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► **To cite this version:**

G. Barba Rossa. modelling high-level-waste vitrification in cold crucibles. JRC-ITU and CEA Marcoule Exchange Visit, Apr 2016, Karlsruhe, Germany. hal-02442260

HAL Id: hal-02442260

<https://cea.hal.science/hal-02442260>

Submitted on 16 Jan 2020

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MODELLING HIGH-LEVEL-WASTE VITRIFICATION IN COLD CRUCIBLES

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JRC-ITU and CEA Marcoule Exchange Visit
11th April 2016

www.cea.fr



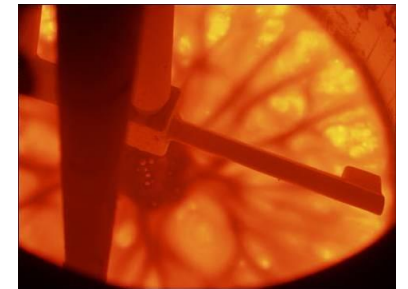
Short overview of the HLW confinement process

- Ensure long-time confinement of High-Level-Waste (HLW) of spent nuclear fuel reprocessing
- Steps
 - **Vitrification:** atomic-scale incorporation of HLW in a glass melt
 - Nuclear glass poured in metallic canisters
 - Underground disposal in a deep geological repository
- Technology used for vitrification
 - **Induction-heated cold crucible**



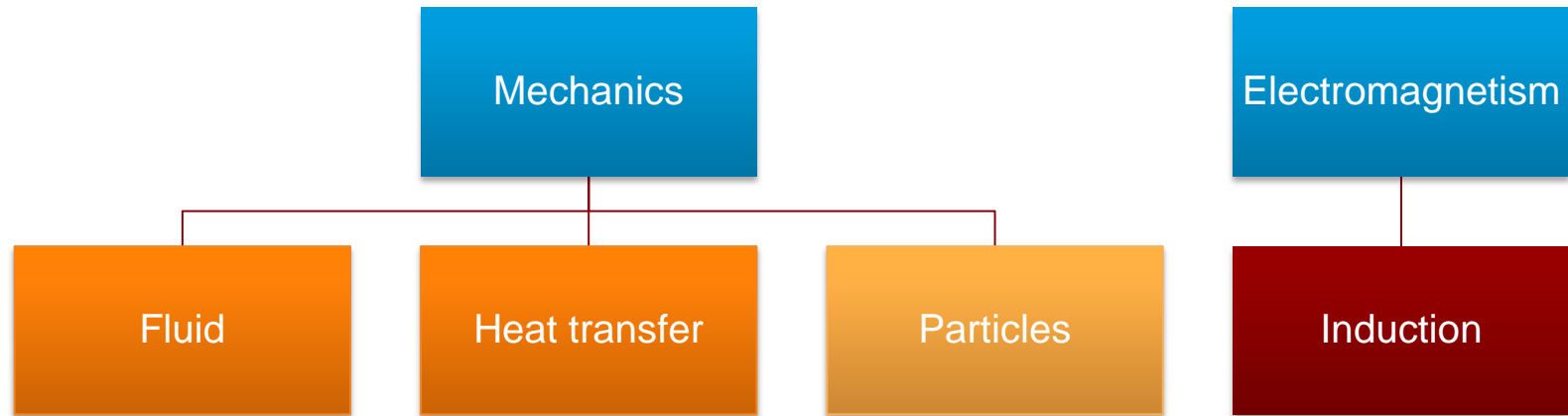
Melting with cold crucibles

- Main principles
 - Calcined HLW and glass frit are heated by direct electromagnetic induction
 - The crucible is cooled by an internal water-cooling system
 - The glass melt is mechanically stirred with a rotating agitator
 - Further homogenization is achieved with air bubbling in the glass
- A cold crucible is already working at the La Hague reprocessing plant (France) since 2010
- Mission of CEA
 - Back industrial support
 - R&D and design of more efficient crucibles for future nuclear waste
 - **Modelling and simulating the full vitrification process (hence diminishing new development costs)**



Glass surface in the crucible

Electro-thermo-hydraulic modelling of the cold crucible



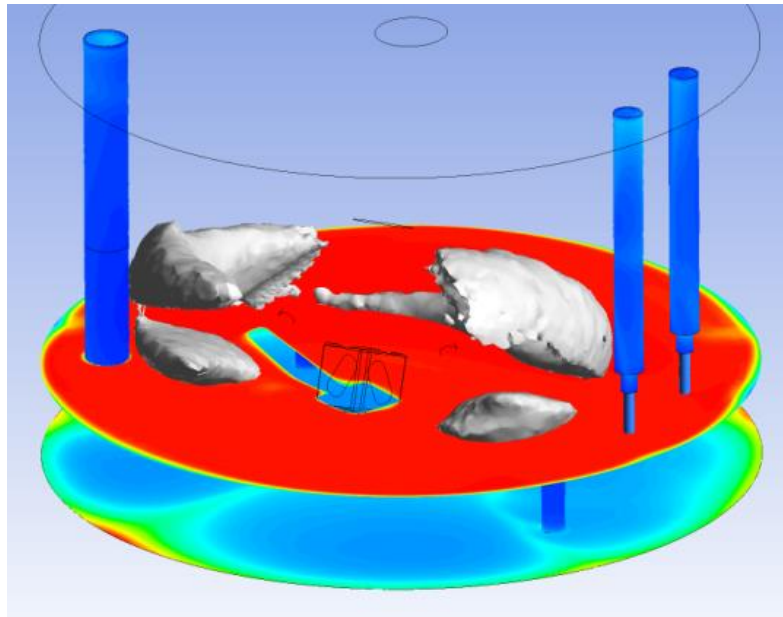
- The all thing is coupled
 - Induction of heat power
 - Time and space-varying physical properties (conductivity, density, ...)

Solving Navier-Stokes equations and energy transport

- Modelling forced heat convection taking into account
 - Radiative heat exchange
 - Temperature-dependent density and viscosity
 - Temperature-dependent Heat Transfer Coefficient at walls
 - ...

Fluid

Heat transfer

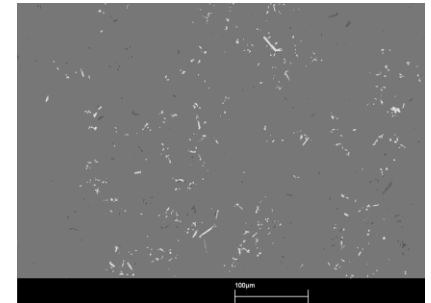


**Full thermo-hydraulic numerical simulation
of the cold crucible**

Solving particles transport

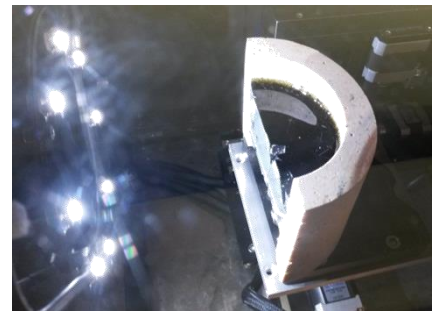
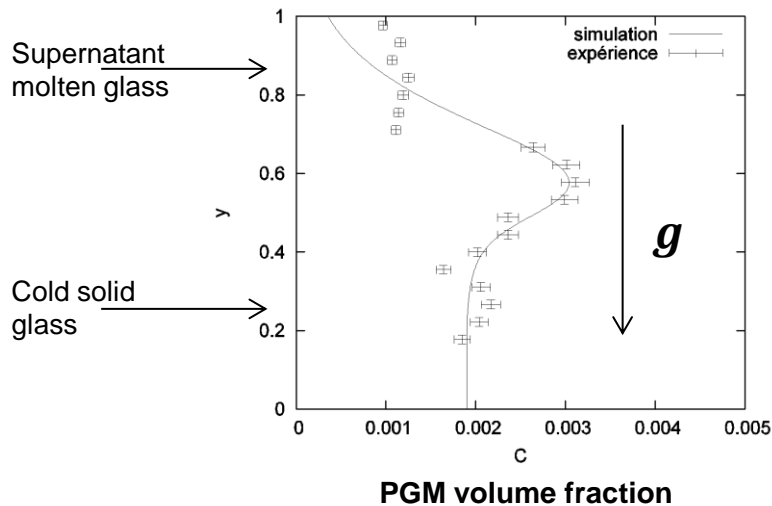


- Strong technological issue
 - Platinum-Group-Metals (PGM) are fission products with low solubility in glass
 - The glass melt is a dilute suspension of **PGM particles**
 - **Particles tend to settle and may impact the distribution of currents and local viscosity**



SEM view of RuO₂ particles in glass

- Designing a “one-fluid” transport model to account for particles settling

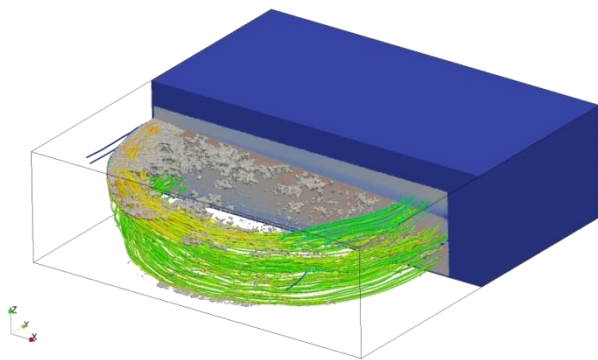


LIBS measurements

Solving Maxwell equations

Induction

- Induction of heat power in the melt (Joule effect) taking into account
 - Temperature-dependent electrical conductivity
 - PGM-concentration-dependent electrical conductivity
- Multi-scale approach to compute electrical conductivity
- Simulations performed on large HPC clusters



Eddy currents in a PGM-loaded-glass



HPC clusters of CEA

THANK YOU FOR YOUR ATTENTION