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天然で変形したオリビンの転位芯に認められる鉄の濃集
Iron concentration around dislocation in naturally deformed olivine

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The concentration of specific atom on dislocation core can be caused by pipe diffusion and Cottrell atmosphere. Both the phenomena are important for the property of materials including rocks and minerals. As an example of the former, Fe concentration has been reported in the naturally deformed olivine (e.g. Plumper et al., 2011). Pipe diffusion is important for atomic migration during various reactions in the Earth, such as metasomatism and serpentinization. On the other hand, Kitamura et al. (1986) and Ando et al. (2001) have reported Fe concentration in the mantle-derived olivine caused by Cottrell atmosphere. The Cottrell atmosphere strongly influences plasticity of materials in the low strain rate regime. Therefore, the discovery of Cottrell atmosphere from the mantle-derived olivine indicates that the effect on the plasticity of olivine is important to understand mantle dynamics under very low strain rate condition. However, the possibility of pipe diffusion cannnot be neglected completely to explain the observations of Kitamura et al. (1986) and Ando et al. (2001). Here, we carried out more detailed chemical composition analysis of the mantle-derived olivine to assess whether the Fe concentration on dislocation core is a common phenomenon, and to clarify the exact mechanism of the Fe concentration, *i.e.* Cottrell atmosphere or not.

We studied two types of peridotites, which are xenolith-type in basalt (Takashima, Megata, Kurose and Salt Lake) and alpine-type (Uenzaru and Horoman) by using EPMA and ATEM techniques. EPMA and ATEM analyses show Fe concentration at dislocations in all the studied samples, which suggests that it is a common phenomenon in mantle peridotites. Fe-enrichment at the rim of olivine grains and other major element concentration on dislocations, which are general features of pipe diffusion, cannot be observed. Therefore, the mechanism of Fe concentration on dislocation core in olivine grains is possibly derived by Cottrell atmosphere, not pipe diffusion.

Ando et al. (2001) Nature, 414, 893; Kitamura et al. (1986) Proc. Japan Acad., 62, 149; Plumper et al. (2011), Contributions to Mineralogy and Petrology, 163, 701.

Keywords: Cottrell atmosphere, olivine, dislocation

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強磁場印加コロイドプロセスを用いた細粒緻密配向性オリビン多結晶体の創製
Fabrication of textured Fe-free and Fe-bearing olivine aggregates using colloidal processing under high magnetic field

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Crystallographic preferred orientation (CPO) of minerals is considered to be widely produced in the Earth's interior. Due to the presence of anisotropic physical properties such as elasticity, plasticity, electron conductivity and etc... of single crystal minerals, their bulk rock properties can significantly be affected by the presence of CPO. To measure CPO effect on the bulk rock properties by room experiments, it is required to prepare polycrystalline materials with ideally controlled CPO.

Magnetic field was applied to fine-grained (∼120 nm) equigranular Fe-free and Fe-bearing olivine particles, which were dispersed in ethanol (solvent) with dispersant (polyethyleneimin). We expected the particles to align with respect to magnetic direction due to their magnetic anisotropy. The aligned particles were gradually deposited on a solid-liquid separation filter during ethanol drainage. The directions of magnetic field and particle deposition were parallel. The dried particles were then densified isostatically at 200 MPa for 10 min and sintered using the alumina tube furnace with vacuum pump.

Highly dense (density of ≧ 99%) and fine grained (∼1 μm) samples with a-axis alignment for Fe-free and c-axis alignment for Fe-bearing olivine to the magnetic direction were obtained. Such synthesized aggregates will allow us to measure CPO effect on the physical properties of olivine aggregate.

キーワード: 結晶方位, オリビン
Keywords: crystallographic orientation, olivine

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ローソン石の高温高圧変形実験による結晶方位定向配列の観察：沈み込むスラブに見られる地震波の低速度異常層の解釈
High pressure and high temperature deformation on lawsonite: Implication for low velocity layers in subduction zones

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Low-velocity layers (LVLs) located in the upper portions of subducting slabs, are regions of lower seismic wave velocities than those in the surrounding mantles. LVLs apparently persist to depths of 100-250 km [1,2]. Hydrated mafic rocks provide a plausible explanation for the origin of LVLs and trench-parallel/normal S-wave fast polarization. Lawsonite ($CaAl_2Si_2O_7(OH)_2{\cdot}H_2O$), which is stable at depths greater than serpentine minerals, is considered to be one of the prime candidate hydrous minerals that can be present deep in the cold subduction zones [3,4]. Single crystals of lawsonite have a high elastic anisotropy, suggesting that the development of the crystallographic preferred orientations (CPOs) when it deformed might strongly affect the seismic properties [5].

This study reports deformation experiments on lawsonite aggregates that were conducted at high pressure and high temperature corresponding to 150 km depth in the subduction zone, to investigate the development of CPOs and the seismic properties of lawsonite. Experiments were performed using a multi-anvil apparatus with six independently acting rams installed at Bayerisches Geoinstitut, Bayreuth University. The starting material consisted of fine-grained (<25 μm) natural lawsonite powder, which was loaded in a Pt capsule and annealed for >20 h at 5 GPa, between 500 and 800 ℃. The samples were then deformed using pure or simple shear geometry at strain rates of 10^{-4}-10^{-6} s^{-1} and a finite strain of 0.3-1.0. Recovered samples were analyzed using a scanning electron microscope (SEM) coupled with an electron backscatter diffraction (EBSD) detector and a transmission electron microscope (TEM).

The deformed lawsonite aggregates display a porphyroclastic texture characterized by a bimodal grain size distribution. The microstructures with dynamically recrystallized grains imply the evidence for the deformation through grain-boundary sliding accommodated by diffusion creep due to the grain size reduction, whereas the porphyroclasts (20-50 μm in size) have undulose extinction, deformation lamellae, irregular grain boundaries, and many sub-grain boundaries. The porphyroclasts also display a CPO characterized by a girdle distribution of the [100] axes in the shear plane with a maximum concentration close to the shear direction. The [010] axes form a maximum subnormal to the shear plane. The microstructures and the occurrence of a CPO show that the dominant deformation mechanism for the porphyroclasts is dislocation creep. These results of CPOs diverge from those of previous studies of natural lawsonite rocks [e.g., 6], which might result from differences in experimental or natural conditions. TEM images show a variety of dislocations with a high density of $\{110\}$ wedge-shaped mechanical twins. Lawsonite seems to have numerous potential slip systems with [100](010) appearing to be the most dominant. The calculated anisotropies of the seismic wave velocities (AVp = 2% and AVs = 6%, respectively) are characterized by the fast propagation of P-wave is oriented subnormal to [010] maxima of the deformed lawsonite aggregates and the polarization of the fastest S-wave is perpendicular to the foliation. This indicates that lawsonite can contribute to the LVL observations and trench-normal S-wave splitting observed at depth of $>$150 km in the cold subducting slab of northeastern Japan [7].

[1] Abers and Sarker Geophys. Res. Lett., 23, 1171-1174 (1996)
[2] Abers, Earth Planet. Sci. Lett., 176, 323-330 (2000)
[3] Schmidt and Poli, Earth Planet. Sci. Lett., 163, 361-379 (1998)
[4] Connolly and Kerrick, Earth Planet. Sci. Lett., 204, 61-74 (2002)
[5] Chantel et al., Earth Planet. Sci. Lett., 349-350, 116-125 (2012)
[6] Kim et al., Phys. Earth Planet. Int., 222, 8-21 (2013)
[7] Nakajima et al., Geophys. Res. Lett., 33, L05305 (2006)

キーワード: ローソナイト, 結晶方位定向配列, 変形組織, 変形実験, 沈込み帯, 地震波速度異常
Keywords: lawsonite, deformation, crystallographic preferred orientation, high pressure, subduction zone, low velocity layer

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Griggs 型高温高圧変形試験機の応力測定値の較正
Calibration for stress measurement of Griggs-type high temperature and high pressure deformation apparatus

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1. はじめに

岩石のレオロジー特性を定量的に明らかにするためには，地球内部に相当する温度・圧力下で変形実験を行う必要がある．岩石変形試験機には，使用する圧媒体の違いから固体圧変形試験機，油圧変形試験機，ガス圧変形試験機がある（例えば，Tullis and Tullis, 1986）．油圧試験機は高温での油の変質を防ぐため，500 ℃以下に実験が制限される．ガス圧試験機は荷重計測器が圧力容器内にあるため，力学データの精度が最も高いが，国内では高圧ガスの規制法規のため封圧 200 MPa 以下に制限されている．固体圧試験機は柔らかい固体の圧媒体を用いているため，比較的容易で長期間安定的に高封圧（~2 GPa，下部大陸地殻~70km に相当）を得られる．しかし，圧媒体と試料や載荷ピストンの間に生じる摩擦を主な原因として，実際の試料の強度よりも高い応力値が測定されてしまう（例えば，Tullis and Tullis, 1986）．

近年，固体圧試験機とガス圧試験機の応力測定値の比較から，固体圧試験機の較正則が示されている（Holyoke and Kronenberg, 2010）．この較正則によって，固体圧試験機を用いて定常領域の差応力を± 30 MPa の誤差で求めることができるようになった．しかし，この較正則は定常領域に当たる歪 5%における応力値を比較することで求めているため，弾性領域や遷移領域，降伏後の歪硬化や歪軟化といった挙動を再現することはできない．また，ガス圧試験機の実験結果と比較可能な低封圧（~300 MPa）の実験結果がほとんどであるため，固体圧試験機の長所である高封圧下での応力測定値の精度に関してよく分かっていない．地殻深部・最上部マントル及び沈み込み帯深部を構成する岩石の詳細なレオロジー特性を明らかにするために，高圧を長期間安定的に発生できる固体圧試験機において，広範な変形挙動を再現可能な較正則が必要である．本研究では，マスターカーブ法を用いて固体圧試験機における応力測定値の較正則の導出を行った．

2. 軸圧縮実験とマスターカーブ作成

本研究では，東北大学所有の Griggs 型固体圧変形試験機（固体塩アセンブリを採用）を用いて，ニッケルやモリブデンといった金属試料に対して軸圧縮実験を行った．実験は，様々な温度・封圧・歪速度条件下（封圧：~300 MPa，~1200 MPa，~1500 MPa．温度：600 ℃，700 ℃，800 ℃，歪速度：2×10^{-4} /s，2×10^{-5} /s，2×10^{-6} /s）で行った．低封圧の応力測定結果は，先行実験（Holyoke and Kronenberg, 2010）の同条件での結果とよく一致していた．しかし，高封圧の実験ほど，応力測定値が大きくなる傾向があった．今回の封圧範囲内では，定常状態における応力測定値の対数は封圧とほぼ線形の関係を持つことが示唆された．得られた力学データを嶋本（1987）において示されている粘弾性構成則に基づいて解析し，様々な温度・歪・封圧の異なる力学データを規格化したマスターカーブを得た．Holyoke and Kronenberg (2010) のガス圧試験機による力学データについても同様の解析を行い，マスターカーブを得た．

3. 較正則の導出と適用

固体圧試験機とガス圧試験機の実験には同じ金属試料を用いて，温度・歪・封圧を規格化しているため，両者のマスターカーブの差はそれぞれの試験機システムを構成する様々なレオロジー要素の差異に由来するものと考えられる．二つのマスターカーブの差から固体圧試験機の応力測定値の較正則を導出した．本研究で導出された較正則を固体圧試験機によって得られた金属の応力測定値に適用したところ，ガス圧試験機による応力測定値を定常領域だけでなく，弾性領域や遷移領域も± 30 MPa 程度の誤差で再現することができた．降伏後の挙動も以前の較正則よりよく再現することができた．また，1500 MPa までの高封圧の実験結果も較正することが可能となった．炭酸塩岩の応力測定値にも較正則を適用したところ，比較的大きな誤差（~70 MPa）があったが，弾性変形領域から降伏後の挙動まで再現することができた．

キーワード: レオロジー, 岩石変形実験, 固体圧変形試験機
Keywords: rheology, rock deformation experiment, solid medium deformation apparatus

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Weak-beam dark-field TEM characterization of dislocations in wadsleyite deformed in simple shear at 18 GPa and 1800 K

Weak-beam dark-field TEM characterization of dislocations in wadsleyite deformed in simple shear at 18 GPa and 1800 K

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Characterization of dislocations in textured wadsleyite is important in understanding crystallographic preferred orientation (CPO) of wadsleyite and in turn seismic anisotropy at the mantle transition zone. A [001](010)-textured wadsleyite was recently obtained by deformation experiments on wadsleyite in simple shear at 15-18 GPa and 1770-1870 K with a deformation-DIA apparatus (Kawazoe et al., 2013; Ohuchi et al., 2014). However, [001] dislocations have been rarely reported in wadsleyite in the literature (cf. Cordier, 2002). To reconcile the wadsleyite CPO pattern with its slip systems, dislocation microstructures of the [001](010)-textured wadsleyite have been investigated in weak-beam dark-field imaging in a transmission electron microscope. 1/2<101>partial dislocations on the (010) plane are characterized with [100] dislocations on the (001) plane and 1/2<111>dislocations forming {011} slip bands. The former partial dislocations are extended on the (010) stacking fault as a glide configuration (i.e. Shockley-type stacking faults with 1/2<101>displacement vector). The [001] slip on the (010) plane occurs by glide of the dissociated dislocations on a sub-oxygen close packing plane, which can play an important role to generate the crystallographic preferred orientation patterns reported in water-poor deformation conditions (e.g., Kawazoe et al. 2013, Ohuchi et al. 2014).

キーワード: wadsleyite, crystallographic preferred orientation, dislocation, seismic anisotropy, transmission electron microscopy, deformation-DIA apparatus
Keywords: wadsleyite, crystallographic preferred orientation, dislocation, seismic anisotropy, transmission electron microscopy, deformation-DIA apparatus