氏　　名	TORII PHILIP DOUGLAS-SONG
授与した学位	博　士
専攻分野の名称	理　学
学位授与番号	博甲第　　７３９０　　号
学位授与の日付	２０２５年　９月　２５日
学位授与の要件	自然科学研究科　　地球惑星物質科学専攻 （学位規則第４条第１項該当）
学位論文の題目	Geochemical characterization of gaseous reservoirs in the enstatite-chondrite forming-region of the proto-solar nebula: Constraints from Li-isotope, O-isotope, and trace-element compositions in chondrule components （太陽系円盤のエンスタタイト・コンドライト形成領域におけるガスの地球化学的記載）
論文審査委員	教授　田中　亮吏　　准教授　国広　卓也　　准教授　Potiszil Christian 教授　小林　桂　　教授　芳野　極　　教授　Michael K. Weisberg

学位論文内容の要旨

The petrography, major-element, trace-element, O-, and Li-isotope compositions of chondrule components in six EH3 and three EH4 chondrules were analysed with the intention of determining the geochemical properties of a Si-rich gas in the enstatite-chondrite forming-region and then compare with the Si-rich gas in the carbonaceous-chondrite forming-region. The motivation of this study is to understand the evolutionary pathway of the enstatite chondrites that results in their reduced nature, along with a Mg/Si ratio and Si-isotope composition that differs from those of Earth despite their isotopic similarities for O, N, Ca, Ti, Cr, Ni, Mo, Ru, Os.

A previous study proposed that the precursors enstatite chondrite chondrules were olivine-rich chondrules. In this study two independent, repeating processes were identified. The first process was silicification (addition of SiO2) and the second process was sulphidation. Both processes can produce enstatite from an olivine-rich precursor. If sulphidation was the dominate process in producing enstatite from olivine, abundant MgS would have been expected without accompanying silica. As this is not the case, silicification was identified as the dominate process in producing enstatite in the enstatite chondrules.

As enstatite is shown to be the result of the precursor olivine interacting with a Si-rich gas reservoir, the O- and Li-isotope compositions of the Si-rich gas were estimated from mass balance equations using the isotope compositions of the olivines and enstatites. The O- and Li-isotope compositions of the Si-rich gas were estimated to be ($\delta^{18}O$, $\delta^{17}O$, $\Delta^{17}O$)=(5.4, 3.7, 1.0‰) and ($\delta^{7}Li$=2‰). The Li-isotope value differs from that of the Si-rich gas in the carbonaceous-chondrite forming-region, indicating isotope heterogeneity in the Si-rich gas of the different chondrite forming regions. This difference was speculated to be the result of light lithium synthesized by galactic cosmic-ray in the interstellar medium allowing for the carbonaceous-chondrite forming-region to maintain its Li-isotope composition heterogeneity.

論文審査結果の要旨

Enstatite chondrites have been considered to be major building blocks of the terrestrial planets, making the elucidation of their origin and evolution an important research topic in planetary science. On the other hand, the fact that they exhibit different Mg/Si ratios and Si isotopic compositions has been discussed as a contradiction to the enstatite chondrite model of Earth formation. Torii has conducted a detailed review of this topic and attempted to resolve this issue using petrological and cosmochemical methodologies. Torii's doctoral thesis is structured into five chapters: (1) An introduction reviewing enstatite chondrite research and outlining the objectives and goals of his PhD research, (2) A petrographic description of various types of enstatite chondrites and enstatite-rich achondrites, (3) Clarification of the formation process of enstatite-rich chondrules based on *in-situ* measurements of elemental composition and lithium and oxygen isotope composition in EH3 chondrules, and characterization of the gas reservoir in the enstatite chondrite chondrule formation region, (4) Application of the same research of (3) to EH4 chondrules, and (5) Conclusions and future research directions. At the thesis defense, Torii mainly presented Chapter 3, the core of the doctoral thesis. The presentation was evaluated highly for the discovery of chondrules formed at different stages and retaining reaction processes between S-rich and Si-rich gases, as well as a new interpretation of the chemical characteristics and evolution of the gas reservoir. However, the thesis was criticized for insufficient description of analytical methods and discussion about spatial geochemical heterogeneity. Additionally, the newly proposed recycling model for EH4 chondrule formation was noted as requiring further robust discussion. Torii agreed to revise his thesis based on these comments. The content of Chapter 3 has already been published in an international journal, and the committee confirmed that Torii played a major role in data acquisition, interpretation, and paper writing, and the published paper was evaluated as an appropriate reference for the PhD degree. His doctoral thesis represents an important contribution to the field of planetary science, and the presentation was well-organized, with appropriate responses to questions and interviews. The committee unanimously decided to pass Mr. Douglas-Son's final doctoral examination.