Size constraints on presolar silicate grains from atomic diffusion processes in thermally evolving planetesimals

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Presolar grains are tiny materials in meteorites and their isotopic compositions are different from those of materials in the Solar System. A typical size range of presolar silicate grains is from 0.1 to 1.0 μm and they might be originated from nearby stars (supernovae and/or asymptotic giant branch stars). Their abundance varies among meteorites: as the degree of thermal metamorphism of meteorites increases, their abundance decreases. This indicates that the presolar grain abundance could be related to thermal history of their host meteorites's parent bodies. If the atomic diffusion affected the isotopic composition of presolar grains while they were embedded in the parent bodies, the original information of their isotopes might be eliminated. Then, we cannot identify such grains as presolar grains anymore. We examine the diffusion process in thermally evolving planetesimals, parent bodies of meteorites, to reveal whether it can wash out the isotopic composition of presolar grains.

We compute the diffusion length of oxygen in presolar silicate grains using a diffusion coefficient of ^{18}O in olivine. We numerically calculate the thermal evolution of various planetesimals (size and formation time) and the diffusion length of ^{18}O in a consistent way, because the diffusion coefficient depends on temperature. The results shows that as temperature increases, the diffusion length increases. We also find that the maximum temperature of planetesimals governs the diffusion length of ^{18}O. Then, we compare the measured size of presolar silicate grains in meteorites and our numerical results. The size of presolar silicate grains in petrologic type 3 chondrites are above the calculated diffusion length, when the maximum temperature is $\sim$ 600 °C which is the estimated peak metamorphic temperature of type 3. This means that the isotopic composition of presolar grains as large as type 3 chondrites are not affected by the atomic diffusion. On the other hands, the grains less than 1.0 μm cannot keep their original isotopic compositions when the maximum temperature is higher than 750 °C, which roughly corresponds to the peak temperature of types 4-6. This could be the reason that we cannot find any presolar grains in types 4-6. Thus, the diffusion process can explain the abundances and size distribution of presolar silicate grains. We also discuss that this process could explain the abundance difference of presolar grains between interplanetary dust particles and chondrites. We propose that the diffusion process could be a key to organize the size distribution of presolar grains in some petrologic types of chondrites.