Precipitates of α-cristobalite and silicate glass in UHP clinopyroxene from a Bohemian Massif eclogite

TINA R. HILL1,2, HIROMI KONISHI1†, FRANKLIN HOBBS3, SEUNGYEOL LEE1‡, and HUIFANG XU1,*§

1Department of Geoscience, University of Wisconsin-Madison, Madison, Wisconsin 53706, U.S.A.
2Bruker Nano, Inc., 5465 E. Cheryl Parkway, Madison, Wisconsin 53711, U.S.A.

ABSTRACT

Low-pressure metastable nanoscale crystals of α-cristobalite have been observed epitaxially exsolved in cores of UHP clinopyroxene from the Bohemian Massif, Czech Republic. SAED patterns and HRTEM images detail the close structural relationship between host clinopyroxene and α-cristobalite precipitate: [001]α || [010]cpx, (010)α ~ (101)α. TEM results indicate that α-cristobalite exsolved from host clinopyroxene. Non-crystalline Al-bearing silicate phases, also exsolved from UHP clinopyroxene, possesses Al/Si ratios close to eutectic compositions in the system NaAlSi2O6-SiO2-H2O system. The presence of glass exsolution suggests a high-temperature formation environment and presence of water. The α-cristobalite formed in a localized low-pressure, micro-environment formed through exsolution of vacancies and excess silica from the host pyroxene lattice. This micro-environment may be a result of negative density changes due to excess lower density silica exsolving from higher density pyroxene during an exsolution process that involved no localized volume change. Interface-controlled exsolution via lattice matching at the diopside/cristobalite interface, and stability changes and melting point depression due to nanoscale size effects contributed to the formation and persistence of this metastable phase. Amphibole in association with α-cristobalite and some non-crystalline silicate phases may be a clue to localized water quantities; silica exsolution with amphibole may have formed below the eutectic temperature and at a later stage than non-crystalline silicate phases without amphibole. Silica rods in Nové Dvory clinopyroxenes were previously thought to be quartz; however, our investigation reveals various low-pressure, high-temperature, and/or metastable phases greatly affected by the presence of vacancy and OH in clinopyroxenes. The results will help us better understand OH in the UHP pyroxene and even water release in the mantle.

Keywords: UHP, diopside, silicate glass, cristobalite, TEM, vacancy, OH, eclogite; Isotopes, Minerals, and Petrology: Honoring John Valley

INTRODUCTION

Discoveries of coesite (Smith 1984) and microdiamond in the Kokchetav Massif (Sobolev and Shatsky 1990) have clearly established that rocks of continental origin were subjected to ultrahigh-pressure metamorphism (UHPM), which required their subduction to a depth of not less than 80–120 km (Chopin 1984; Smith 1984; Schreyer et al. 1987; Sobolev and Shatsky 1990; Xu et al. 1992; Coleman and Wang 1995; Dobrzhinetskaya et al. 1995; Wain 1997; Ye et al. 2000; Van Roermund et al. 2002; Carswell et al. 2006; Dobrzhinetskaya et al. 2006). It is in these deeply subducted terranes that micro- and nanoscale minerals within stable host minerals such as garnet and pyroxene are often preserved, even though prograde textures and mineral parageneses are typically obliterated during exhumation from great depth. Micro- and nanoscale minerals of these orogenic terranes are of particular interest to investigators because they are windows to the special conditions required to develop UHPM terranes when no other evidence persists, and aids in elucidating the geodynamic processes endured by them.

Crystallographically oriented silica rods exsolved in clinopyroxene, many coexisting with amphibole, are well-documented from ultrahigh-pressure (UHP) terranes around the world: (Bakun-Czubarow 1992; Smith 1984; Gayk et al. 1995; Wain 1997; Katayama et al. 2000; Schmadicke and Muller 2000; Tsai and Liou 2000; Dobrzhinetskaya et al. 2002; Zha and Ogawasara 2002; Klemd 2003; Song et al. 2003; Janak et al. 2004; Sajeev et al. 2010; Dokukina and Konilov 2011; Konilov et al. 2011; Bi et al. 2018; Song et al. 2018). Although there is at present evidence of HP (and not UHP) clinopyroxenes possessing these crystallographically oriented silica precipitates in the Blue Ridge Mountains, U.S.A., the Kontum Massif, central Vietnam, and the Greek Rhodope (Page et al. 2005; Anderson and Moecher 2007; Nakano et al. 2007a, 2007b; Proyer et al. 2009; Faryad and Fisera 2015; Li et al. 2018), in the dearth of other UHP evidence the siliceous rods are often used as indicators of rocks experiencing UHP conditions. The breakdown textures of clinopyroxene and its chemical variations may help us to investigate pre- and post-park rock evolution of the host rock.

Reports of silica exsolution in clinopyroxene have previously been identified by micro- and macroscale techniques as either coesite or quartz (Bakun-Czubarow 1992). For instance, Zhang et al. (2005) demonstrated that silica exsolution took place in...