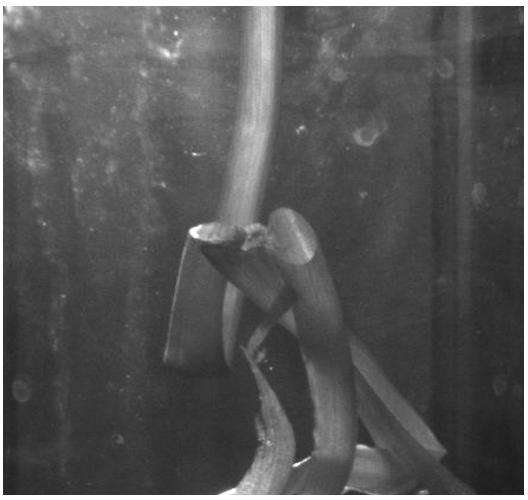
Liquid-to-solid phase transition near triple point at very low temperature

The quick depressurization of a liquid is a field still to be studied thoroughly. It can be found in various fields of research from cavitation to blasts in vacuum and reservoirs draining (for example during reservoirs leaking at ambient pressure). The SBT department has conducted some research for the CNES (French Centre National d'Études Spatiales) about the effects of liquid propellant (hydrogen, oxygen, methane) leaks to vacuum. The measurements show complex phase transition physics near the propellant triple point: cooling of the propellant occurs due to evaporation of liquid in vacuum down to a temperature where the liquid solidifies. A side product of these experiments is, under certain conditions, the production of hollow cylinders of solid at the leak location (the "hollow" shape is due to the geometry of the Joule Thomson valve between liquid and vacuum). A better understanding of these phenomena could allow for a complete control of the complex evaporation/condensation processes and could be used to produce well-calibrated thin ribbons ("macaronis" like, figure further in the text). This could offer an interesting solution for another field of research where SBT is currently involved in: the production of very thin (in the 10 µm range) ribbons of solid hydrogen.

These condensation phenomena are not well-known and involve complex mechanism coupling gas, liquid and solid phases. A good understanding of the growth of these films is required to produce reproducible films. SBT and SIMAP (laboratoire de Science et Ingénierie des Matériaux et Procédés Of Grenoble Alpes University) gathered to conduct a numerical study of this physics. The EPM group of SIMAP has a strong experience in the modeling of complex liquid-solid transition, in particular in the field of crystal growth.

In the framework of the Tec21 « laboratoire d'excellence », we are proposing a postdotoral position to perform the numerical study of the hollow cylinders extrusion. This work will connect with an experimental thesis on the production of the cylinders and their exploitation in laser facilities for interaction laser/matter studies.



Hollow cylinders produced by Joule-Thomson expansion at 94 K.

Work to be performed:
The numerical study will deal with the modeling of a cylinder extrusion experiment. It will consist in two main parts:

- 0D study: a review of solidification near triple point mechanisms will be performed to determine the main physical characteristic driving the physics. This will be performed based on extrusion measurements conducted at SBT. Complementary experiments could be setup to complete data if necessary.
- Finite Elements modeling: a full thermo-hydraulic of the experiment will be conducted with the COMSOL Multiphysics software with a focus on liquid-gas, and liquid-solid on selected components (methane and hydrogen). This study aims at proposing an optimized design of the extrusion nozzle and the main optimal extrusion parameters.

The candidate shall have a good knowledge of the COMSOL software, experience in the field of process and phase transitions physics. Knowledge of cryogenics is welcome.

The work will mainly take place at the SIMAP lab premises at the Grenoble Alpes University. Measurements and experiences will be conducted at CEA-SBT, Grenoble

Contacts:

SBT: nicolas.luchier@cea.fr
denis.chatain@cea.fr

SIMAP: thierry.duffar@grenoble-inp.fr
Kader.zaidat@grenoble-inp.fr