ISOTOPIC ANOMALIES IN METEORITES GENERATED FROM INITIALLY INHOMOGENEOUS MOLECULAR CLOUD CORE. T. Nakamoto[1] and A. Takeishi[1], [1]Department of Earth and Planetary Sciences, Tokyo Institute of Technology (I2-11, Meguro, Tokyo 152-8511, Japan).

Temporal Change of Isotopic Ratio in Various Meteorites: Chromium has four stable isotopes: mass numbers of them are 50, 52, 53, and 54. The ratio of ^{54}Cr to the major isotope ^{52}Cr in various meteorites such as chondrites, differentiated meteorites, and iron meteorites shows variations (anomalies). The degree of anomalies is of the order of 10^{-4}.

Formation ages of each meteorite parent body were evaluated [1]. According to the results, meteorite parent body ages and the degree of ^{54}Cr isotope ratio anomaly in the meteorites have a good correlation. Authors thought that this relation is caused by an increase of material carrying ^{54}Cr included in meteorites. And they carried out numerical simulations, in which small dust particles carrying ^{54}Cr are injected into the solar nebula, and showed that the correlation can be reproduced by this injection model.

Their model seems to be able to reproduce the temporal change of ^{54}Cr anomalies in various meteorites. However, it may be hard for their model to explain the relationship between ^{46}Ti and ^{50}Ti anomalies found by Trinquier et al. [2] and the large anomalies of ^{50}Ti and ^{54}Cr in CAIs.

In this study, we examine a new model for the isotopic ratio in various meteorites. In this model, inhomogeneous distribution of presolar grains in the initial molecular cloud that formed the sun and the solar nebula is assumed. With this model, we calculate the temporal evolution of presolar grain distributions in the solar nebula. And we discuss if this model could explain isotopic anomalies of ^{46}Ti, ^{50}Ti, and ^{54}Cr in various meteorites.

Model: The model in this study consists of two parts [3, 4]. One is a molecular cloud core, which collapses and forms the sun and surrounding solar nebula. The dynamical collapse process can be characterized by the angular momentum of the initial cloud core, or equivalently, the initial angular velocity ω of the cloud core. The other is the turbulence in the gaseous solar nebula. The turbulence causes the viscous force and drives the dynamical evolution of the solar nebula. Also, it causes the diffusion of small dust particles in the nebula. The strength of the turbulence is characterized by the non-dimensional parameter α, which can be interpreted as the ratio of the typical velocity of the turbulent motion to the sound velocity. We simulate the formation and dynamical evolution of the solar nebula with this model. Also, the distribution of small dust particles, which are assumed to be coupled well with the gas motion, is calculated.

We assume that the presolar grains in the initial molecular cloud core are not well mixed, though we assume that the gas-to-dust mass ratio has the nominal value independent of the position. For example, ^{54}Cr-rich presolar grains are assumed be more concentrated in the center of the molecular cloud core. In this study, we divide the core into four regions according to the distance from the center. Dust particles that are located in the central sphere initially are named "dust A". The dust A could be ^{54}Cr-rich particle or ^{46}Ti-rich particle, for example. We calculate the ratio of "dust A" to all the dust particles as a function of the time and the place in the solar nebula. The dust growth in the solar nebula is not taken into account. The infall of material from the molecular cloud core to the solar nebula lasts 0.4 Myr.

Results: The distribution of the concentration of "dust A" is shown in Figure 1. Model parameters are $\omega = 10^{-14}$ s^{-1} and $\alpha = 0.001$. Materials from the molecular cloud core falls in the region where the distance from the sun is about 25 AU or less. Dust A falls within about 0.1 Myr. Dust A in the solar nebula moves under the influence of the gas advection motion and the diffusive motion, which makes the uniform low value in the inner region (less than about 10 AU). In contrast, the dust A concentration in the outer region can be high, because materials in the outer region come from the inner region due to the outward motion of the nebula gas and the dust A is included in the gas fraction formed the solar nebula in the early phase and moves outward.

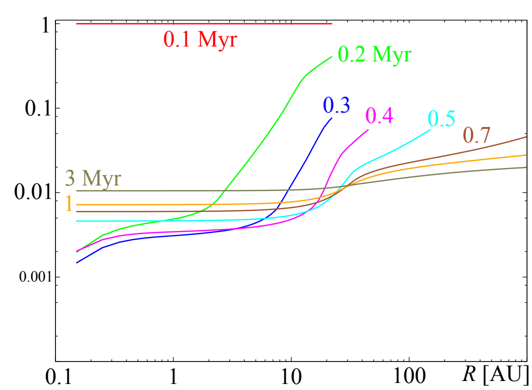

Figure 1: The concentration of "dust A" as a function of radius R. Model parameters are $\omega = 10^{-14}$ s^{-1} and $\alpha = 0.001$.

Figure 2 shows the evolution of the dust A concentration at some selected places. Model parameters are the same with those for Figure 1. In the early phase (< 0.4 Myr), the dust A concentration decreases because of the addition of other dust component. Later (> 0.4 Myr), no material is input from the molecular cloud core. Then, dust A concentration shown in Figure 1 is smoothed out thanks to the diffusion. Because of the diffusion, the concentration in the inner region (< 20 AU) increases gradually.

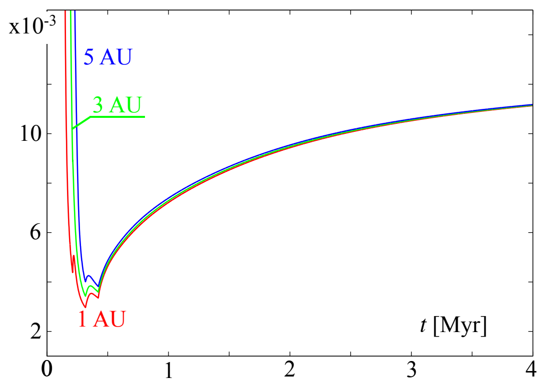

Figure 2: The evolution of the dust A concentration at 1 AU, 3 AU, and 5 AU, respectively. Model parameters are the same with those for Figure 1.

If meteorite parent bodies are formed from materials calculated in this model, and if ^{54}Cr-rich presolar grains are concentrated in the central part of the initial molecular cloud core, the isotopic anomalies of ^{54}Cr in various meteorites [1] can be reproduced. According to [2], ^{54}Cr and ^{50}Ti are on the same carrier, so the anomaly of ^{50}Ti can also be explained.

The dust A concentration in the very early phase is quite high. If dust A contains ^{54}Cr-rich presolar grains and if CAIs are formed from the material, the large anomaly of CAI may be explained.

In order to explain the anomaly of ^{46}Ti, we should assume again that the ^{46}Ti-rich presolar grains are concentrated in the central part of the initial molecular cloud core. Then, we can reproduce all the three anomalies.

Discussion and Conclusion: The current model may reproduce the observed isotopic anomalies of ^{46}Ti, ^{50}Ti, and ^{54}Cr. However, the model is a very simple one and some processes, that may be important, are not taken into consideration. The dust growth is the one, which should be included in the future work. The dust growth leads to the radial drift of dust particles with respect to the gas. The dust growth may also cause the planetesimal and meteorite parent body formation, which leads to the mass deposit as planetesimals and meteorite parent bodies. Thermal processing is also the one that should be considered; solid materials should be liquid or gas so that the isotopic ratio changes and homogenizes. Studies on the isotope homogenization and the origin of the isotopic anomalies should be one of the keys to understand the evolution of planet forming materials and the origin of the solar system.

References: [1] Sugiura, N. and Fujiya, W. (2014), *Meteorit. Planet. Sci.* 49, 772 - 787. [2] Trinquier A. et al. (2009) *Science, 324,* 374. [3] Nakamoto T. and Nakagawa Y. (1994) *ApJ 421*, 640. [4] Yang L. and Ciesla F. J. (2012) *Meteoritics & Planet. Sci., 47,* 99.