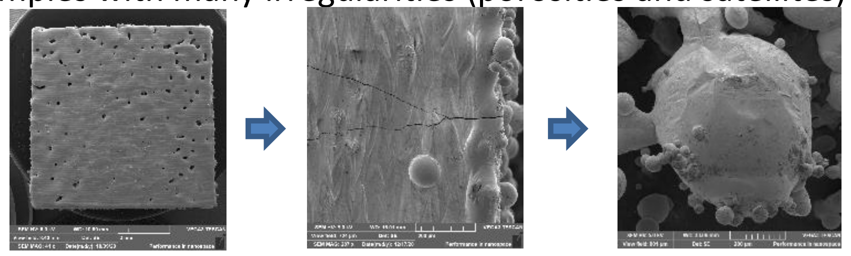
UMo Cube sample manufacturing

❑ Use of a 0-90µm spherical UMo powder

- First experimental plan observations:

❑ Lots of melted drops ejected from the melt pool (key hole effect)

❑ Samples with many irregularities (porosities and satellites)



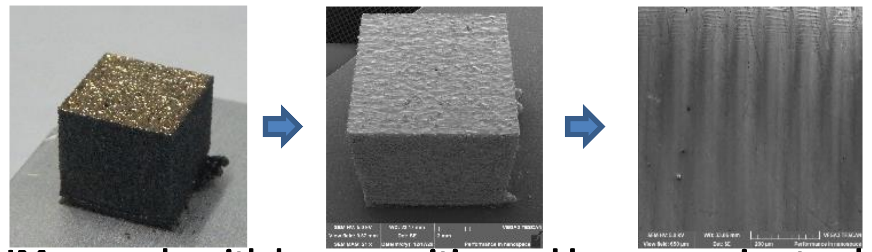
UMo sample: cube surface; surface satellites

❑ Solution: Reduce the laser power and adjust the scanning speed

- Second experimental plan observation:

❑ Reduction of melted drops and irregularities

❑ Samples denser, smoother and with less geometrical deformations



UMo sample with low porosities and laser scanning tracks

❑ Samples presents no cracks or irregularities.

❑ Promising results of UMo samples additive manufacturing

Conclusion :

- ❑ **Framatome-CERCA™ has manufactured the world first 3D printing U3Si2 and UMo sample**
- ❑ We have demonstrated that 3D printing technologies can be nuclearized and can produce samples in metallic Uranium alloys
- ❑ Now, Framatome-CERCA™ will continue the development works to improve the quality and to increase the sample sizes towards metallic Uranium fuels and metallic Uranium targets for Mo99.