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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  
11<sup>th</sup> April 2016

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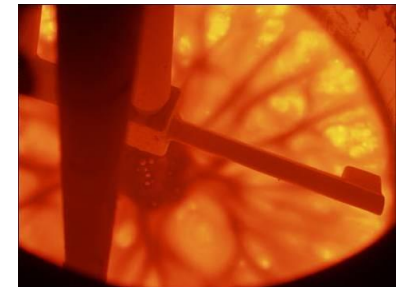
# Short overview of the HLW confinement process

- 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**



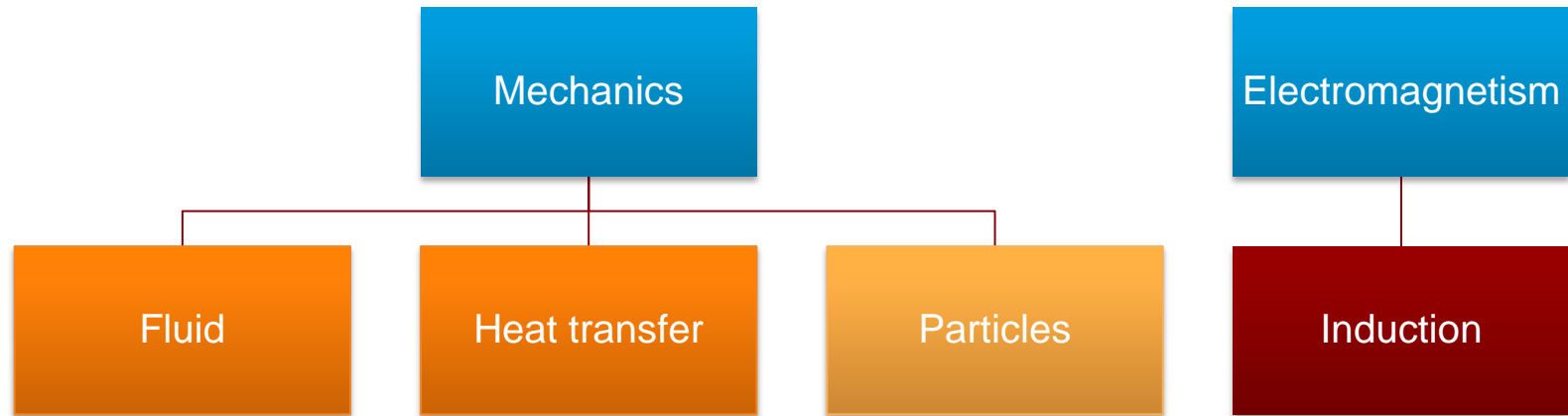
# Melting with cold crucibles

- 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



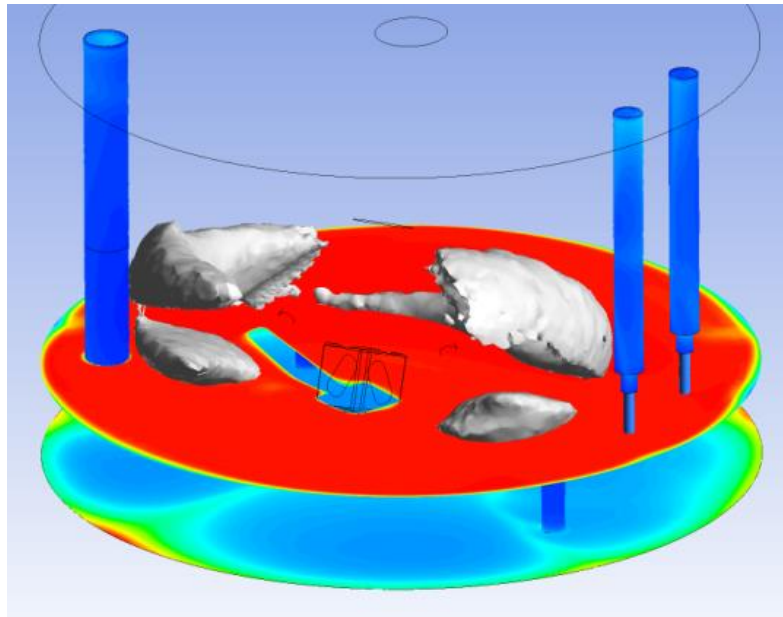
- The all thing is coupled
  - Induction of heat power
  - Time and space-varying physical properties (conductivity, density, ...)

# 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

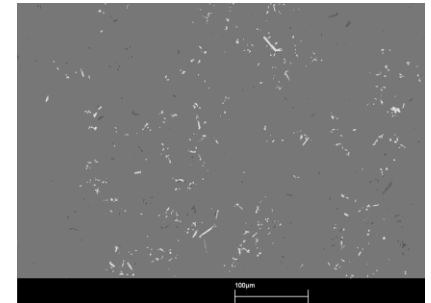


**Full thermo-hydraulic numerical simulation  
of the cold crucible**

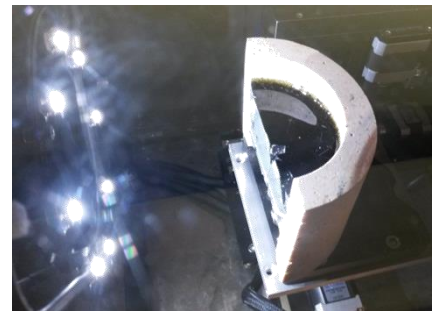
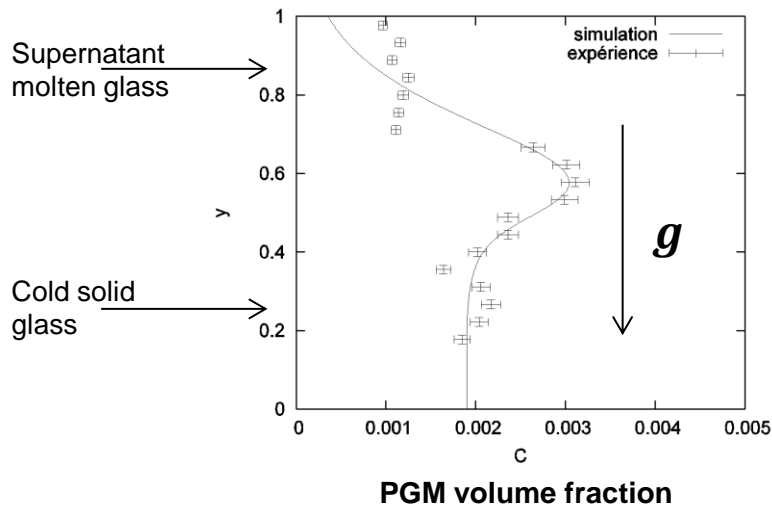
# Solving particles transport

## Particles

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



SEM view of RuO<sub>2</sub> particles in glass

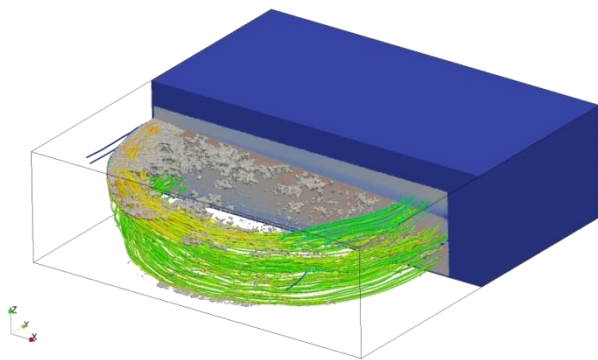


LIBS measurements

# 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**