COLLISIONAL FRAGMENTATION OF DUST AS A NECESSARY STEP IN EARLY SOLAR SYSTEM EVOLUTION. T. Fukui and K. Kuramoto, Department of Cosmosciences, Hokkaido University, Sapporo 060-0810, Japan (ftakashi@ep.sci.hokudai.ac.jp)

Introduction: Global redistribution of dust and gas in protoplanetary disks plays a crucial role in various aspects of the early (extra-)solar system evolution. This process determines the spatial dust mass distribution of the disks, which would affect the dynamical structure of the resulting planetary systems. In addition, because of the difference in the radial mobility of dust and gas, the local dust-to-gas ratio varies both temporally and spatially. This would be responsible for the chemical and isotopic diversities observed in chondritic components such as chondrules and CAIs.

Effect of Collisional Fragmentation: The dust redistribution process is closely related to collisional growth of dust grains because their mobility strongly depends on their size. Recently, laboratory experiments have indicated that collisional fragmentation suppresses growth of dust grains at sizes much smaller than planetesimals [1]. However, its potential impact on the dust redistribution process has been poorly investigated.

In this study, we simulate the global redistribution of dust and gas considering the effect of collisional fragmentation. We also include evaporation and recondensation of H_2O ice at the snow line. From the numerical result, we suggest that dust fragmentation offers potential explanations for several aspects of the early solar system evolution as follows.

Dust Mass Distribution: Recent observations of the disks have suggested that the radial profile of the dust surface density in their outermost region is flatter than that of the minimum mass solar nebula [2]. Because extrapolating the profile into the inner region indicates too little dust is available to form planets, the profile must be different between the inner and outermost regions.

Our result indicates that such difference can be explained in terms of dust growth and fragmentation. In the inner region, dust growth rapidly proceeds and eventually stops at the size at which collisional fragmentation begins. In contrast, dust grains in the outermost region grow slowly and start to drift inward before collisional fragmentation occurs. This affects the dust redistribution process and originates the difference in the dust surface density profile between the inner and outermost regions.

Oxygen Isotopic Systematics: We confirm that the dust redistribution process causes the concentration of H_2O vapor released from dust grains inside the snow line. This process potentially explains the distinct difference in the oxygen isotopic composition of chondrules and CAIs if H_2O in the solar nebula was ^{16}O-poor relative to the solar composition [3].

We newly find that silicate dust also concentrate inside the snow line. Because silicate is less sticky than H_2O ice, the grain size of silicate dust inside the snow line is considerably smaller than that of ice-covered dust in the outer region. As a result, inward transport of silicate dust is decelerated at the snow line, leading to a "traffic jam" of silicate dust. The concentration of silicate dust with the solar O isotopic composition would moderate the temporal and spatial variation of the local mean O isotopic composition associated with the concentration of the ^{16}O-poor H_2O vapor. This mechanism is potentially responsible for the small O isotopic diversity among chondrules.

Typical Size of Chondrules: It is widely accepted that chondrules were formed by melting of precursor dust grains in the inner solar nebula. However, it has been unclear how the typical size of chondrules (roughly mm) was determined.

Our result shows that fragmentation of silicate dust grains begins when they grow to $\sim$ mm in size under the condition of the inner region of the disks. Thus, the typical size of chondrules is possibly determined by collisional fragmentation of their precursor grains.

References

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