Imperfect accretion during the giant impact stage of terrestrial planet formation

H. GENDA[1], E. KOKUBO[2] AND S. IDA[3]

[1]Research Center for the Evolving Earth and Planets, Tokyo Institute of Technology, Tokyo, Japan (genda@geo.titech.ac.jp)
[2]Division of Theoretical Astronomy, National Astronomical Observatory of Japan, Tokyo, Japan (kokubo@th.nao.ac.jp)
[3]Department of Earth and Planetary Sciences, Tokyo Institute of Technology, Tokyo, Japan (ida@geo.titech.ac.jp)

In the standard scenario of planet formation, terrestrial planets are formed in two stages: the formation of several tens of Mars-sized protoplanets through accretion of planetesimals, and collisions among these protoplanets (called ginat impacts). Although the nature of giant impacts determines the final masses, spin parameters, and orbital elements of the terrestrial planets, all the previous *N*-body simulation of terrestrial planet formation (e.g., Chembers 2001, Raymond *et al*. 2004, Kokubo *et al*. 2004) have been based on the assumption of the perfect accretion, that is, colliding two protoplanets always merge without mass loss. Agnor and Asphaug (2004) performed 48 SPH simulations for mutual collision of 1 × Mars-mass protoplanets. They showed that the two protoplanets bounce and escape to infinity for collision with relatively faster impact velocity (e.g., > 1.4 × escape velocity for 30 deg of the impact angle), and they estimated that more than roughly half of giant impact events are not coalescence events.

In order to incorporate the effect of imperfect accretion into *N*-body simulations, we need to know the accretion condition for various types of giant impacts. Using the special-purpose computers for gravitational *N*-body problems (GRAPE), we performed more than 1000 runs of impact SPH simulations for various mass ratios (γ), impact angles (ξ), and impact velocities (v_{imp}). From the results of more than 1000 runs, we formulated the boundary of v_{imp} between coalition and rebound as parameters of γ and ξ. We also formulated the mass(es) and orbit(s) of post-impact planet(s).

We applied the above formulation to the impact events obtained by Kokubo *et al*. (2006), and found that 261 out of 635 giant impacts, that is 41%, are not coalescence events. We will also report the effects of imperfect accretion on the final states of the terrestrial planets such as the largest mass and rotation velocity.

References

Agnor, C. and Asphaug, E., (2004), *Astrophys*. *J*. **613**, L157-L160.
Chembers, J. E., (2001), *Icarus* **152**, 205-224.
Raymond, S. N., Quinn, T. and Lunine, J. I., (2004), *Icarus* **168**, 1-17.
Kokubo, E., Kominami, J. and Ida, S., (2006), *Astrophys*. *J*. **642**, 1131-1139.

Isotopic evidence for Silicon within the Earth's core

R.B. GEORG[1,2], A.N. HALLIDAY[2], E.A. SCHAUBLE[3] AND B.C. REYNOLDS[1]

[1]ETH Zurich, Department of Earth Sciences, Isotope Geology, Zurich, Switzerland (bastian.georg@earth.ox.ac.uk, reynolds@erdw.ethz.ch)
[2]University of Oxford, Department of Earth Sciences, Oxford, UK (Alex.Halliday@earth.ox.ac.uk)
[3]University of California Los Angeles, Department for Earth and Space Sciences, Los Angeles, USA (schauble@ucla.edu)

We present the first isotopic evidence for Si within the Earth's Core. It has long been proposed that the Earth's core must contain significant quantities of light elements, such as H, C, Si, S and K [1]. The high Mg/Si of the terrestrial mantle has been used to argue that Si in particular is an important component in the core [e.g 2]. Recent estimates indicate that it contains as much as 5-7wt% [e.g. 3], and the partitioning of Si into the metallic core should yield isotopic effects because of differences in bonding of Si between metals and silicates.

We analysed the Si isotope compositions for different bulk silicate reservoirs of the solar system as sampled by chondrites, basaltic achondrites thought to come from Vesta and Mars, and basaltic rocks from the Moon and the Earth's mantle. The mean values of these reservoirs obtained for this study are in excellent accord with previous estimates, however, the spread in the data is an order of magnitude lower. A significant difference is found between the bulk silicate Earth (BSE) and Moon on the one hand and meteorites on the other.

It appears unlikely that this observed Si isotope shift can be produced by volatilisation processes during the early accretion history of the Earth. Rather, the observed Si isotope shift was probably produced during Si partitioning into the Earth's core. We modelled the potential Si isotope fractionation during silicate-metal partitioning and can show that both the direction and magnitude of such fractionations are consistent with the observed isotopic differences between BSE/Moon and meteorites.

References

[1] F. Birch, (1964) *J. Geophy Res.*, **69**, 4377-4388.
[2] C.J. Allègre, J.P. Poirier, E. Humler, A.W. Hofmann, (1995) *EPSL*, **134**, 515-526.
[3] J. Wade, B.J. Wood, (2005) *EPSL*, **236**, 78-95.