A new experimental approach to study magma oceans differentiation processes

Nicolas Jaisle*[1], Cébron David , and Guillaume Morard

[1]Géodynamo – Institut des Sciences de la Terre – France

Résumé

The understanding of the differentiation processes driving young telluric exoplanets at their magma ocean stage is of prime importance to assess the future inner chemical and mass distributions.
Probing mineralogy of deep planetary interiors is commonly made by X-ray diffraction in a laser-heated diamond anvil cell (DAC), a method which can suffer some biases like chemical migration or carbon contamination (Morard et al. 2018). This is mainly due to the fact that laser heating generates huge temperature gradients, inherent to their gaussian shape. To reduce these effects, we present a high-pressure approach based on a pulsed laser heating, combined with MHz frequency pulsed X-ray diffraction. This technique aims to limit the chemical migration effects with a short duration of YAG laser heating (~ 250 ns). At the same time, the high pulse frequency of the X-ray (2.27 MHz) allows to acquire a great number of diffraction spectra upon the heating and cooling phase.

We conducted such experiments at the Eu-XFEL platform of the Hamburg facility and present promising results obtained with this technique on an Fe-Si-O alloy. The several diffraction spectra acquired for each run show the recrystallization of different phases over time. We analyzed the sample texture by performing focused ion beam (FIB) cutting and scanning electron microscopy (SEM) images.

Comparing our results with previous experiments performed on ID27 beamline at the ESRF synchrotron of Grenoble, we observed main texture differences and, in some cases, no chemical migration for samples shot by short-time laser pulses.

In parallel, we created a finite element model (FEM) aiming to reproduce temperature, pressure and volume conditions in the DACs at any moment of the experiment. FEM is a powerful complementary tool which completes experimental analyzes by establishing, for example, the inner temperature distribution of the sample.
Further experiments shall now focus on more complex alloys like (Fe,Mg)SiO, closer in terms of composition to that of primordial magma oceans, with the goal to get one step closer to the understanding of magma ocean differentiation in exoplanets.

*Intervenant

sciencesconf.org:colloque-pnp:412857