Simulation of an Aerodynamic Furnace for Thermodynamic Data Acquisition

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INTRODUCTION: For high temperature thermodynamic data acquisition contactless acquisition methods are preferred to avoid chemical interactions with the container. A promising one is to use a spherical sample in aerodynamic levitation (ADL) heated by a laser beam at temperature up to 3000 K [1] in a conical nozzle. Density can be evaluated over a very large range of temperature by an infra-red camera by cutting off the laser beam and analyzing the temperature decay and profile of the sample (figure 1).

This technic has a major drawback: the nozzle obstructs the view to the whole sample. As experimental densities measurements appear slightly dependent of the size of the sample as well as the type of gas used (figure 2), the whole shape need to be checked and effective influence of the levitation gas to be clarified.

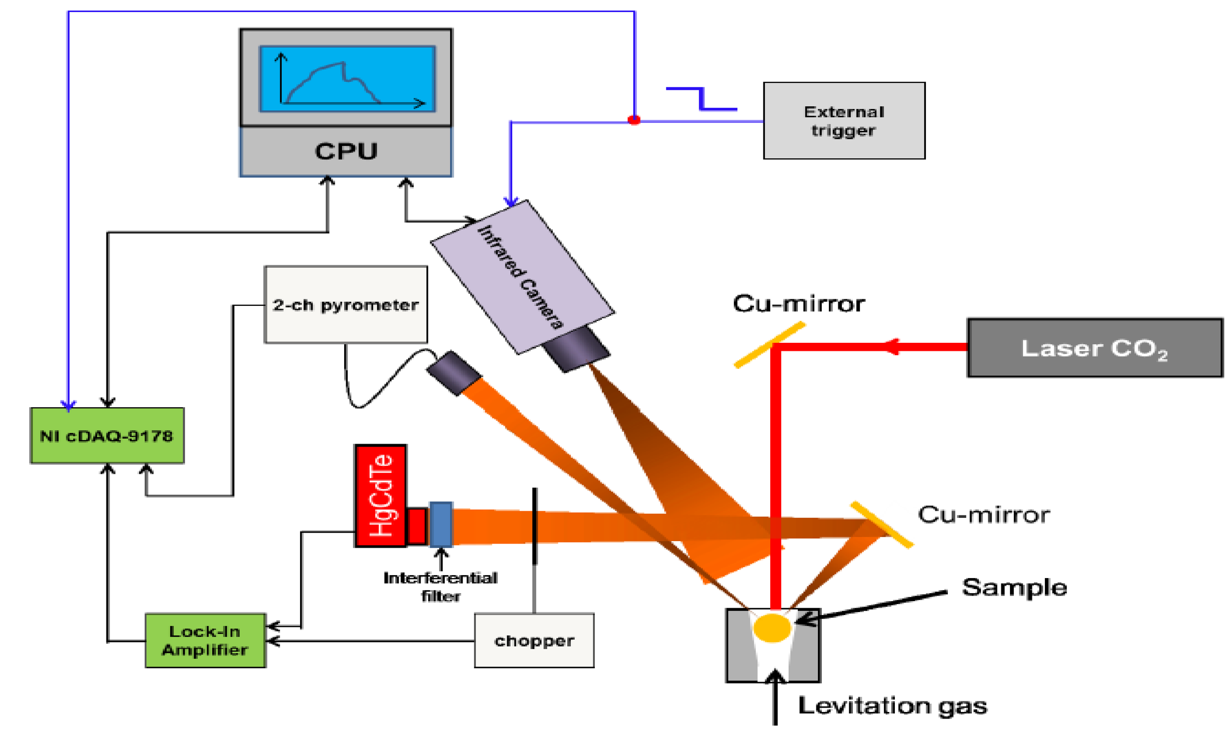


Figure 1. experimental setup

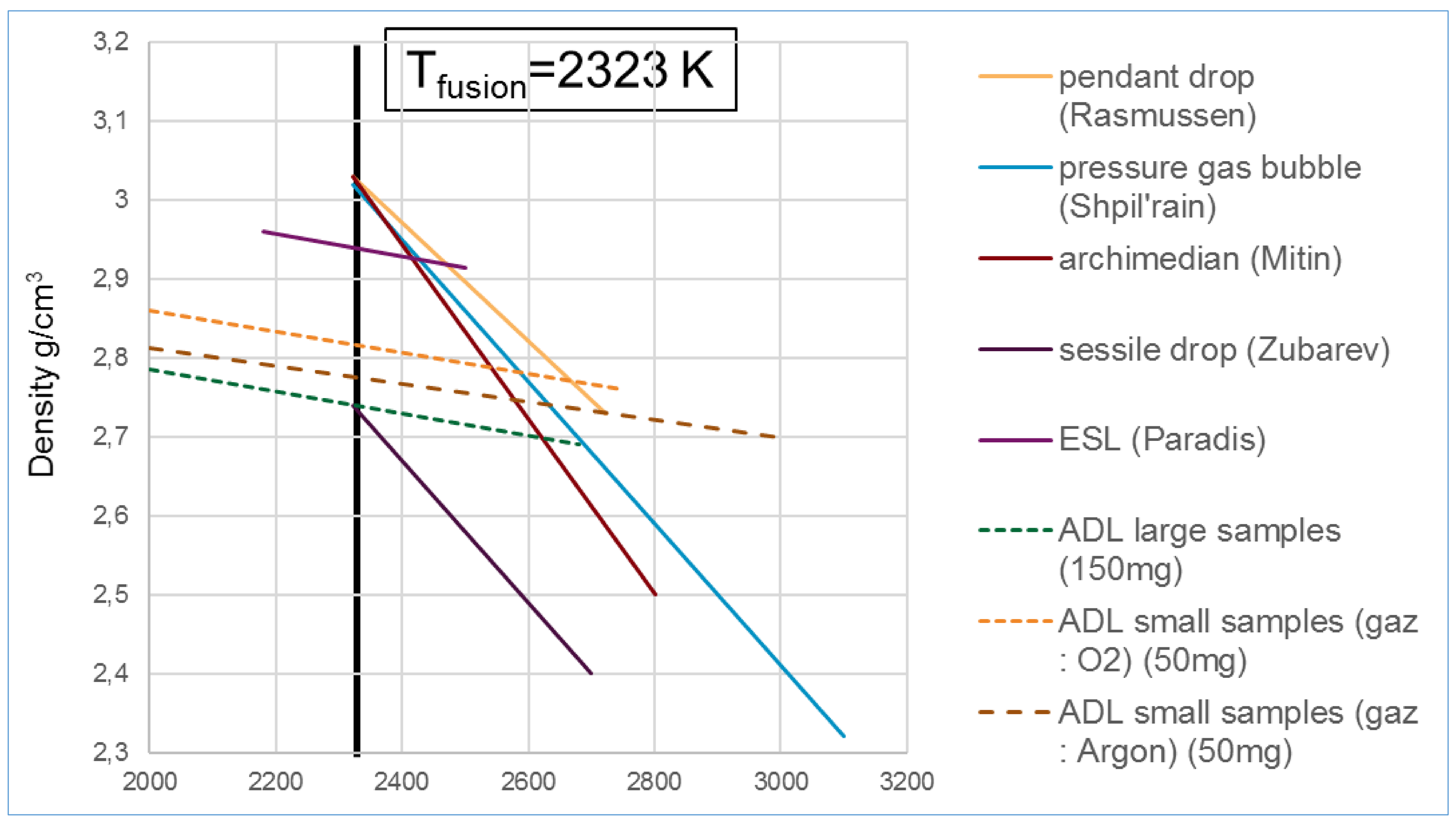


Figure 2. review of estimation of liquid alumina density[2,3] including ADL estimations with spherical approximation

COMPUTATIONAL METHODS:

Challenges :

- Temperature gradient (**1000 K / 10 µm**) close to LG interface
- Sample position in noozle: major impact on gas flow
- Strong Marangoni effect due to temperature gradient (200K) inside sample

Software :

Heat + Microfluidic Comsol® modules + moving mesh ALE

(first order Winslow smoothing for LG interface temporal evolution)

Convergence strategy :

Preliminary thermomechanical solution :
Undeformable spherical sample – no gravity – ramping viscosity

Controlled temporal iteration until stationary solution :

Balance internal and external forces at LG interface

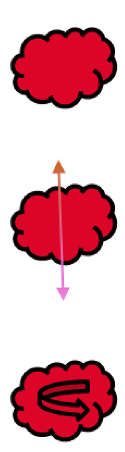
δT = 1 e-08 s ΔT = 1.e-04 s

Vertical stabilization of sample

δT = 1 e-05 s ΔT = 1.e-02 s

Convergence of internal liquid flow

δT = 0,001 s ΔT = 2 s



RESULTS:

Figure 3 shows the temperature map close to the sample for a 50 mg alumina sample in levitation at rest in argon gas. Figure 4 shows the pressure variation inside the nozzle and its impact at the bottom of the sample for 50 mg (left)and larger 100 mg sample (right).

Figure 5 shows the average temperature decay after laser cut-off for a 50 mg alumina sample with O_2 as levitation gas compared with experimental data [1] and calculations with another carrier gas (argon) with a lower conductivity.

Figure 6 shows the temporal evolution of the volume using the spherical approximation (S) and COMSOL® global volume (C) estimation for various levitation gas.

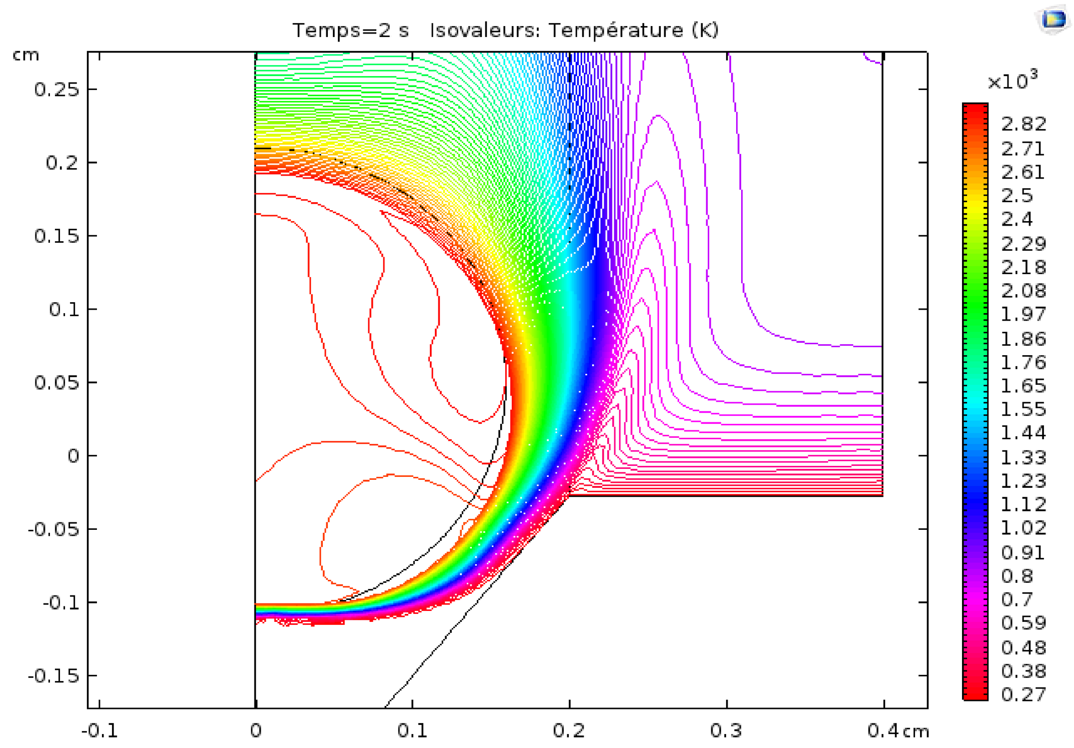


Figure 3. temperature map close to sample at rest

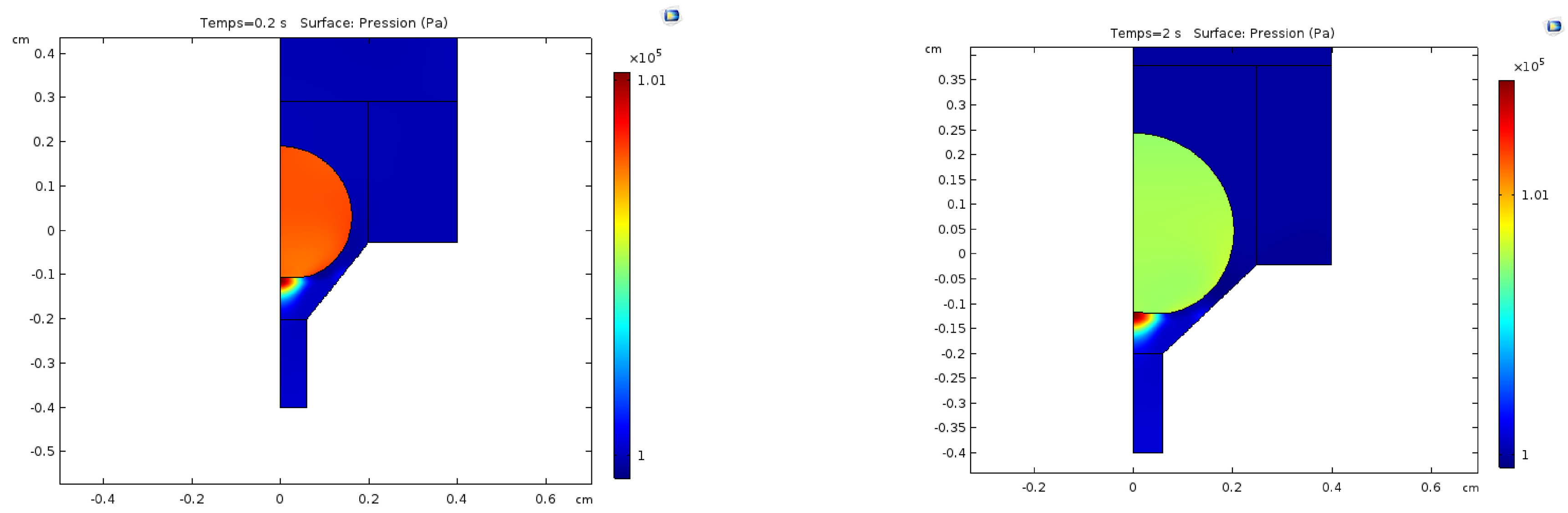


Figure 4. pressure variation for 50 and 100 mg samples at rest

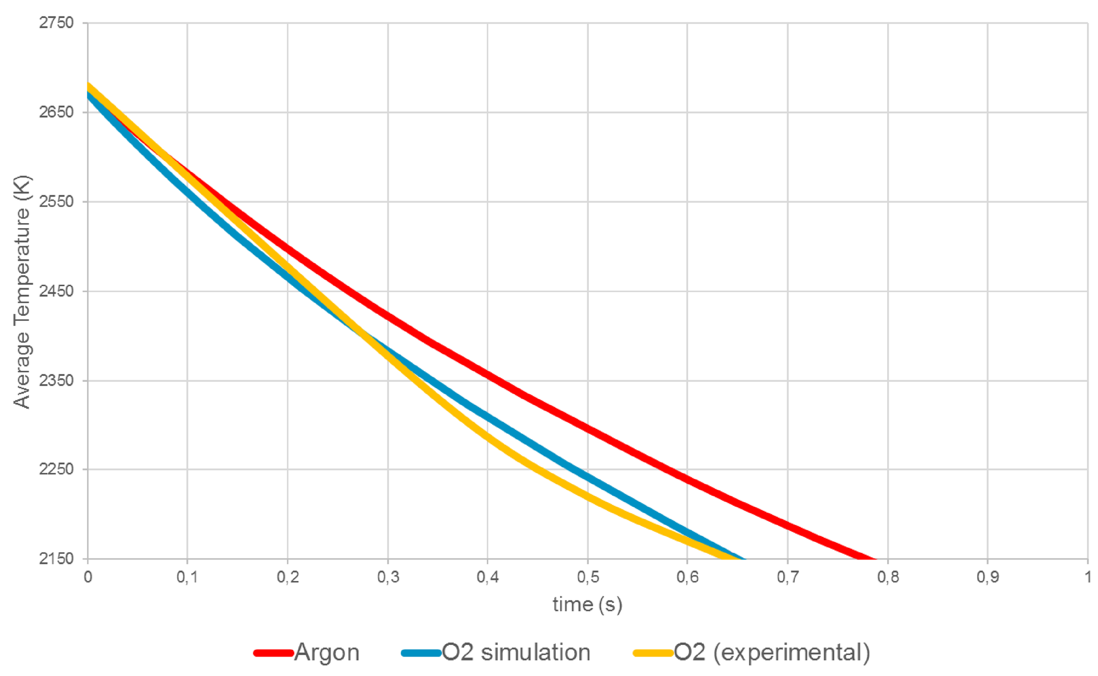


Figure 5 average temperature decay after laser cut-off

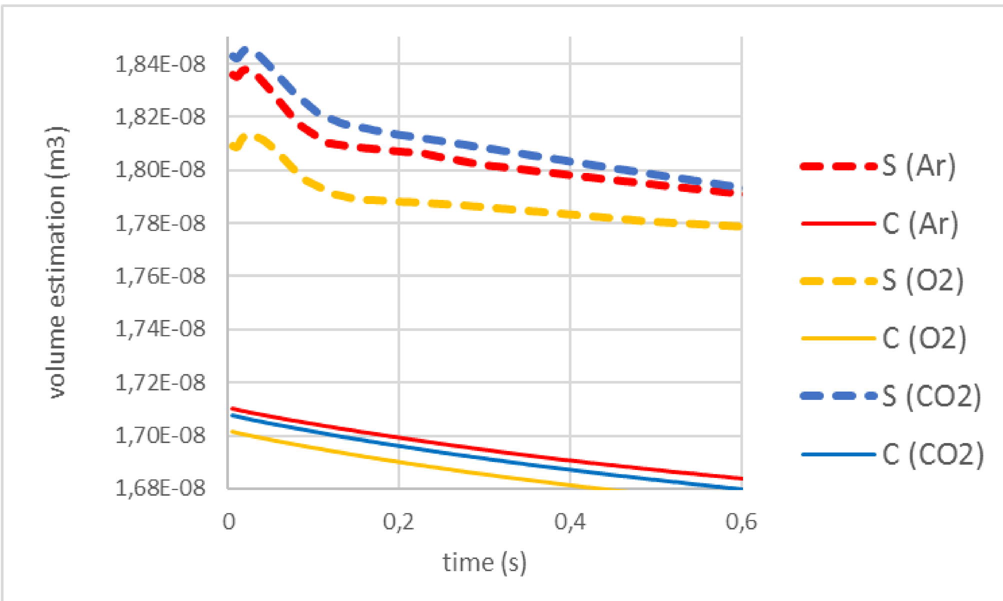


Figure 6 volume variation estimation after laser cut-off for various gas

CONCLUSIONS:

In contrast to other levitation technics, temperature decay is not purely radiative and influence of conductivity of the levitation gas has to be taken into account.
The gas impact on the bottom of the nozzle tends to deform the invisible part of the sample, therefore density evaluations from the camera are underevaluated.
For aluminum oxide, in accordance with experimental data, oxygen seems the most stable carrier gas.
Future work will include a second laser and the numerical optimization of both laser beams profiles to minimize the temperature gradient in the sample and increase its stability.

REFERENCES:

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