Japan Geoscience Union Meeting 2011
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PPS025-01 会場:101 時間:5 月 23 日 14:15-14:30

銀河のダスト量決定機構
Mechanism determining dust content in galaxies

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銀河におけるダストの起源は惑星科学の基盤を支える重要性を持つ。本講演では、銀河における星、星間媒質、金属（ヘリウムより重い元素）、ダストという４成分の物質循環を記述する「銀河の化学進化モデル」をもとに、銀河スケールのグローバルなダスト量決定機構について紹介する。

キーワード: 銀河, ダスト形成, ダスト成長, ダスト破壊
Keywords: galaxy, dust formation, dust growth, dust destruction

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PPS025-02 会場:101 時間:5 月 23 日 14:30-14:45

赤外線観測に基づく Wolf-Rayet 連星系周囲に形成されたダストの性質
Properties of Dust Formed around Wolf-Rayet Binary System based on Infrared Observations

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我々はすばる望遠鏡中間赤外線観測装置 COMICS を用いて、周期的なダスト形成を行う Wolf-Rayet 連星系 WR140 の継続観測を行ってきた。WR140 は最も近傍にある Wolf-Rayet 連星系の一つで、周期おおよそ 8 年で伴星が主星である Wolf-Rayet 星の近日点を通過し、その度ごとに多波長での光度曲線の変化を示すことが知られている (spectroscopic event)。特に赤外線で捉えられる変化は、ダスト形成活動に密接に関連すると考えられており、8m 級の望遠鏡による中間赤外線高空間分解能観測は、こうした星周ダスト形成の現場とその後の変質過程を理解するためにきわめて有用である。本講演では、2009 年の近日点通過後、すばる望遠鏡 COMICS を用いて複数回にわたって取得した中間赤外撮像、分光データによって得られた、広がり行くダスト雲の性質について、それらの組成や質量の変化などを含めて議論する。

キーワード: 星周ダスト, シリケイト, 炭素質ダスト, 中間赤外線観測, すばる望遠鏡
Keywords: circumstellar dust, silicate, carbonaceous dust, mid-infrared observation, subaru Telescope

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PPS025-03 会場:101 時間:5 月 23 日 14:45-15:00

s-process 核種同位体比の温度・密度依存性と惑星物質との比較
Estimation of s-process condition based on the isotopic composition of heavy elements

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一般に、天然に存在する鉄よりも重い元素の約半数は、太陽のような中小質量星の進化末期の AGB 星内 He 層で起こる遅い中性子捕獲反応（以下、s-process）で生成されたと考えられている。この s-process が起こっている領域の温度・中性子密度・中性子源として、比較的低温・低中性子密度環境でおこる 13C(α, n)16O 反応の中性子を源とする s-process と、高温・高中性子密度環境でおこる 22Ne(α,n)25Mg 反応の中性子を源とする s-process の２種類が提唱されている。我々は先行研究で、153Eu/151Eu 比が s-process の環境変数（温度と中性子密度）に敏感であることに着目し、(1) 高感度・高分解能イオンマイクロプローブを用いたプレソーラー SiC の Eu 同位体分析、(2) 波長分解能の高いすばる望遠鏡高分散分光器 HDS を用いた s-process 元素に卓越した天体の Eu 同位体比の分光観測、行ってきた (Terada et al. NewAR 50, 2006)。

本研究では、他の s-process 核種の同位体比の温度-中性子密度依存性について報告する。さらに、過去に報告された AGB 星起源のプレソーラー SiC の文献値、及び s-process 核種 rich な隕石酸残渣の同位体比と比較する事で、s-process の環境変数の普遍性／多様性について議論する。

キーワード: 元素合成, 同位体, 隕石, AGB 星, s プロセス, 中性子捕獲反応
Keywords: Nuclear synthesis, Isotopic composition, meteorite, AGB star, s-process, Neutron capture process

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PPS025-04 会場:101 時間:5 月 23 日 15:00-15:15

星周コランダム形成の理解に向けたプレソーラー粒子形状の解析
Morphology of presolar corundum grains from unequilibrated ordinary chondrites

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Corundum (Al_2O_3) is one of the first refractory minerals that condense directly from gas of the solar composition. Presolar corundum grains, which have highly unusual oxygen isotopic compositions compared to solar-system materials, are condensates in outflows from oxygen-rich AGB stars and/or su-pernovae. It is therefore important to understand the formation conditions of corundum grains in order to understand the first stage of dust formation around evolved stars. The morphological and crystallographic features of presolar corundum grains should reflect the formation conditions and subsequent thermal his-tory of the grains. In order to understand morphology and crystallographic orientation of presolar corun-dum grains, we first made detailed observations of morphology and crystallography of corundum grains from residues unequlibrated ordinary chondrites using field-emission scanning electron microscopy (FE-SEM) and electron back-scattered diffraction (EBSD) and the oxygen isotopic compositions of the grains were then measured to identify the circumstellar condensates.

The acid-residues of ordinary chondrites, Semarkona (LL3.0), Bishunpur (LL3.1), and Roosevelt County (RC) 075 (LL3.2) were used for this study. Corundum candidate grains were found with cathodo-luminescence imaging, and 198 corundum grains were confirmed by EDS equipped to a FE-SEM. For individual grains, secondary electron images were taken from four different directions and crystal-lographical information was obtained by EBSD. Oxygen isotopic compositions of 111 grains were measured with UH Cameca ims-1280 ion microprobe. The details of analytical technique are described in Makide et al. (2009). After the isotopic measurements, the presolar corundum grains were reexamined by FE-SEM and EBSD.

The 198 corundum grains discovered were classified into three types according to their morphology. Type A grains have smooth surfaces (73 grains), type B grains are irregularly shaped and have rough sur-faces with 10-nm-sized fine structures without crystal faces (62 grains). Intermediate grains that cannot easily be classified into either type A or B are type C (73 grains). The 111 corundum grains, of which oxygen isotopic compositions were measured. Nine presolar corundum grains were found: seven grains have oxygen isotopic compositions with positive ^{17}O excesses and small ^{18}O depletions; two grains show 17O depletions. The presolar grains consist of 6 type B, 2 type A, and 1 type C grains.

The observed presolar/solar corundum ratio of 8% is higher than that of 1% reported by Makide et al. (2009). This difference could be attributed to the difference in size of grains analyzed. The size of grains measured in our study is about 1 micron on average, but only larger grains (1-5 micron) were measured by Makide et al. (2009). Because larger grains have a higher possibility of survival during thermal events in the early solar system, these observations may imply that circumstellar corundum grains are dominantly <~1 miicron in size. Hoefner (2008) showed that corundum dust grown to ~1 micron could be easily ejected by mass-loss winds due to radiation pressure, indicating that further growth could be suppressed by rapid cooling, which may support our observation.

Choi et al. (1998) argued that presolar grains have irregular surfaces or are aggregates of smaller grains. This is consistent with the dominance of type B presolar corundum grains in this study. We ob-tained 10 EBSD patterns for different spots on the type B presolar grain. The EBSD patterns of all spots were the same, which are also the same as that taken prior to isotopic analysis, suggesting that the grain is not an aggregate of small grains but is a single alpha-corundum crystal. The present results may suggest common formation of fluffy and fine-structured corundum grains around various evolved stars.

キーワード: プレソーラー粒子, 星周ダスト, 晩期型星, 酸素同位体
Keywords: presolar grain, circumstellar dust, evolved star, oxygen isotope

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星周ダストシェルにおけるスピネル凝縮カイネティクス
Kinetics of spinel formation under circumstellar conditions

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Spinel ($MgAl_2O_4$) is one of the most abundant presolar oxides found in primitive chondrites with highly unusual oxygen isotopic compositions compared to solar-system materials. Presolar corundum and spinel grains are considered to be condensates in outflows from oxygen-rich AGB stars and/or supernovae. It has been reported that Mg/Al ratios of some presolar spinel grains are lower than the stoichiometric ratio (Choi B.-G.- et al., 1998). Spinel can form through the reaction between pre-existing corundum and Mg gas, and the non-stoichiometry of presolar spinel and the presence of presolar corundum may imply that corundum and Mg gas did not react completely. In order to discuss the origin of presolar spinel and evolution of refractory materials in circumstellar environments, it is important to understand the kinetics of spinel formation under low-pressure circumstellar conditions. In this study, we conducted spinel formation experiments through a reaction between corundum and Mg+O gas (Al_2O_3(s) + Mg(g) + O(g) = $MgAl_2O_4$(s) in vacuum.

An MgO pellet as a gas source of Mg and O was put in the bottom of an alumina crucible. The alumina tube was set in a vacuum chamber and evacuated to ~10^{-3}-10^{-4} Pa, and then heated at desired temperatures (1640, 1590, and ~1450 degree Celsius) for desired durations (6-695 h). The wall of the alumina tube was almost isothermal at 1640 and 1590 degree Celsius, and a small temperature gradient existed at 1450 degree Celsius, where it was 1470 and 1420 degree Celsius at the bottom and top of the tube, respectively. The inner wall surfaces and the cross sections of reacted alumina tubes were observed with FE-SEM, and their chemical compositions were determined by EDS and EPMA. Thicknesses of the reacted layer were measured at different heights from the bottom.

A spinel layer was formed on the inner wall of the alumina tube under all the experimental conditions. The thickness of the layer was largest at the bottom, and became smaller with increasing the distance from the bottom. The thickness of the spinel layer increases linearly with time. The Mg/Al compositional profile of the spinel layer showed that the layer was depleted in Mg, and the typical ratio of Mg and Al was Mg:Al = 0.72:2.18, 0.61:2.26 and 0.59:2.27 at 1450, 1590, and 1640 degree Celsius for O=4, respectively.

The linear increase of the thickness of the spinel layer with time suggests that the spinel formation rate is controlled by the surface chemical reaction, i.e., the reaction rate can be expressed by the Hertz-Knudsen equation. In order to obtain the condensation coefficient for spinel formation, we developed a model for steady-state diffusion of Mg gas inside the alumina tube under the molecular flow conditions. We fitted the growth rates of the spinel layer with the model, and obtained the spinel reaction coefficient of ~0.02 and supersaturation ratio (S) of ~5 at 1450, 1590, 1640 degree Celsius. Therefore, we conclude that only ~2 percent of colliding Mg gas can react to form spinel in the reaction of Al_2O_3(s) + Mg(g) + O(g) = $MgAl_2O_4$(s) at a low super saturation ratio (S~5),.

The obtained condensation coefficient was applied to spinel formation in an expanding mass-loss wind around a cool-low-mass evolved star with gas of the solar composition. The mass-loss velocity where spinel grains form may be much lower than the terminal velocity of the wind (~10 km/s) and vary with time. The reaction efficiency between corundum and Mg+O gas changes with the wind velocity: corundum grains (1 micron) react almost completely with gas to form spinel in the case of wind velocity of 0.01 km/s, while little reaction occurs in the case of faster wind (1 km/s). Spinel formation under kinetic conditions in mass-loss winds with various velocities therefore may result in the variation of circumstellar oxides, which is consistent with the presence of both presolar spinel and corundum in the solar system materials.

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ＣＯガスを反応物としたＳｉＯダストの形成過程
SiO dust formation from CO gas as a reactant

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Circumstellar dust of silicates and other oxides finding in carbon rich star (C/O>1) suggests the possibility that the stellar atmosphere underwent an oxygen rich (C/O<1) environment of previous mass loss rate phase. This is based on the thermal stability of CO molecule. When this ratio is larger than unity, all oxygen will be trapped in the very stable CO molecule.

Since CO is one of the most abundant molecule in the dust-forming region, we considered that the reaction pathway of using CO molecule as a reactant for oxidation of silicon. Silicon oxides are the main components of silicate dust and precursor substances.

Our laboratory experiments of grain formation in a CO gas atmosphere show that amorphous SiO grains can be directly produced from silicon oxidation. SiO smoke produced by the evaporation of a fragment of Si (10 mg) from the tungsten boat at a gas pressure of 10 kPa of CO.

The color of the collected grains was yellow brown and their electron diffraction pattern showed a halo. No existence of tungsten in the produced SiO grain was detected by energy dispersive x-ray spectroscopy. The mid-IR feature of the SiO grain embedded in KBr pellet is similar to that of beta-cristobalite, i.e., the grain may be composed of microcrystallites of Si and beta-cristobalite. Moreover, the residue of evaporation was examined by transmission electron microscopy and turned out the beta-SiC which has cubic structure of high temperature phase. Graphite layer was formed to be parallel to the surface of {111} SiC planes.

Demonstration of formation of circumstellar oxide dust on oxidative or reductive condition requires the introduction of gas species other than oxygen controlled partial pressure.

キーワード: 一酸化炭素, 一酸化ケイ素, 星周塵, グレインフォーメーション, 透過型電子顕微鏡法, 赤外分光分析法
Keywords: carbon monoxide, silicon monoxide, circumstellar dust, grain formation, transmission electron microscopy, infrared-spectroscopic analysis

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超高過飽和ガスから生成するダスト類似物の均質核形成と接合成長
Homogeneous nucleation and coalescence growth of dust analogs in supersaturated vapor

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To investigate the homogeneous nucleation and growth process of nanoparticles in vapor phase, interferometric observation was attempted for the fist time to the gas evaporation method, which has been a commonly accepted physical production method of nanoparticles. Using the gas evaporation method, fine particles with the size of several nm to ~1 micron are directly produced from the gas phase and recognized nanoparticles have a crystalline habit similar with the bulk crystal even in such tiny particles. When an evaporant is initiated in an inert gas, the evaporated vapor subsequently cools and condenses in the gas atmosphere, i.e., solid grains are obtained via homogeneous nucleation from the vapor phase. Therefore it can be assumed that nucleation occurs far from the equilibrium state, but it is not obvious how far condensation takes place. However, there is no report concerning nucleation and limited study in view of crystal growth for smoke experiment, although significant numbers of smoke experiments have been performed so far. Although there has been reports concerning homogeneous and heterogeneous nucleation from solution phases [1], there has been few reports concerning homogeneous nucleation from a vapor phase in recent years. Homogeneous nucleation rates of droplets were measured as a function of temperature and supersaturation using ethanol and nonane [2, 3]. The nucleation rates were different in several orders of magnitude from the classical nucleation theory.

In preliminary experiment, Tungsten oxide was evaporated by electrical heating of a tungsten wire in a mixture gas of Ar and O_2. WO_3 nanoparticles were formed via homogeneous nucleation and growth during a gas cools following a thermal convection produced by the evaporation source. The degree of supersaturation for nucleation was extremely high, $6.6*10^6$, which was determined from the interferogram. Surface free energy of WO_3 at 1100 K was calculated based on the classical nucleation theory and was $1.38*10^3$ erg cm^{-2}, which is within the reported values. Homogeneously condensed WO3 nuclei initially maintain their temperature for ~5 ms and then cool down with a rate of ~$5*10^4$ K/s. A part of the difference between actual formation rate of produced nanoparticles, which were determined based on a transmission electron microscope, and calculated values based on the semi-phenomenological nucleation theory [4] were well explained if we adopt the idea of coalescence growth.

[1] X. Y. Liu, K. Tsukamoto, M. Sorai, Langmuir, 16 (2000) 5499.
[2] J. L. Schmitt, G. W. Adams, R. A. Zalabsky, J. Chem. Phys. 77 (1982) 2089.
[3] G. W. Adams, J. L. Schmitt, R. A. Zalabsky, J. Chem. Phys. 81 (1984) 5074.
[4] K. K. Tanaka, Katsuyuki Kawamura, Hidekazu Tanaka, and Kiyoshi Nakazawa, J. Chem. Phys. 122 (2005) 184514.

キーワード: 核形成, 結晶成長, ナノ粒子, ダスト, 干渉計, その場観察
Keywords: nucleation, crystal growth, nanoparticle, dust, interferometer, in-situ observation

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気相からの凝縮過程における均質核生成の分子動力学シミュレーション
Molecular dynamics simulation of nucleation from vapor

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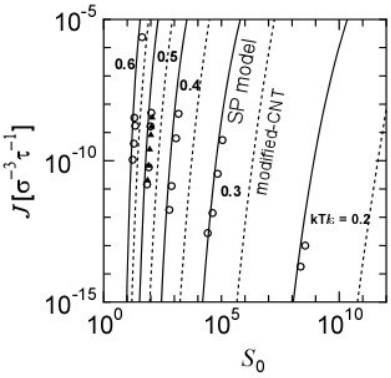
気 相からの凝縮に伴う均質核生成の記述において、古典的核生成理論はさまざまな分野で用いられているが、これから得られる核生成率は多くの場合実験値と比較すると桁で合わないことが知られている。実験値を良く再現するものとして半現象論的モデルが１９９０年代に提唱された [1] が、その適用の可能範囲は明らかではない。本研究ではレナードジョーンズ型分子（Ar を想定）に対し気相からの均質核生成過程の分子動力学シミュレーションを行い、核生成理論の検証を行った。我々の以前の研究 [2] ではガスから液相に凝縮する温度領域（80-120K）に対し計算結果が古典的理論よりも半現象論モデルで良く再現されることを示した。本研究では固体に凝縮する低温領域（24-72K) における１万-10 万粒子の分子動力学シミュレーションを行った。その結果、凝縮核はまず液相として形成し５０Ｋよりも低温の場合にはその後凝縮核の成長に伴い結晶化する様子が得られた。得られた核生成率はすべての計算において半現象論的モデルと高い精度で一致していることを表す (図参照)。我々の結果はレナードジョーンズ型分子系において半現象論的モデルが広い温度、過飽和度範囲に対して非常に有効であることを示す。

[1]A.Dillmann,G.E.A.Meier,J.Chem.Phys.,94,3872(1991)
[2]K.K.Tanaka,K.Kawamura,H.Tanaka,K.Nakazawa,J.Chem.Phys. 122,184514 (2005)



キーワード: 核生成, 凝縮, 分子動力学シミュレーション
Keywords: nucleation, condensation, MD simulation

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星間塵表面反応による化学進化および重水素濃集
Grain-surface reactions: chemical evolution and deuterium fractionation in molecular clouds

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Surface processes on interstellar icy grains play an important role in chemical evolution in molecular clouds. Until now, there have been many experimental works which report the synthesis of many molecules by energetic processes, such as UV, electron and ion bombardments, in interstellar ice analogues. Even formation of amino acid was observed after such energetic processes in ices. However, in dense core of molecular cloud where the radiation field is very weak, since the energetic processes are relatively suppressed, nonenergetic processes like neutral-neutral surface reactions become important. In this context, our group has performed a series of experiments regarding surface reactions of cold H(D)-atoms and OH radical with molecules to produce H_2O, CO_2, H_2CO, and CH_3OH. We have also tackled an important issue, deuterium fractionation of molecules in molecular clouds and demonstrated for the first time that tunneling surface reaction on interstellar ice is the key for the deuterium enrichment of some organic molecules. In the presentation, we will review our series of works described above and talk briefly about the very recent experiment for H-atom diffusion on the ice surface.

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水素および重水素原子の氷表面拡散と水素分子生成
Diffusion of hydrogen and deuterium atoms and molecular hydrogen production on amorphous solid water

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In interstellar dense clouds where a radiation field is very weak, nonenergetic reactions of hydrogen atoms on dust grains, including quantum tunneling reactions, play an important role in chemical evolution. For example, it has been widely accepted that molecular hydrogen which is the most abundant molecules in the Universe is formed by recombination of H-adatoms on the dust surface. Successive reactions of H- and D-atoms with carbon monoxide are also key molecular steps in the synthesis of many organic molecules observed in the ice mantles, such as formaldehyde and methanol.

These reactions proceed through the sequence of elementary processes of H-atoms, i.e., adsorption, diffusion, and encounter with another adsorbed species. Therefore, to understand formation of not only molecular hydrogen but also complex molecules, above-mentioned physical and chemical properties of H- and D-atoms on cold surfaces should be clarified.

In this talk, we report a spectroscopic approach for the behavior of H-atoms on the surface of amorphous solid water (ASW) using photo-stimulated desorption and resonance enhanced multiphoton ionization methods.

The diffusion rate of H-atoms was directly measured after H atom deposition on ASW at 8 K. In addition, we measured the ortho/para nuclear spin ratio (OPR) of nascent molecular hydrogen formed via recombination, and observed the spin conversion of molecular hydrogen adsorbed on ASW.

Efficient molecular hydrogen formation was observed on ASW during the H-atom deposition on ASW at 8-15 K, while some fractions of H-atoms were successfully detected even after H-atom deposition at 8 K. These results show the presence of at least two types of potential sites on ASW. The analysis of attenuation curve of H-adatoms at 8 K provides the two different activation energies of H-atom surface diffusion with about 20 meV and >50 meV. Quantitatively similar results were obtained in the case of deuterium atom, suggesting that the thermal hopping mechanism better explains the diffusion rather than tunneling diffusion, because a large isotope effect should be observed if it is tunneling.

The nuclear spin temperature, which is defined by OPR of hydrogen molecules, of nascent hydrogen molecules formed from H-atoms on ASW at 8 K is very close to that of adsorbed molecular hydrogen directly from the gas phase. However, when we left the hydrogen molecules on ASW, it was found to decreases on ASW by the spin conversion.

キーワード: 水素原子, 重水素原子, 水素分子, アモルファス氷, 表面拡散
Keywords: hydrogen atom, deuterium atom, molecular hydrogen, amorphous solid water, surface diffusion

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高密度分子雲内部におけるラジカル－分子表面反応による二酸化炭素生成
CO_2 formation through radical-molecule reactions on a solid surface inside dense molecular clouds.

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Solid CO_2 is ubiquitously distributed in icy grain mantles in molecular clouds. Since gas phase reactions cannot explain the observed abundance of CO_2 in those environments and CO is also abundant in the ice, CO_2 is considered to form on the surface of icy grains. It has been experimentally demonstrated that CO_2 is formed in interstellar ice analogues processed by UV, ions, or electrons. Recent astronomical observations found solid CO_2 in dense molecular clouds, where the UV field is weak, implying that there should be additional routes to the formation of CO_2 besides UV photolysis. We performed the experiment on surface reactions of CO with cold OH radicals to investigate a possible CO_2 formation route in dense molecular clouds.

OH radicals were produced by dissociating H_2O molecules in microwave-induced plasma and cooled to 100 K before reaction. CO and OH radicals were continuously codeposited onto an Al substrate at 10-40 K. Reaction products were monitored in-situ by FTIR. We found that the formation of CO_2 occurred at all temperatures investigated. Up to 10 % of CO was converted into CO_2 under the present experimental conditions. We propose that surface reactions of CO with non-energetic OH radicals are potential pathways to the formation of CO_2 in dense molecular clouds.

キーワード: 星間分子雲, 化学進化, 二酸化炭素, ラジカル－分子反応
Keywords: interstellar molecular clouds, chemical evolution, carbon dioxide, radical-molecule reactions

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近赤外線水素分子輝線比から探る原始惑星系円盤内ダスト進化
Probing dust evolution in protoplanetary disks by near-infrared line ratios of molecular hydrogen emission

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近年の観測技術の向上により、原始惑星系円盤からの水素分子輝線の検出が可能になってきた。ここで近赤外線水素分子輝線は天体の物理状態を探るプローブとして役立つことが知られており、これまでに様々な天体で観測されてきた。
本研究では、すばる望遠鏡 IRCS+AO188 により、原始惑星系円盤からの近赤外線水素分子輝線比 2-1 S(1)/1-0 S(1) の観測を行った。AO188 を用いた非常に高空間分解能の観測を行った結果、2-1 S(1)/1-0 S(1)<0.14 の上限を与えることができた。さらに、円盤内の動径方向の移動も考慮したダスト合体成長・沈殿計算および円盤温度・密度構造の計算を行い、円盤からの水素分子輝線をモデル計算した。ここで円盤からの水素分子輝線比は円盤表層部のガス温度を反映するため、輝線比は、紫外線に起因するダスト上の光電加熱を通じて円盤表層部の (サイズの小さい) ダスト／ガス比に制限を与える。我々の計算結果と観測結果を比較したところ、円盤表層部のダスト／ガス比が分子雲中の値の 0.1 倍よりも大きいことが示された。ダスト合体成長計算の結果では、円盤表層部においてガス降着と共にダストが外縁部より供給されれば、このようなダスト／ガス比を取ることが可能である。またこの場合、円盤赤道面付近で局所的にダスト密度が上昇し、微惑星が形成されやすい状態となることが示された。

キーワード: ダスト進化, 原始惑星系円盤
Keywords: dust evolution, protoplanetary disks

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形成期の原始惑星系円盤内の物質混合
Material mixing in a protoplanetary disk formed by the collapse of a molecular cloud core

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太陽系最古の年代を示す CAI を含め，これまでに調べられたほとんどの太陽系固体物質中の元素同位体組成は，一部の同位体分別を受けやすい揮発性元素を除いてほぼ一定であることが知られている．このことは，初期の原始惑星系円盤内において同位体組成が均質化されていたことを示す．しかしながら，プレソーラー粒子や短寿命放射性核種の痕跡の存在から，原始惑星系円盤の母体となる分子雲コア内では同位体組成は不均質だったと考えられている．従って，原始惑星系円盤内で均質化を引き起こす物質混合が起き，引き続き現在の太陽系天体を構成する物質の形成が起きたと考えられる．また，短周期彗星の彗星塵の分析や，周星円盤の赤外観測の結果から，原始惑星系円盤内の低温領域に存在するダストに，結晶質ケイ酸塩がかなりの割合で含まれていることが分かっている．これら結晶質ケイ酸塩は，太陽近傍の高温領域で形成され，円盤全体にわたって輸送されたことが強く示唆される．そのような円盤動径方向の混合は，原始惑星系円盤初期に起きた同位体組成の均質化と同じ機構によってもたらされた可能性がある．

本研究では，形成期の原始惑星系円盤における物質混合過程について，分子雲コアからのガス供給と乱流混合を考慮した 1 次元軸対称円盤モデルを用いて解析した．特に原始惑星系円盤への流入年代と，最高到達温度に応じてガスを区別し，それぞれを独立した成分とみなして乱流による濃度拡散を計算した．流入年代による区別は，分子雲コア内でのガスの存在位置の違いに対応し，したがってその混合について調べることで，円盤内での同位体組成の均質化を表現できる．

主な結果を以下に示す．まず，同位体組成は乱流粘性が大きいほど早く均質化され，粘性パラメータ $\alpha \geqq 10^{-2}$ の場合の均質化時間スケールは百万年程度である．一方結晶質ケイ酸塩の存在度は，分子雲コアの角運動量が大きいほど小さくなる．これは分子雲コアの角運動量が大きいほど，中心星から離れた領域にガスが流入し，高温環境を経験し結晶化するケイ酸塩の質量比が小さくなるためである．分子雲コアの観測ならびに単独性の形成と整合的な角運動量の範囲を与えた場合，円盤ダストの結晶化度が 1-30% となった．

このようなパラメータの範囲内で，太陽系を説明できる円盤質量 (> 0.01 太陽質量)，同位体組成の均質性，結晶質ケイ酸塩の存在度を同時に満たすことのできる解が得られた．円盤質量と結晶化度の相関の傾向は，T-tauri 型星の周星円盤の観測結果と整合的である．同位体組成均質化の達成年代からは，太陽系最古の物質形成年代がガス流入完了後であり，コア収縮開始からおよそ百万年の時期であることが示唆される．

キーワード: 原始惑星系円盤, 分子雲コア, 物質混合, 始原的隕石, 同位体異常, 結晶化度
Keywords: protoplanetary disk, molecular cloud core, material mixing, primitive meteorite, isotopic anomaly, crystallinity

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GEMS 平均組成の非晶質ケイ酸塩の還元雰囲気における加熱実験
Heating experiments on the reductive condition of amorphous silicates with the mean composition of GEMS

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GEMS (glass with embedded metal and sulfides) are spherical objects of < 500 nm in diameter and characteristically included in anhydrous IDPs (Interplanetary Dust Particles), which are considered to be of the cometary origin. They have nanometer-sized (10-50 nm) Fe-Ni metals and sulfides embedded in the matrices of amorphous silicate. In spite of several propositions for the origin of GEMS [e.g. 1, 2], non of them were widely accepted. Infrared astronomical observations strongly suggest that interstellar silicates are almost amorphous [3]. If the amorphous interstellar silicates were brought into the early solar nebula and heated, the reduction of the silicates might occur. It is proposed that metallic Fe in GEMS are reduction products of FeO-bearing amorphous silicates with carbonaceous materials based on reduction experiments of thin amorphous olivine foils in a reducing atmosphere [4]. However, detailed discussion of metal formation process in the glass was not made. In this experiment, in order to study possible GEMS origin by reduction of interstellar silicates, we synthesized amorphous silicates with the mean composition of GEMS and performed heating experiments under reducing atmosphere.

The amorphous silicates as the starting material of the reduction experiments were prepared by quenching the melt of the mean composition of GEMS in a simple MgO-FeO-SiO_2 system (MgO = 28 wt.%, FeO = 22 wt.%, and SiO_2 = 50 wt.%). The quenched glass was cut and shaped for cubes of about 2 mm on a side. The starting materials were heated at 923 K and 973 K for 3 hours, and at 1023 K for 1-48 hours at one-atmosphere in a gas mixing furnace using a H_2-CO_2 gas mixture. The oxygen fugacity in this reduction experiment was-1.5 log unit above the IQF (Iron-Quartz-Fayalite) buffer (fO_2 ~ 10^{-23} atm).

The X-ray diffraction (XRD) analysis shows that clino-pyroxene was crystallized in the heated samples. Many cracks (typically ~10um in length and ~1um in width) were observed both on the surfaces and cross sections, and metallic Fe grains of a few microns in size were recognized nearby clacks under a field emission-scanning electron microscope (FE-SEM) observations. Metal grains present in the cracks have euhedral shapes. Magnetite or maghemite grains of 50-100 nm in size were also observed inside of the sample under FE-SEM and a transmission electron microscope (TEM). For the TEM observation an ultra-thin sections was made by focused ion beam (FIB).

These results suggests that cracks were formed by volume change of the pyroxene crystallization and metallic Fe grains were formed on the surface or along the cracks by reaction with the reducing gas. The crystallization of the metallic grains and the magnetite or maghemite nano-particles shows that reduction did not occur inside of the glass but only near the glass-gas interface.
If metallic iron grains were formed by the reduction of FeO-bearing amorphous silicates for GEMS, metallic nano-grains can be formed only around the interface. In contrast, TEM observation for natural GEMS shows that metal grains are uniformly embedded in amorphous silicates. So, the present study suggests that metal grains in GEMS is not reduction products.

[1] Bradley J.P. and Dai Z. R. (2004) ApJ. 617, 650.
[2] Keller L.P. and Messenger S. (2008) LPS XXXIX, Abstract #2347.
[3] Kemper F. et al. (2004) ApJ, 609, 826.
[4] Davoisne C. et al. (2006) A&A, 448, L1

キーワード: 非晶質ケイ酸塩, GEMS, 還元実験
Keywords: amorphous silicate, GEMS, reduction experiment

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LL コンドライト中に含まれるアルカリ元素に富む岩片
Alkali-rich Fragments in LL-chondritic Breccias

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Alkaline elements, Na, K, Rb, and Cs, are classified as moderately volatile elements, and large fractionations are expected as a result of evaporation/condensation processes.

K-rich igneous fragments were identified in brecciated LL-chonderites, Kraehenberg (LL5) [1], Bhola (LL3-6) [2], and Yamato (Y)-74442 (LL4) [3,4], and show characteristic fractionation patterns (e.g., Na~0.5 x CI, K~12 x CI, Rb~45 x CI, and Cs~70 x CI [5]). In order to understand fractionation processes of moderately volatile elements as well as origin of alkali-rich fragments in chondritic breccias, we have undertaken mineralogical and petrological studies on K-rich fragments in Kraehenberg, Bhola, and Y-74442. Rb-Sr isotopic studies on the K-rich fragments in Bhola and Y-74442 are in progress.

Kraehenberg, Bhola, and Y-74442 consist of mineral fragments, K-rich fragments, impact-melt clasts, and chondrules. Kraehenberg and Bhola contain large K-rich fragments (1-2 cm in size). Small K-rich fragments (1-2 mm in size) are heterogeneously distributed in Bhola and Y-74442. These K-rich fragments show quenched textures and are composed largely of olivine (50-100 um in size) and groundmass of brown glasses which are highly enriched in alkaline elements. The boundaries between K-rich fragments and their hosts are sharp, and no reaction relation is observed along the boundaries. Dendritic Ca-pyroxene and chromite (~1 um in size) along with troilite (~10 um in size) are commonly observed in the groundmass of K-rich glasses. Tiny Fe-Ni metal grains are identified together with troilite in K-rich glasses.

Chemical compositions of olivine in the K-rich fragments fall within the compositional range of equilibrated LL-chondrites (Fa26-32 [6]). Data points of groundmass glasses of the K-rich fragments are overlapped when plotted on a ternary diagram of Na+K+Al-oxides, Ca+Mg+Fe-oxides, and SiO2. These K-rich fragments are almost identical to their host matrix in major element compositions except Na and K.

Although grain sizes of olivine are somewhat different, textures and constituent phases of the K-rich fragments in Kraehenberg, Bhola, and Y-74442 are indistinguishable.

Abundances of Rb in the whole-rock (WR) samples of Bhola and Y-74442 [7] (50-100 mg in weight) are three to ten times of chondrites, suggesting that K-rich fragments are heterogeneously distributed.

Similarities in textures, chemical compositions, and fractionation patterns of K-rich fragments in LL chondritic breccias suggest that they might be formed from identical precursor materials with related processes.

Alkaline elements are also classified as large ion lithophiles and are partitioned into residual phases during crystallization. The K-rich fragments in Kraehenberg and Bhola possess flat REE patterns, which are different from the GRA 06128/06129 meteorites (alkali-rich early planetary objects showing LREE/HREE fractionations [8]). Geochemistry (i.e., solid/liquid fractionation process) could not be responsible for the enrichments of heavier alkalis in the Kraehenberg, Bhola, and Y-74442 fragments. Taking into account the lack of K isotopic fractionation [9] and the old formation ages of ~4.56 Ga [1,10], an alkali-rich component of the K-rich fragments could have formed during the early stages of solar system evolution.

References: [1] Kempe W. and Mueller O. (1969) Meteorite Res., pp. 418. [2] Noonan A.F. et al. (1978) Geol. Survey Open File Report 78?701, 311. [3] Yanai K. et al. (1978) Mem. Natl. Inst. Polar Res. Spec. Issue 8, 110. [4] Ikeda Y. and Takeda H. (1979) Mem. Natl. Inst. Polar Res. Spec. Issue 15, 123. [5] Wlotzka F. et al. (1983) Geochim. Cosmochim. Acta 47, 743. [6] Dodd R.T. (1981) Meteorites pp. 368, Cambridge Univ. Press. [7] Okano O. et al. (1990) Geochim. Cosmochim. Acta 54, 3509. [8] Day J. M. D. et al. (2009) Nature 457, 179. [9] Humayun M. and Clayton R.N. (1995) Geochim. Cosmochim. Acta 59, 2131. [10] Nishiya N. et al. (1995) Okayama Univ. Earth Sci. Rep. 2, 91.

キーワード: 角礫岩コンドライト, アルカリ元素
Keywords: chondrite, breccia, alkali elements

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原始惑星系円盤条件でのマグネシウムケイ酸塩凝縮実験
Condensation experiments of magnesium silicates under protoplanetary disk conditions

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Magnesium silicates are one of the most abundant materials condensing in the system of solar abundance. Condensation from vapor is the fundamental process for formation of Mg-silicates, and there have been many experimental studies to simulate Mg-silicate formation. However, quantitative discussion on condensation kinetics, especially on the condensation coefficient that reflect the efficiency of condensation of gas species colliding with the surface of condensate, has not yet been made due to experimental difficulties.

In this study, we conducted condensation experiments of magnesium silicates at low pressures in the H2-H2O atmosphere to simulate condensation of magnesium silicates under controlled conditions of pressure, temperature, and gas chemistry close to protoplanetary disk conditions and to discuss condensation kinetics of magnesium silicates quantitatively.
Several important findings were made in this study:

(1) Crystalline forsterite condensed on the substrate of forsterite under controlled conditions (1340 K; total pressure of 1 Pa; Si/H2O/H ratios of ~0.07/~70/1 relative to the solar ratios; supersaturation ratio of ~7), which are much more similar to protoplanetary disk conditions and better controlled than those in previous studies.

(2) The condensation coefficient of forsterite under the above condition was estimated to be <0.2 (or possibly <0.01).

(3) Forsterite (possibly olivine) condensed on the surface of metallic iron under the same condition, but not on molybdenum and corundum. Metallic iron also condened on the substrate of forsterite with a similar supersaturation ratio.

(4) The evaporation rate of forsterite was suppressed under H2O-rich conditions.

These findings, for instance, suggest that forsterite and metallic iron can nucleate and grow mutually in protoplanetary disks but with different efficiencies, and they will make huge contribution to discussion on dust evolution and chemical fractionation in protoplanetary disks and on physical properties (especially thermal structure) of disks as fundamental kinetic data for condensation of magnesium silicates.

キーワード: 原始惑星系円盤, ダスト, 凝縮, ケイ酸塩, 速度論, 不均質核形成
Keywords: protoplanetary disk, dust, condensation, silicate, kinetics, heterogeneous nucleation