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Competence Center Energy and Mobility

PINE

Platform for Innovative Nuclear FuEls

This project started in 2008.

Scope of project

Presently fast breeder reactor (FBR) fuels consist in pellets made of uranium-plutonium-oxide $(U,Pu)O_2$, clad in steel tubes. Within the CCEM PINE Platform we shall demonstrate the advantages of chemically and geometrically alternate fuel forms prepared by lesser and «simpler» processes, which show many physical and safety relevant advantages and are less expensive.

Summary of project

The Research and Development PINE platform shall develop a lean, dust-free, chemically versatile, remotely operable particle fuel preparation path. At a later stage (to highlight the advantages or possible drawbacks) vibro-compacted (sphere-pac) carbide and/or carbonitride fuel, clad in stainless steel, shall be irradiated in a Na- or He-loop of a fast breeder research reactor.

Compared to standard $(U,Pu)O_2$ pellet fuel for sodium- or gas-cooled fast reactors the proposed carbide and/or carbonitride fuel concept has many advantages:

- higher breeding gain due to higher fissile density and low neutron absorption cross section,
- more compact core design options,
- lower operation temperature due to higher thermal conductivity.

The fuel shall be produced by «direct conversion», precipitating green spherical fuel particles instantaneously when falling from a nozzle through a microwave cavity. The envisaged fuel conversion method shows highly interesting advantages compared to standard (pellet) fuel manufacturing processes:

- significant reduction in process steps compared to pellet fuel preparation, thus considerably reducing fuel preparation costs and increasing attractiveness for on-site (remotely operated) fuel production,
- reduction in fire risks by wet chemistry steps,
- improved in-pile fuel swelling behaviour compared to pellet fuel (due to principal differences in the sintering and restructuring behaviour of particle fuel).

The (presently remaining) disadvantage of difficulties in acid dissolution of carbides (compared to oxides) could possibly be overcome by pyrochemical processing (thermal cycling and/or molten salt reprocessing techniques) or by introducing alternate fuel matrices (carbonitrides instead of carbides). This question is also focused on within the present proposal.

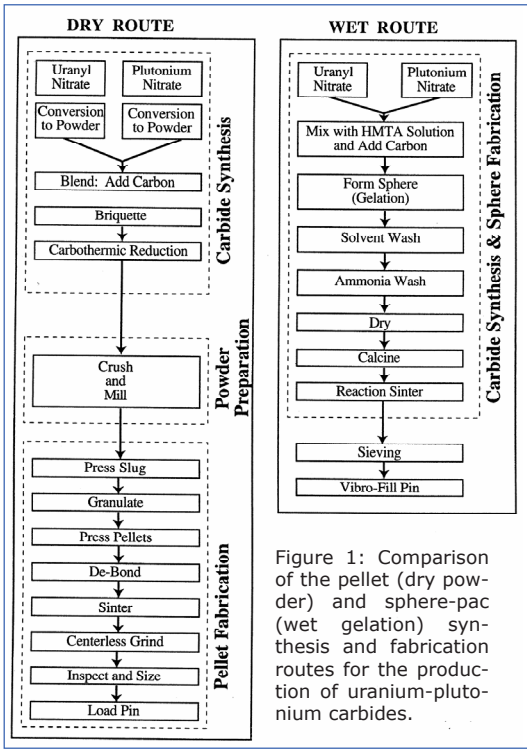

Figure 1: Comparison of the pellet (dry powder) and sphere-pac (wet gelation) synthesis and fabrication routes for the production of uranium-plutonium carbides.

Goals and activities

The platform of the Nuclear GenIV Fuel CCEM partners (project PINE-1) in the ETH-domain would provide (in a first 3 year program phase) laboratory scale answers to the following topics:

- 1: Fuel particle development (UC-particles) by microwave gelation (ETHZ/PSI-LWV).
- 2: Rotary kiln techniques for carbothermal reductive particle heat treatment (drying, calcining, reductive sintering) (EMPA/PSI-LWV).
- 3: Reprocessing options for UC (and (U,Pu)C) particles (PSI-LWV).
- 4: Neutronics of (U,Pu)C fuel, compared to (U,Pu)O2 (EPFL/PSI-LRS).

Main Investigator
Manuel Pouchon, PSI

Project Partners
Empa
EPFL
ETHZ
PSI

In a second program phase (project PINE-2) (U,Pu)C and (U,Pu)N particles would be prepared at PSI.

The platform should result in a world-leading GenIV fuel (and fuel fabrication) concept, being simple, versatile and apt for sodium-cooled or gas-cooled fast breeder reactors. In the frame of a long-term cooperation between Empa, ETHZ, EPFL and PSI (within CCEM), the fuel would be tailored for optimized safety and economy.

Future third-party money is expected from international research co-operations, as well as through bilateral contracts between research centers and industry.

Many challenging R+D questions have to be answered with excellent publication and education chances. Applying microwave gelation and rotary kiln techniques makes the direct conversion fuel preparation path very attractive as remotely operable, chemically versatile (safeguard self-protecting) process. Such a Swiss program has best chances to be imbedded in European (see EU-7: PARFUEL, ACSEPT) and worldwide networks such as the GenIV International Forum GIF.

While Switzerland is not expected to enter the nuclear fuel market, technology development like microwave gelation and staged rotary kiln particle sintering processes might well enter into Swiss industry companies, supplying high-tech products to large internationally operating fuel manufacturers or (with respect to dual use) be introduced into other industrial fields.

Expected results

- Proven application of microwave gelation process to prepare green diuranate fuel particles.
- Proven rotary kiln heat treatment process to prepare uranium-carbide fuel particles sintered up to 1900°C.
- Summary report on pyrochemical head end reprocessing options for UC and (U,Pu)C.
- Neutronically sound fissile material density requests concept(s) for envisaged (U,Pu)C sphere-pac fuel concept for PINE-2.

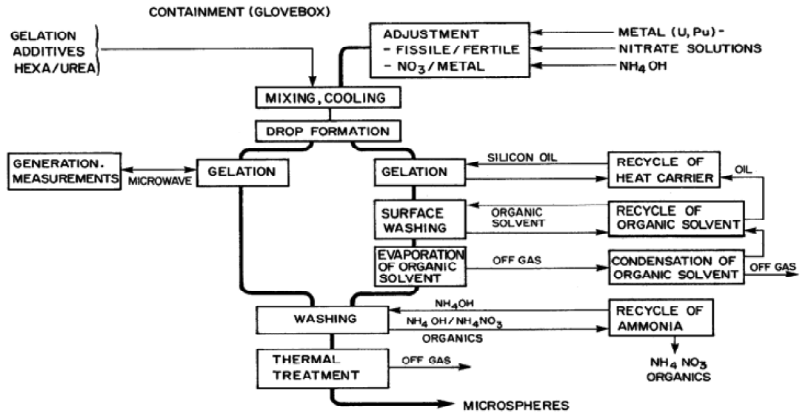

Figure 2: Sol-Gel Fuel Preparation
(left: microwave gelation; right: gelation in hot oil bath).

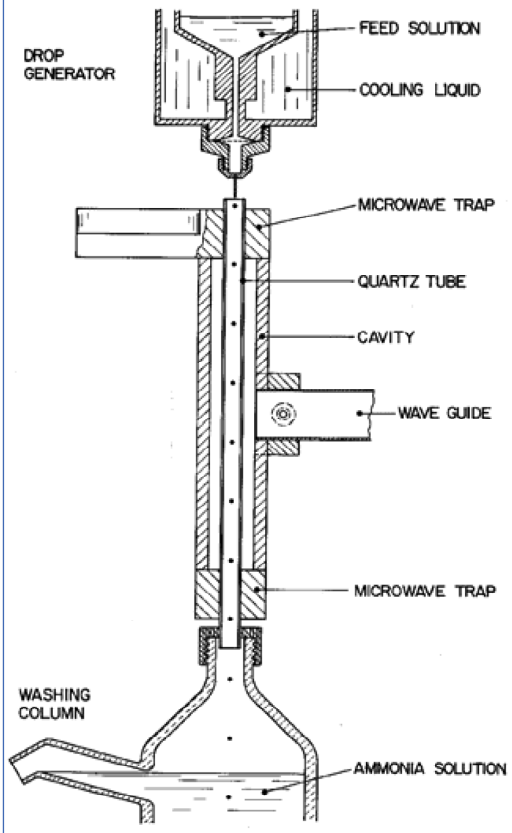

Figure 3: Concept of fuel droplet gelation with microwave cavity.

International research activities

GenIV fuel questions are presently addressed in several international programs such as in the 6th European research program RAPHAEL (gas-cooled reactor development), the specific EU-support action EISOFAR (for sodium- and gas-cooled reactor development), the GenIV International Forum GIF (where PSI is representing Switzerland), the US Advanced Fuel Cycle Initiative (AFCI) and the Global Nuclear Energy Partnership (GNEP) (to (re-)develop a US sodium breeder reactor). We shall also participate within ACSEPT to the 7th European framework program.

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