The New Shape of Clean Energy

Enfission

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Lightbridge Fuel™: Innovative UZr metallic fuel

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CONTEXT:

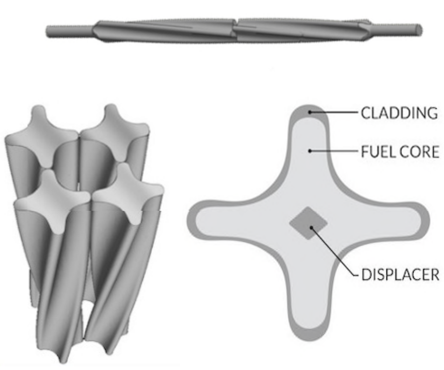
- Enfission™ aims to complete the commercial deployment worldwide of new metallic nuclear fuel assemblies for power reactors.
- The Lightbridge Fuel™, currently developed, has a high loading in Uranium (40-60%wt) and U-235 enrichment (19%wt) conferring the ability to be used either in power reactors or research reactors.
- Fundamental studies to define industrialization parameters as well as understanding and anticipating the behaviour of the U-Zr alloy have been launched in 2018.

1. Enfission™ Company

Enfission is a US-based 50-50 joint venture between Lightbridge Corporation and Framatome. Enfission was established January 25, 2018 to complete the development, regulatory licensing, and commercial deployment worldwide of nuclear fuel assemblies based on multi-lobe metallic twisted fuel technology. Enfission will produce Lightbridge Fuel™ assemblies initially for operators of U.S. commercial nuclear power plants, then follow with production of Lightbridge Fuel™ assemblies for other types of reactors and for markets around the world.

2. Lightbridge Fuel™

- ❑ Lightbridge Fuel™ is the first product developed by Enfission™ for nuclear PWR on 17x17 fuel assembly.
- ❑ Designed to optimize new and existing nuclear power plants to both reduce operating cost and to increase safety.
- ❑ Innovative shape and composition.
- ❑ Significant reduction of fuel operating temperatures (under 600 K).
- ❑ Improving of the fuel's structural integrity.
- ❑ Enhancing response to abnormal events.
- ❑ Three components: a uranium-zirconium alloy fuel core, a corrosion-resistant zirconium alloy barrier, and a central displacer.
- ❑ Fission meat near 50/50 %wt U-Zr composition.



Lightbridge fuel™ rods design.

⇒ **Insertion of Lead Tests Rods in a commercial Reactor in the U.S. by 2021.**

3. R&D in progress – The GENESIS project

3.1. GENESIS project

The first project launched by the company is aiming to respond to the urgency of bringing safer and better economical solutions to maintain nuclear power plants in operation in the United States, targeting the standard pressurized water reactors that power cities. Named Genesis, this first project started in early 2018.

3.2. GENESIS Fabrication team highlights

- ❑ Fully integrated with Design and Licensing, the Fabrication team is working on the materials characterization and process development, as well as the build-up of a pilot facility.
- ❑ Transversal contribution and expertise from Framatome's CERCA™, Zr research center, Zr manufacturing, US based Richland fuel fabrication facility, together with Lightbridge's experts.

⇒ **Current focus on fabrication of rodlets for irradiation in research reactor by 2020, and Lead Test Rods fabrication**

3.3. Partnership with University of Lille

Located on the scientific campus of Lille University, at Villeneuve d'Ascq (France), the PUMA (Powder Uranium Metallurgy) laboratory is conducting research works in material chemistry, physical metallurgy and modeling for the understanding of fundamental behaviors of Enfission's new metallic material for nuclear power plants.

⇒ **Launch in mid of 2018 of a preliminary study on U-Zr alloy fabrication.**

⇒ **First samples and material characterization results presented end of 2018 and still in progress.**

Inauguration of the LRC PUMA with Enfission™.

4. UZr alloy properties preliminary study

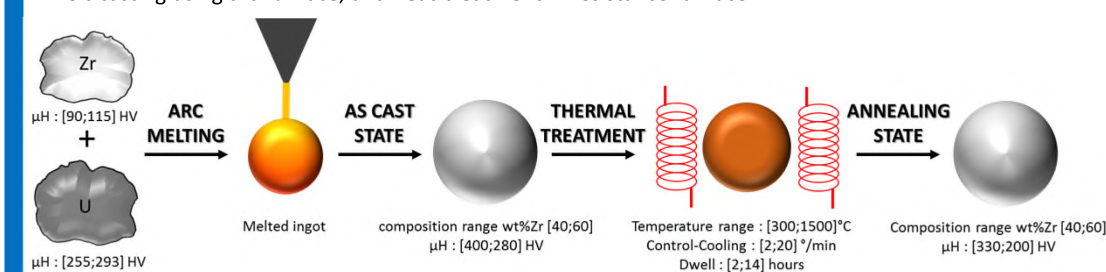
4.1. Goals

- ❑ To understand the metallurgical behaviour of U-Zr at as-solidified and annealed states
- ❑ To characterize the microstructure, mechanical properties, chemical and phase compositions of the U-Zr alloy (Depending of composition, cooling rate after casting, thermal treatment (Max T°, duration, cooling rate …), environment (carbon crucible, reducing atmosphere …), processes)
- ❑ To determine significant markers of phases
- ❑ To draw up a phase diagram of the U-Zr in the range 40 to 60% wt of Zr [1, 2]

⇒ **Fundamentals for process optimization to obtain adequate δ-UZr_2 properties on final product**

4.2. First step on elaboration process

Melt-casting using arc-furnace, and heat-treatment in resistance furnace

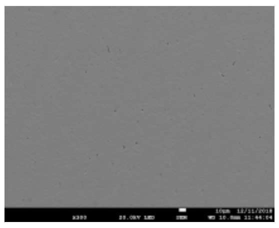


Process schematic for UZr samples production.

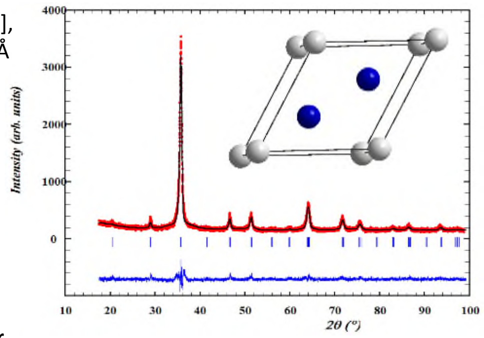
4.3. As-cast sample : δ–UZr_2 phase

- ❑ No γ–(U,Zr) phase on the as-cast samples,
- ❑ Pure δ–UZr_2 phase : hexagonal UHg_2 type of structure [3],
- ❑ Refined lattice parameters : a = 5.021(1) Å, c = 3.091(1) Å

Laboratory-scale samples.



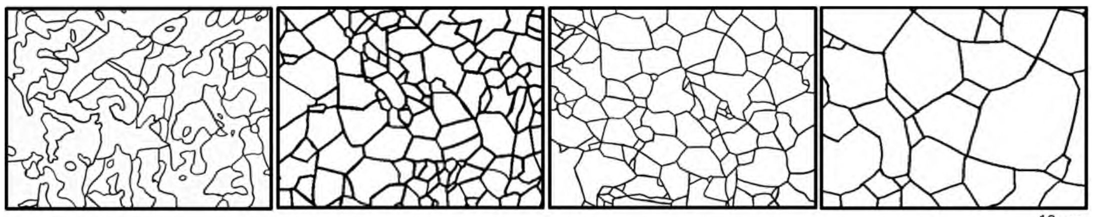
SEM Microview of U-Zr with 45.2 wt.% Zr.



Rietveld plot of the U-Zr with 52.2 wt% Zr with the UHg_2-type of structure.

4.4. Grain refinement with heat-treatment

- ❑ Recovery, recrystallization and grain growth



- Annealing : 2 hours, 590°C
- Average grain surface : 30,5 µm²
- Micro-hardness : [227;240] HV
- wt % Zirconium : 48,1%

- Annealing : 2 hours, 750°C
- Average grain surface : 14,8 µm²
- Micro-hardness : [206;226]HV
- wt% Zirconium : 52,6%

- Annealing : 2 hours, 900°C
- Average grain surface : 17,5 µm²
- Micro-hardness : [195;213] HV
- wt% Zirconium : 56,6%

- Annealing : 2 hours, 1050°C
- Average grain surface : 88,4 µm²
- Micro-hardness: [200;230] HV
- wt% Zirconium : 45,3%

Evolution of microstructure during thermal treatment of U-Zr alloys

4.5. Perspectives

- ❑ Process parameters impacts on UZr material
- ❑ Full modelling of the properties (Chemical, mechanical, microstructural, thermodynamical) of the U-Zr will be performed in function of parameters (composition, temperature, heat treatment, cooling rate).

References

[1] M. Akabori, A. Itoh, T. Ogawa, F. Kobayashi, Y. Suzuki, Stability and structure of the d phase of the U-Zr alloys, J. Nucl. Mater., 188 (1992) 249-254.
[2] W. Xiong, W. Xie, C. Shen, D. Morgan, Thermodynamic modeling of the U–Zr system – A revisit, J. Nucl. Mater., 443 (2013) 331-341.
[3] M. Akabori, T. Ogawa, A. Itoh, Y. Morii, The lattice stability and structure of d-UZr2 at elevated temperatures, J. Phys.: Condens. Matter, 7 (1995) 8249-8257.

CONCLUSIONS :

- ❑ **Enfission is developing a high-tech innovative fuel technology which will be the first to bridge the gap between the current fleet of nuclear power reactors needs and future advanced reactors designs.**
- ❑ **The microstructural and mechanical properties of the Innovative UZr Lightbridge Fuel™ are under characterization to provide a better knowledge of the material behavior.**
- ❑ **Investigations on the phase stability of the U-Zr are in progress.**

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