EXPERIMENTAL REPRODUCTION OF RIMS IN BARRED OLIVINE CHONDRULES BY EVAPORATION. Y. Osada, and A. Tsuchiyama, Department of Earth and Space Science, Graduate School of Science, Osaka University, 1-1 Machikaneyama-cho, Toyonaka, 560-0043, JAPAN, osada@ess.sci.osaka-u.ac.jp, akira@ess.sci.osaka-u.ac.jp

Introduction: Barred olivine is a unique texture that appears in chondrules. It was formed by rapid cooling of silicates, which were melted completely [1]. There are two basic types of barred olivine texture. (1) Classic barred olivine texture is composed of a single-plate (barred) dendrite with an optically continuous rim. (2) Much more common is the multiple barred chondrule containing several plate dendrites, which may or may not have a rim or partial rim. Barred olivine chondrule textures have been reproduced in a laboratory to understand processes and conditions of chondrule formation in the primitive solar nebula. Some researchers succeeded in reproducing the multiple barred textures [1-3]. They reported that the textures were formed at initial heating temperatures of several to several hundreds degrees above the liquidus for heating durations of several minutes to several hours at cooling rates of 100 to 2000 °C/hr at 1atm. However, the rim had not been reproduced. Lately, Tsukamoto et al. [4] reported to reproduce barred olivine rim in cooling experiments of forsterite melt droplets levitated acoustically. They attributed the rim formation to recalculation during crystal growth of forsterite after nucleation on droplet surfaces. However, time scales of cooling and crystallization in the experiment are different from those estimated from the previous chondrule reproduction experiments [1-3]. Moreover, the experimental charges have many plates and the texture seem to be different from natural barred olivine textures.

Alternative candidate responsible for rim formation is evaporation during chondrule formation. If nucleation and growth of olivine crystals occurred on the surfaces of chondrules by evaporation loss of some elements, rims should be formed. In this study, we carried out cooling experiments in vacuum to reproduce barred olivine with rims by partial evaporation.

Experiments: A starting material with FeO-rich bulk composition (54 wt.% FeO) was prepared. We chose this material as melting and evaporation occur easily (liquidus temperature is about 1210 °C). This composition is almost the same as that used in [4] except for Na2O and K2O. We did not add the alkalis because evaporation of alkalis will damage a silica muffle tube used in a furnace. Powder of the starting material put into a graphite capsule (5 mm in inner diameter) was placed on a hot spot of a gold image furnace. As silicate melts do not wet graphite, a melt spherule was formed by melting. Two types of sample sizes were used; large samples (30-40 mg) and small samples (<10 mg). The masses before and after runs were also measured to obtain evaporation loss. The pressure in the furnace was about 10⁻⁵ Torr to promote evaporation from the melts. The initial heating temperature was ranged from 1250 to 1430 °C. The initial heating duration was 10 minute in all runs. After the heating the charges were cooled at 500 to 1200 °C/hr. Thin sections were made and their textures were observed under an optical microscope and SEM.

Results: In the large samples at cooling rate of 1000 °C/hr, parallel platey dendrites consisting of several crystals (texture A) were formed when the samples were cooled from 1350 to 1430 °C (Fig.1a). From 1250 to 1300 °C, dendrites consisted of many crystals and oriented randomly (texture C). From 1310 to 1340 °C, intermediate textures between A and C (texture B) were formed. With increasing the cooling rate, the width of olivine bars decreases. When the small samples were used, a platy dendrite consisted of a single or a few crystals was formed (Fig.1b).

Very thin rims (10-20 µm thick) were formed in many charges. Two types of rims were observed: (I) rim consisting of very fine crystals (Fig.2a) and (II) rim consisting of a single crystal (Fig.2b). A relation between texture, rim, initial heating temperature and mass loss by evaporation at cooling rate of 1000 °C/hr is shown in Fig.3.

Discussion: The mass loss by evaporation increases with increasing the initial heating temperature. At the same initial heating temperature, the mass loss of the small samples is larger than that of the large samples because the surface area/volume ratio is higher in the small samples than the large samples. It is seen in Fig.3 that both barred textures and rims formed well at higher initial heating temperatures and large mass loss. The above results can be explained by the combination of nucleation-growth and evaporation. Evaporation mainly of FeO occurs from the surface of a melt droplet. The composition of the melt near the surface becomes rich in MgO and thus the liquidus temperature becomes higher. Nucleation begins at the surface because the melt at the surface is supercooled largely than the interior and finally rim forms. For the small samples, textures similar to the classical barred olivine chondrules (Fig.1b) were reproduced for the first time by the present experiments. This is because a single or a few crystals were formed by a few chances of nucleation in the small samples and a rim was
formed by high degree of evaporation. The present experiments strongly suggest that barred olivine chondrules were formed by partial evaporation during chondrule formation. This is consistent with chondrule formation in an open system: e.g., it was proposed that FeO-poor chondrules were formed by evaporation of FeO and SiO2 from FeO-rich chondrules [5].