**LETTER**

Dislocation microstructures in simple-shear-deformed wadsleyite at transition-zone conditions: Weak-beam dark-field TEM characterization of dislocations on the (010) plane

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**ABSTRACT**

Dislocation microstructures of an (010)[001]-textured wadsleyite have been investigated in weak-beam dark-field imaging in a transmission electron microscope. \(\frac{1}{2}<101>\) partial dislocations on the (010) plane are characterized with [100] dislocations on the (001) plane and \(\frac{1}{2}<111>\) dislocations forming \{011\} slip bands. The partial dislocations are extended on the (010) stacking fault as a glide configuration (i.e., Shockley-type stacking faults with \(\frac{1}{2}<101>\) displacement vector). The [001] slip on the (010) plane occurs by glide of the dissociated dislocations, which can play an important role in the generation of the crystallographic preferred-orientation patterns reported in water-poor deformation conditions. The glide mechanism on the (010) plane leaves the oxygen sub-lattice unaffected, but changes the cation distribution, forming a defective stacking sequence of the magnesium cations in the process of dislocation gliding. The mechanism might be related to transformation plasticity and related effects, such as transformation-enhanced weakening and deep-focus earthquakes in the mantle transition zone.

**Keywords:** Wadsleyite, slip systems, slip plane, Burgers vector, Shockley-type extended dislocation, Frank’s rule, Chalmers-Martius criterion

**INTRODUCTION**

Enigmatic [001] glide on the (010) plane; i.e., the [001](010) slip system, in deformed wadsleyite has been recently deduced from crystallographic preferred orientation (CPO) patterns obtained by deformation experiments (Demouchy et al. 2011; Kawazoe et al. 2013; Ohuchi et al. 2014). In their studies, wadsleyite aggregate was deformed at pressure-temperature conditions characteristic of the mantle transition zone, and a [001] (010)-textured CPO pattern was found from electron backscatter diffraction (EBSD) measurement on recovered samples. The CPO pattern is primarily controlled by the easiest slip system. In the case of olivine, a polymorph of wadsleyite, deformation fabrics are well correlated with the dominant slip systems (Karato et al. 2008). Therefore, activation of the [001](010) slip system is simply expected in deformed wadsleyite. Identification of the easiest slip system in wadsleyite is important in understanding the physical mechanisms of its plastic deformation (Tommasi et al. 2004) and, in turn, for interpretation of seismic anisotropy observed in the mantle transition zone (Foley and Long 2011; Yuan and Beghein 2013).

However, real activation of the [001](010) slip system has not yet been confirmed clearly by dislocation microstructures in conventional bright-field and dark-field transmission electron microscopy (TEM) (Cordier 2002). TEM observations in the early 1980s were made on wadsleyite that had been naturally deformed in shocked meteorites (Price et al. 1982; Madon and Poirier 1983; Price 1983). The (010) stacking faults were found in the deformed wadsleyite, and a topotaxial transformation from ringwoodite to wadsleyite was suggested to occur by a martensitic shear mechanism. In addition, wadsleyite was experimentally deformed in a Kawai-type multi-anvil apparatus (Sharp et al. 1994; Thurel and Cordier 2003; Thurel et al. 2003a). Subsequent TEM characterization of recovered samples revealed activation of the following slip systems: [100](010), [100](001), [100] {011}, [100] {021}, \(\frac{1}{2}<111>{101}\), [010](001), [010] {101}, and <101>(010). Wadsleyite was also deformed at 14–20 GPa and 1690–2100 K using a rotational Drickamer apparatus (Hustoft et al. 2013; Kawazoe et al. 2010a; Farla et al. 2015). However, the [001](010) slip system could not be determined by TEM because the dislocation density was too high to apply the invisibility criterion using conventional bright- and dark-field TEM imaging.

The (010) stacking fault is a characteristic microstructure in deformed wadsleyite having the (010)[001]-textured CPO (Demouchy et al. 2011; Ohuchi et al. 2014). Previous studies have discussed that Shockley-type (010) stacking faults can be formed through the glide of \(\frac{1}{2}<101>\) partial dislocations on the (010) plane (e.g., Price 1983; Sharp et al. 1994). Based on their theoretical study on crystal chemistry and anisotropic linear elasticity of wadsleyite, Thurel et al. (2003b) reported a possible dissociation along [001] = \(\frac{1}{2}[101]+\frac{1}{2}[101]\). They recommended further detailed investigation on the precise core structure of the dislocations in wadsleyite to better understand and model the plastic behavior of wadsleyite. In this context, Metsue et al. (2010) concluded that, from their calculation of the generalized stacking faults energies on the (010) plane, [001] shear is only possible in (010) where the dislocations dissociate into two non-collinear partial dislocations of \(b = \frac{1}{2}<101>\), i.e., \(\frac{1}{2}[101]+\frac{1}{2}[101]\). Also, as mentioned in Demouchy et al. (2011), viscoplastic self-consistent (VPSC) modeling of CPO evolution using the previously reported glide systems for wadsleyite, i.e., [100] \{0k1\} and \(\frac{1}{2}<111>{101}\), cannot reproduce the measured CPO pattern, unless the [001](010) system is also activated. However,

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