The development of shape- and crystallographic-preferred orientation in CaPtO₃
post-perovskite deformed in pure shear

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ABSTRACT

Knowledge of the deformation mechanism of post-perovskite is important for interpreting observed seismic anisotropy in terms of mantle flow. Experiments on post-perovskite MgSiO₃ and the low-pressure analog material CaIrO₃ yield different textures, leaving the interpretation of the observed seismic signatures unclear. Here we present results of deformation experiments on CaPtO₃ post-perovskite that may be a better analog to MgSiO₃. Post-perovskite CaPtO₃ deforms by glide of [100] dislocations on the (010) plane, consistent with previous experimental results on CaIrO₃. In addition, samples containing a weak minority phase also display shape-preferred orientation with grains elongated in the crystallographic a-direction forming a planar fabric perpendicular to the compression direction. This shape-preferred orientation strengthens the observed crystallographic-preferred orientation and results in a rapid development of texture during deformation. This observation supports the recent suggestion that the D” reflector might be due to a rapid generation of texture in post-perovskite. Furthermore, the role of shape-preferred orientation in generating seismic anisotropy in multi-phase assemblages should be considered for the D” assemblage.

Keywords: CaPtO₃, post-perovskite, deformation mechanism, shape-preferred orientation, crystallographic-preferred orientation, seismic anisotropy

INTRODUCTION

The D” region at the base of the Earth’s lower mantle has anomalous seismic properties. In particular, it has a laterally variable seismic anisotropy with regions below long-lived subduction zones showing strong transverse anisotropy in which horizontally polarized shear waves travel faster than vertically polarized shear waves (e.g., Thomas and Kendall 2002). This seismic anisotropy has been interpreted in terms of horizontal flow at the base of the mantle as subducted slab material is deflected by the density contrast at the core–mantle boundary (McNamara et al. 2002; Panning and Romanowicz 2004). The recently discovered post-perovskite phase of MgSiO₃ (Murakami et al. 2004; Oganov and Ono 2004; Tsuchiya et al. 2004) shows considerable elastic anisotropy (e.g., Stackhouse et al. 2005); hence, crystallographic-preferred orientation (CPO) in post-perovskite could readily explain the observed seismic anisotropy in much of D”. Therefore considerable effort has been put into determining the CPO developed in post-perovskite during deformation to be able to definitively interpret the seismic observations in terms of mantle flow.

Post-perovskite MgSiO₃ is stable only above ~120 GPa making experiments on the silicate system very challenging. Early room-temperature deformation experiments have developed textures in MgSiO₃ and MgGeO₃ post-perovskite consistent with slip on (100) or (110) glide planes (Merkel et al. 2006, 2007). The structure type material, CaIrO₃, crystallizes in the post-perovskite structure at atmospheric pressure and has been extensively studied as a structural (Martin et al. 2007; Boffa Ballaran et al. 2007; Lindsay-Scott et al. 2007) and mechanical (Yamazaki et al. 2006; Miya et al. 2007; Walte et al. 2007, 2009; Miyagi et al. 2008; Hunt et al. 2009; Miyajima et al. 2010) analog to MgSiO₃. Deformation experiments performed at pressures of a few gigapascals and ~1273–1673 K in deformation-DIA apparatus produced textures consistent with slip on the [100] (010) glide system (Yamazaki et al. 2006; Walte et al. 2007). More recent experiments on MgSiO₃ and the analog substance MnGeO₃ suggest deformation by slip on (001) (Miya et al. 2010; Miyajima et al. 2010). This slip system would produce strongly anisotropic aggregate elastic properties during deformation and thus require small amounts of deformation to generate the observed seismic anisotropy in D” (e.g., Nowacki et al. 2010). The reason for the discrepancy between the two types of study is currently unclear. It is possible that there is a change in active slip system between low and high temperature or due to the different differential stresses of the experiments. Alternatively, the textures might have been generated in the diamond-anvil experiments during transformation of the starting material to the post-perovskite structure under non-hydrostatic stress (e.g., Okada et al. 2010). Experiments on the CaIrO₃ analog would not