

Argon isotopic study of Allende chondrules: Implication to the Ar-Ar dating

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Chondrules of carbonaceous chondrite are the most important primitive component to evaluate the early evolution of the inner solar system. The $^{40}\text{Ar}/^{39}\text{Ar}$ dating always requires estimation of initial ^{40}Ar component from the initial $^{40}\text{Ar}/^{36}\text{Ar}$ ratio and the total ^{36}Ar content in the material. The initial $^{40}\text{Ar}/^{36}\text{Ar}$ ratio may be estimated by the analyses of K-free phases such as olivine. The total ^{36}Ar in chondrules includes cosmogenic ^{36}Ar , which is a decay product from cosmogenic ^{36}Cl . If chondrite includes a Cl-bearing phase, the radiogenic ^{40}Ar will be underestimated due to the cosmogenic ^{36}Ar , yielding apparently younger $^{40}\text{Ar}/^{39}\text{Ar}$ age.

Five individual chondrule grains were first analyzed using laser step-heating method to outline of their history. The results give the integrated ages of 2.77 ± 0.03 - 3.22 ± 0.06 Ga. They all show the discordant age spectra and irregular $^{37}\text{Ar}/^{39}\text{ArK}$ ratios in the step-heating analyses. However, some of them have the well-defined plateau age of 3.32 ± 0.06 Ga for 81% of the total ^{39}Ar fraction. The plateau fractions have variable $^{37}\text{Ar}/^{39}\text{ArK}$ ratios, suggesting that the chondrule experienced a 3.3 Ga event acquiring the isotopic homogenization. The event of about 3 Ga has been recorded in other chondrules too. Significant loss of argon was also recorded in the low temperature fractions.

EMP analyses of chondrules having olivine, nepheline, sodalite and mesostasis phase revealed that nepheline and sodalite occur in mesostasis among olivine crystals. Nepheline would be the reservoir of radiogenic ^{40}Ar because it has K_2O up to 2.2 wt%. It is most suitable for age dating. The thin sections without neutron irradiation were analyzed with a spot analysis method using a Nd-YAG pulse laser. Olivine has the $^{40}\text{Ar}/^{36}\text{Ar}$ ratios from 670 to 2000, indicating that it is not a suitable phase to estimate the initial ratio. Its relatively high $^{40}\text{Ar}/^{36}\text{Ar}$ ratios indicate that most olivine in these chondrules have radiogenic ^{40}Ar , rather than primordial, suggesting that significant amount of potassium seems to be present though potassium was undetectable by EMP. The isochron analysis was applied to determine the initial ratio and age of these olivine and other minerals. K-bearing nepheline has $^{40}\text{Ar}/^{36}\text{Ar}$ ratios of 2000-2200, which are lower than that of the bulk chondrules (1500-13000). This suggests that nepheline formed secondarily or degassed during the secondary alteration due to an event such as an impact. Alternative explanation is that nepheline may also have high ^{36}Ar concentration due to a cosmogenic origin. Sodalite has relatively high ^{36}Ar concentration and its $^{38}\text{Ar}/^{36}\text{Ar}$ ratios are 1/3, suggesting the ^{38}Ar and ^{36}Ar are from the cosmogenic ^{38}Cl and ^{36}Cl , respectively. Although it has relatively high ^{40}Ar concentration, it is not a suitable phase for age determination.

We have carried out in-situ argon isotope analyses using a pulse laser and detected significant amount of ^{39}Ar from ^{39}K by cosmic ray reaction. This indicates a possibility of $^{40}\text{Ar}/^{39}\text{Ar}$ age determination of extraterrestrial materials without neutron irradiation in a reactor.