framatome

Framatome Fuel Research Centers & Labs

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Manufacturing and Testing Facilities at Framatome for R&D programs

Richland

- Mechanical & Thermal-hydraulics tests (PHTF)
- Manufacturing capabilities for R&D (incl. Innovative Fuel, LEU+, deconversion)

Karlstein

- Prototyping lab (FDKP)
- Thermal-hydraulics tests

Lingen

- Manufacturing capabilities for R&D

Erlangen

- Mechanical tests
- Corrosion – Chemistry
- Hot Cells

Ugine

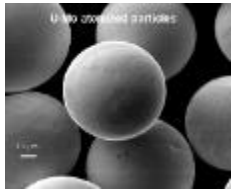
- Zr Alloys Metallurgy and Manufacturing (CRC)

Le Creusot

- Mechanical & Hydraulics tests
- Corrosion - Chemistry

Romans

- Research Reactors & Innovative Fuel (CRIL)
- Manufacturing capabilities for R&D



Fuel Labs

Fuel Manufacturing capabilities

Technical Centers

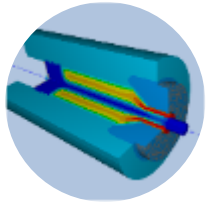
Components Research Center (CRC)

- Dedicated primarily to Zirconium, Titanium and Hafnium Alloys
- Wide range of manufacturing, modelling and characterization capabilities

Develop and elaborate new alloys

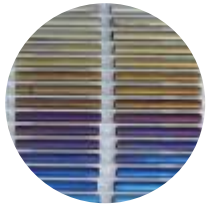
Develop pilots of industrial processes

Perform metallurgical and out-of-pile characterizations

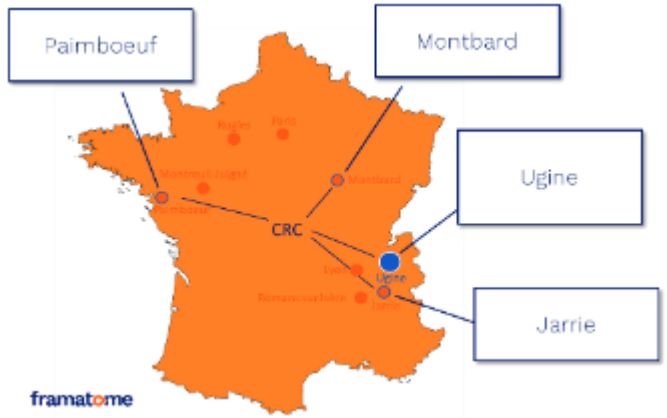


Optimize Manufacturing Processes

Contribute to new product development



Study out-of-pile behavior



Components Research Center (CRC)
Experimental capabilities

Manufacturing of Experimental alloys

- Skulls melting : Levitation Cold Crucible Furnace (LCF)
- Forging / Rolling / Heat Treatments / Surface conditioning

Melting

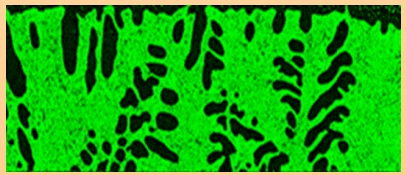
Skulls: mall ingots

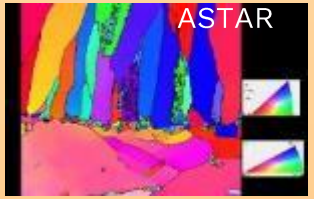
Cold rolled plate

Characterization techniques

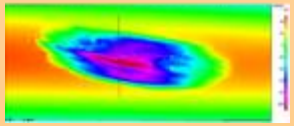
- 2 SEM + EDS + EBS
- TEM + EDS + ASTAR
- EPMA
- Optical Microscopy
- Roughness, µhardness

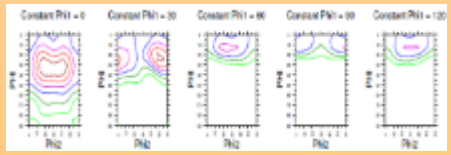
EPMA





3D roughness





XRD on M5

µhardness

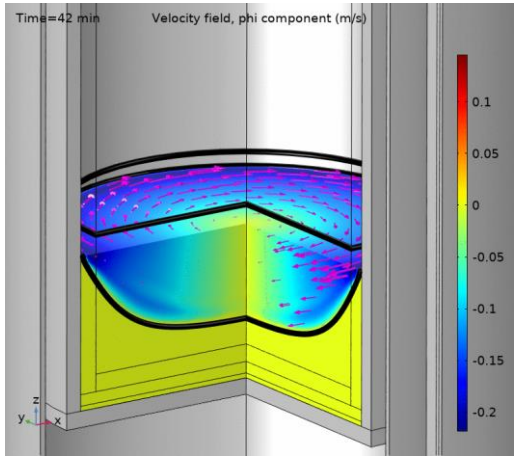
Out of pile properties

- Corrosion
- Mechanical testing
- Tribology
- Heat treatments

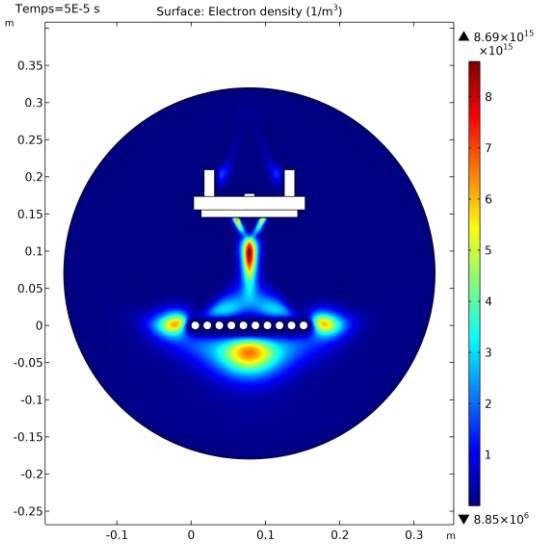
Components Research Center (CRC) Process Modelling

VAR melting 2D/3D Simulation (Solar)

- Heat transfers
- Flow in the liquid pool
- Material transfer liquid/solid

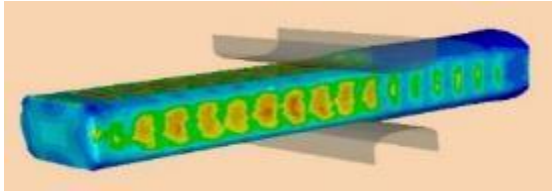


Cr-coating of cladding tubes (COMSOL)

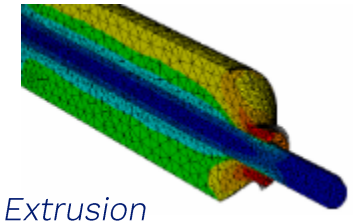


Thermo-mechanical simulations (FORGE)

- Manufacturing route optimization



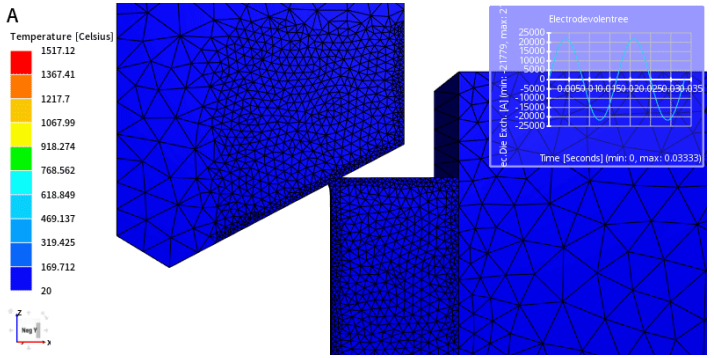
Forging



Extrusion

USW welding (FORGE)

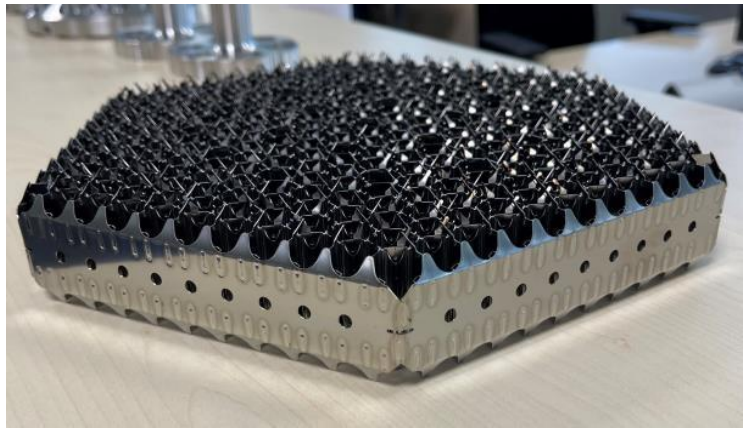
- Determination of welding parameters

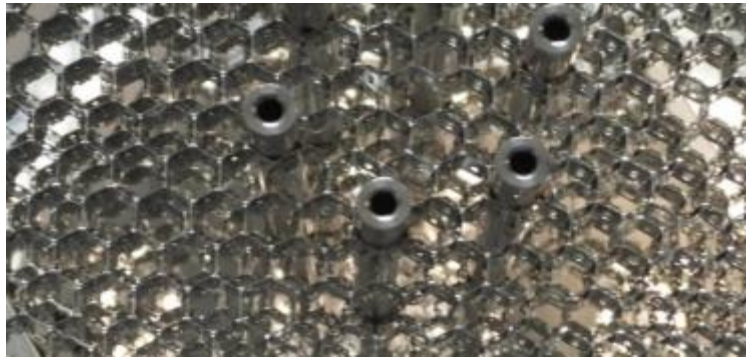


Prototyping Lab (FDKP)

- **Prototyping of Fuel Assemblies and components**
- **Inspection and mechanical testing on full scale mock-ups**

- Prototyping of Fuel Assemblies, spacer grids and Components during development, optimization up to LTAs
- Assembling of BWR, PWR and VVER fuel mock-ups (resp. ATRIUM 11, GAIA, VVER 1000 & 440)
- Manufacturing of pressurized rods and of material test rods
- Wide range of scales: from reduced size up to Full-size Fuel Assembly LTAs
- Conditioning and instrumentation of components and mock-ups before testing
- New manufacturing processes development and support for the industrialization of new products
- Mechanical Tests on components



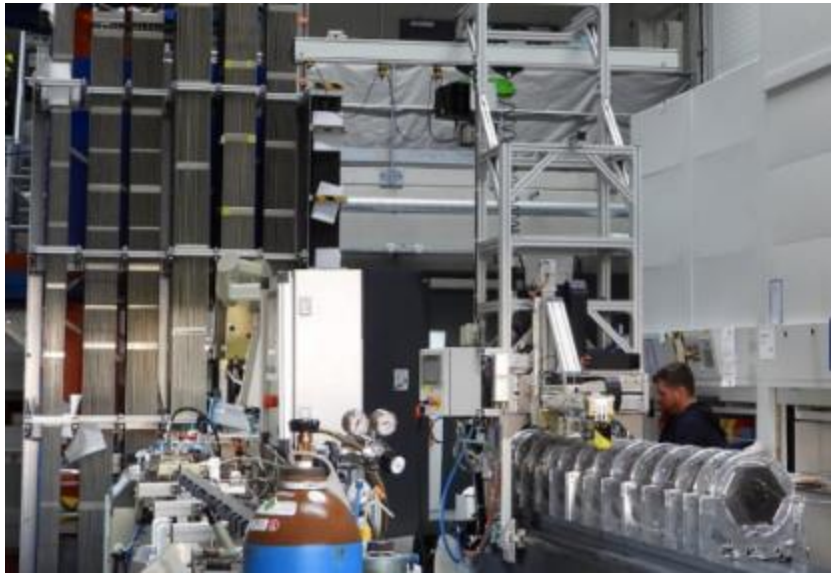


Prototyping Lab (FDKP)

Laser Lab:
- Material treatment with Laser
- Laser cutting
- Laser beam welding Optical analysis of cutting shapes

Fuel Assembling:
- Fuel assembly bench
- Fuel rod insertion system
- Fuel assembly welding
- TIG welding / Upset shape welding of fuel rods

Mechanical Lab:
- Manufacturing of fixtures, tools
- CNC-milling and turning
- 3D-EDM eroding
- Material forming (stamping, bending)
- Robot stamping cell



Advanced manufacturing & inspection methods:
- Rapid Prototyping & Tooling
- 3D print in metal and polymer
- Computed tomography analysis
- 3D scanning
- Robot applications

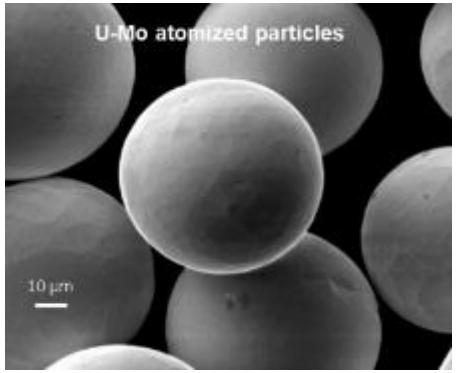
Measurements & Testing:
- Mechanical design tests
- Integral tests on fuel elements
- Dimensional measurements
- Stress analysis

CERCA Research & Innovation Laboratory (CRIL)

- Uranium Fuel manufacturing with enrichment up to 20 % U-235
- Wide range of nuclear fuel types for Research Reactors & Advanced Modular Reactors: uranium alloys (e.g. U-Al, U-Si, U-Mo) and various fuel types (Metallic fuel, UO_2, UCO, …)

FACILITY DESIGNED FOR PROTOTYPING

- Modular workspaces with rapid commissioning process
- Able to produce very pure metallic uranium alloys powders
- Equipped with 3D metallic Uranium printer



CUSTOM-MADE PROJECTS

- From fuel concept to prototype fabrication
- Flexible outputs, from single measurement to small series production

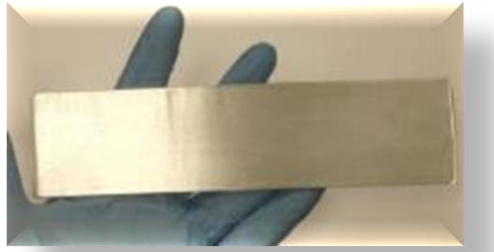
NEW TECHNOLOGY ORIENTED

- Operational in metallic uranium developments (targets for radioisotopes, research reactors, AMRs)
- Upcoming uranium oxides developments (LWR, HTR, LFR, GFR, SFR, microreactor)

TRIGA© fuel elements

U-Zr-H rods

U Plate made by Additive Manufacturing



CERCA Research & Innovation Laboratory (CRIL) Experimental Facilities

URANIUM LABORATORY WITH STATE-OF-THE-ART MANUFACTURING AND INSPECTION EQUIPMENT

- 17 glove boxes
- 4 fume hoods
- Arc and induction melting furnace
- Annealing furnaces
- Hot and cold rolling mills
- Powder atomization and transformations
- Laser Beam Fusion Melting
- Cold Spray
- Compaction presses
- Laser welding and marking
- X-ray inspection
- Ultrasonic inspection, Acoustic microscope
- 3 dimensional inspection, Laser cutting systems

INDUSTRIAL DEVICES

- Accurate characterization of chemicals
- Corrosion detection

R&D DEVICES

- Optical microscopy
- Micro hardness
- SEM & EDX microscopy
- Tensile and compression measurement up to 1100°C
- Thermal measurements

Framatome Technical Centers

- Framatome Technical Centers dedicated to Mechanical, Thermal-Hydraulics and Materials Testing
- Located in Le Creusot, Karlstein, Erlangen

Kathy Loop (Karlstein)

- A unique facility for CHF measurements
- Tests performed on fuel rod bundles
  - Critical heat flux (CHF) measurements
  - Mixing measurements
  - Void fraction measurements
  - Pressure drop measurements
  - Stability tests
  - Transient tests

→ CHF tests for Fuel BU R&D Programs on new products and for external customers (e.g. EDF, NuScale)

Take aways

- A unique range of facilities and expertise to support new Fuel materials & product developments as well as manufacturing process development or optimization
- Wide range of capabilities: Prototyping, testing & qualification, characterization, process modeling

Thank you