

Magnetic stability of dusty olivine chondrule: An experimental study

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A remanent magnetization of chondrule has been thought to be a direct evidence of paleosolar nebula magnetic field that played an important role in the evolution of the early solar system. However, the remanent magnetization in some chondrules may be spurious remanence due to chemical alteration or low coercivity of their magnetic minerals. Although chondrules show various textures, previous paleomagnetic studies of chondrules have not concerned about them. Some chondrites contain a characteristic textured grain known as `dusty olivine` that is a Mg-rich olivine grain contains abundant fine Fe inclusions. Recent study of `dusty olivine` in primitive chondrite (e.g., Semarkona LL3.0) confirmed that dusty olivines were produced by reduction of Fe-rich olivines at high temperature (Leroux et al, 2003), suggesting these fine Fe inclusions were formed by high temperature reduction above Currie temperature. Therefore, the dusty olivine chondrule are expected to reflect a stable thermal remanent magnetization (TRM) during chondrule formation. To test this, I conduct a dynamic crystallization experiment under magnetic field and discuss about the magnetic stability of `dusty olivine` chondrule.

The starting material was a crushed olivine (Fo90, 5-50um) with small amount of Ca-rich pyroxene and Al-Cr-rich spinel. Two experiments added carbon in the form of graphite powder into olivines, resulting in a reduced condition. About 10-50mg of the material was placed in a graphite crucible, and heated in a fabricated evacuated (~0.01 Torr) quartz glass tube furnace under 1-12mT magnetic field by solenoidal coil. The crucible was heated to peak temperature (1140 - 1450 C), held it for 200 to 500 sec, and cooled at 1300 - 7600 C/hr down to 750 C, then quenched. Therefore, the remanent magnetization of synthetic chondrules are TRM in origin.

Back-scattered electron microscopy observation confirmed three typical textures: barred olivine texture, porphyritic olivine texture, and `dusty olivine` texture. Barred and porphyritic olivine textures were produced in graphite free experiments. The porphyritic texture contains small amount of coarse (~50um) Al-Cr-rich metal assemblages, whereas the barred olivine texture contains no metals. On the other hand, a `dusty olivine` texture was produced under reduced condition that was achieved by reaction with a graphite crucible or added graphite powder. The `dusty olivine` texture contains abundant metals, as submicron-sized (~1um) Fe inclusion enclosed in Mg-rich (Fo96) porphyritic olivine grains, mimicking natural dusty olivines, or as micron-sized (1-20um) Fe-Ni globules within the glass matrix at the olivine grain boundaries. Remanent magnetization of `dusty olivine` texture is strong and stable against AF demagnetization up to 80mT, whereas that of the barred and porphyritic olivine textures are weak and easily demagnetized below 25mT. A thermal demagnetization of dusty olivine indicates high unblocking temperature around 700 C.

Although thermal stability should be examined, the present study suggests that the dusty olivine can carry both high coercivity components and stable TRM acquired during chondrule formation. Moreover, the fine inclusions as likely stable-TRM carriers may have been armored against chemical alteration by surrounding host olivine. Therefore, such `dusty olivine` chondrules are supposed to be a rather good candidate of a reliable recorder for an ambient magnetic field in the early solar nebula, than porphyritic or barred olivine chondrules.