KINETICS OF OLIVINE DISSOLUTION IN CHONDRULE MELTS : AN EXPERIMENTAL STUDY. C. Soulié[1,2], G. Libourel[1,2], L. Tissandier[1], J.-M. Hiver[3]. [1]CRPG-CNRS, 15 rue Notre-Dame des Pauvres, BP 20, F-54501 Vandoeuvre lès Nancy, France, csoulie@crpg.cnrs-nancy.fr, [2]ENSG-Université de Lorraine, [3]IJL-Université de Lorraine.

Introduction: Although cooling rates for chondrules were extensively studied [1], timescales for the high temperature event still remain poorly constrained. Up to now, only volatile abundances are able to constrain the duration of exposure at peak temperature [2].

Otherwise, it has been shown that most of the magnesium-rich olivines in type IA chondrules are not in chemical equilibrium with their surrounding mesostasis [3-5]. Accordingly, these forsterite grains in type I chondrules are thought to be relicts that have experienced a significant dissolution episode at high temperature above the glass transition temperature (T_g). The duration of this episode could be only quantified by estimating the rates of olivine resorbtion. This imply to be able to measure the kinetics of reaction for a wide range of composition, typical of the chondrule mesostasis.

Previous studies have been dedicated to olivine dissolution in melts of terrestrial compositions from basalts to rhyolites. These include experimental approach [6-9] and have been more recently extended to modelisation works [10]. For extraterrestrial compositions however, only modelisation approach has been proposed [11] but stand on scarce experimental constraints.

In order to extend our knowledge on these kinetics and to quantify the compositionnal and temperature influence on dissolution rates of pure forsterite, we performed a set of experiments at the Centre de Recherches Pétrographiques et Géochimiques (CRPG), Nancy. X-ray computed microtomography has been used to image the partially resorbed olivines in the three dimensions. This promising approach, using volumes instead of sections, has been employed to observe the evolution of the crystal shapes and to determine the dissolution rates.

Experimental and analytical procedures: We performed isothermal dissolution experiments of pure forsterite crystals into 3 different melts in the system $CaO-MgO-Al_2O_3-SiO_2$ (CMAS). The temperature range for the runs is between 1456°C and 1541°C.

Starting materials : Starting glasses had been prepared to cover a large compositional range encompassing the one of typical type I chondrules mesostasis composition (Table 1). Forsterite crystals had been cut from a synthetic and oriented crystal of pure forsterite into small parallelepipedic slices. Individual crystals were then measured (characteristic lenghts, volume and external surface) under microscope.

Oxydes (wt%)	Melt 2	Melt 3	Melt 4
SiO_2	34.1	52.7	72.1
Al_2O_3	30.0	22.8	15.7
MgO	7.6	5.2	2.4
CaO	28.9	19.7	10.2
Total	100.6	100.4	100.4
$T_{liquidus}$ (°C)	≈1450	≈1400	≈1430

Table 1: Composition of starting glasses

Typical dimensions of olivine before experiments are around : 1500x800x500 µm, S_{ext}=5.20 mm^2, V=0.73cm^3 (Figure 1).

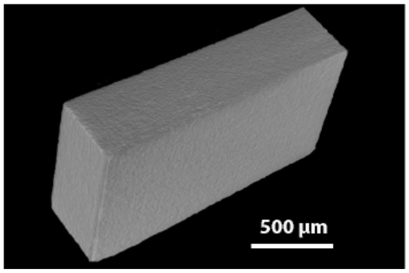

Figure 1: 3D image obtained by computed microtomography of a typical forsterite crystal used as starting material for dissolution experiments.

Experiments : At specific temperature and melt composition, dissolution experiments of different duration were performed (in the range of 4 min to 25 min). For each run, an olivine crystal of known dimensions had been placed into a graphite crucible with a small pellet of starting glass. In order to avoid any reservoir effect during the dissolution experiments, the glass/olivine initial weight ratio was averaged around a value of 60. Heating experiments were then performed in isothermal conditions in a GERO 1 atm high temperature vertical furnace. The target temperatures were chosen to be above the liquidus temperature of the melts. At least 3 different temperatures were tested per melt composition in order to determine the activation energy of the dissolution process. The experiments were conducted in neutral atmosphere, under a flux of Ar and at 1 atm pressure. The runs were stopped by quenching into air. The final charge consisted of a glassy pellet of 4-5mm in diameter with partialy resorbed olivine inside.

Analytical procedures : The charges were then scanned by X-ray microtomography in a Phoenix Nanotom at the Institut Jean Lamour, Université de Lorraine. After reconstruction, full three dimensional information of the charges are recovered. Due to differential X-rays attenuation, the greyscale of olivine contrasts with that of surrounding glass and measurement of final lenghts of olivine is possible. If the contrast is high enough, a threshold permits to isolate and measure the volume of the partially resorbed olivine.

Results : In agreement with previous studies, preliminary results reveal a direct relationship between the kinetics of dissolution, the composition of experimental melt and the temperature. By comparison with previous studies, 3D imaging allows to have better resolution on the dissolution process, notably at the edges and corners of the crystal, and reveals that forsterite dissolution at high temperature is a fast process (Figure 2). The compilation of composition and temperature dependence of these chondrule-like compositions leads to a maximum rate of several thousands of µm/h when forsterite dissolution occurs in melt 2 at T>1530°C. This rate drops to only few hundreds of µm/h in the melt 4, the most polymerized melt studied.

Detailed kinetics (rates and activation energy) of dissolution of forsterite in silicate melts will be presented and discussed at the conference. We will show that these new kinetics data have profound implications for the timing of chondrules formation.

References: [1] Hewins R.H. et al. (2005) *Chondrites and the Protoplanetary Disk* 341, 286-316. [2] Hewins R.H. et al. (1991) *GCA*, 55, 935-942. [3] Libourel G. et al. (2006) *EPSL*, 251, 232-240. [4] Chaussidon M. et al. (2008) *GCA*, 72, 1924-1938.[5] Ruzicka A. et al. (2008) *GCA*, 72, 5530-5557. [6] Thornber C.R. and Huebner J.S. (1985) *Am. Min*, 70, 934-945. [7] Kuo L.-C. and Kirkpatrick R.J. (1985) *Am. J. Sci.*, 285, 51-90.[8] Donaldson C.H. (1990) *Miner. Mag.*, 54, 67-74. [9] Chen Y. and Zhang Y. (2008) *GCA*, 72, 4756-4777. [10] Alexander C.M.O'.D. (2011) *GCA*, 75, 558-607. [11] Alexander C.M.O'.D. (2010) *LPSC XLI,* Abstract #2181.

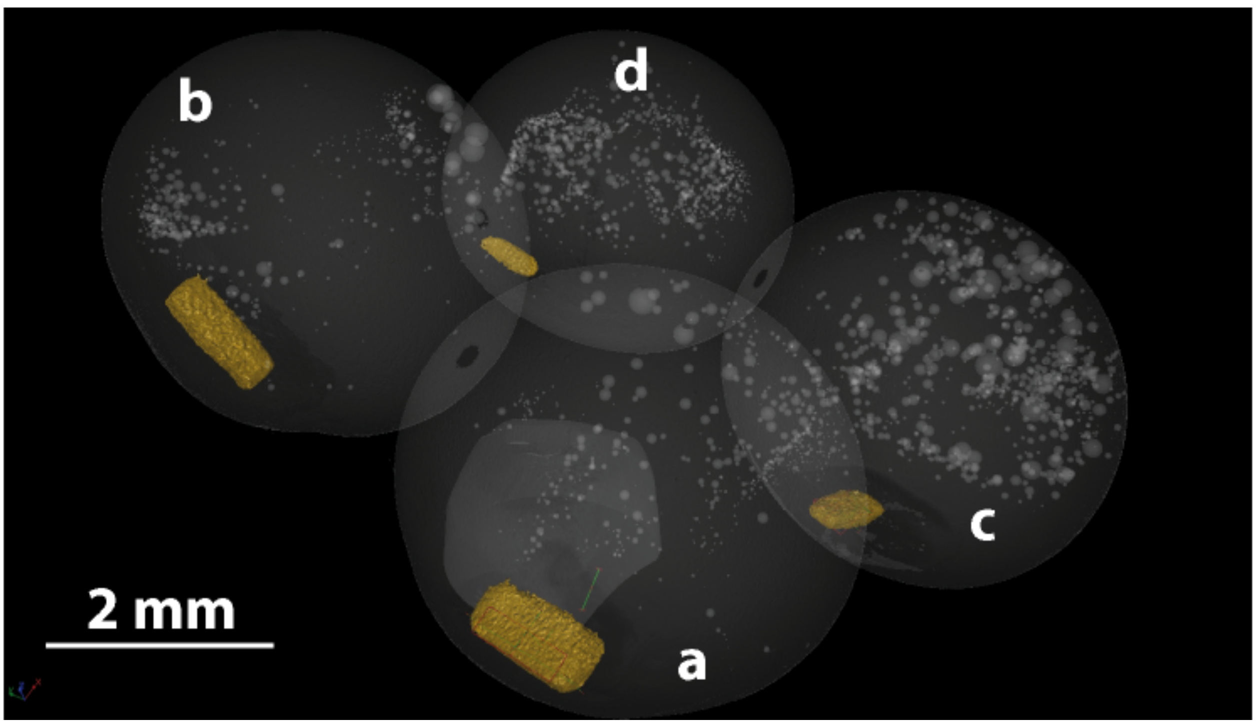

Figure 2: 3D microtomography image of 4 charges after dissolution in melt 3 at 1510°C. The duration of the experiments was of 3min30, 5min, 7min and 10min for charges a, b, c and d respectively. Partially resorbed forsterites appear in yellow, glass pellets in grey and gas bubbles in white.