Chondrule formation model by lightning in high dust density regions

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Chondrules are spherical objects of 0.1 - 1 mm in radius and are the main component of chondrite meteorites (Scott 2007). It is known that chondrules were formed early in the solar system. So, chondrules may have important information about early solar system nebula. It is believed that chondrules melt with dust particles heated within several minutes and have cooled and solidified at a rate of 1-1000 K/hour in the early solar nebula (Desch et al. 2012). Also, since chondrules contain volatile substances, it is considered that they are formed in a high dust density region (Alexander et al. 2008). Although the formation mechanism of chondrules have not been elucidated, formation theories include the shock wave model, astronomical collision model, X-wind model, and lightning model. In this study, we examine the chondrule formation by lightning from the viewpoint of thermal evolution of chondrules.

Thermal evolution of chondrules has been studied by Horanyi et al. (1995). In that study, assuming the occurrence of lightning in the solar nebula, they calculated the time evolution of the gas and dust in the lightning. As a result, the cooling rate of the chondrule became faster than the cooling inferred from observations of crystals in chondrules. On the other hand, according to studies on the occurrence of lightning, the mass ratio of dust to gas needs to be 100:1 or more for lightning generation (Muranushi 2010). However, Horanyi et al. (1995) considered the situation where only one dust particle is present inside the lightning.

In this study, we consider the occurrence of lightning in the high dust density region and calculate the thermal evolution of chondrules numerically. Especially, we investigate if the cooling rate condition for the chondrule formation is satisfied under the high dust density situation. As a result, it was found that there are circumstances suitable for chondrule formation. It is suggested that chondrule formation by lightning is possible in the solar nebula.

Keywords: chondrule, lightning

