



Atomic scale structure of a plagioclase – magnetite interface

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Magnetite (Mt) is the foremost carrier of rock natural remanent magnetization (NRM). Needle- and lath shaped Mt micro-inclusions in plagioclase (Pl) from gabbro often have systematic crystallographic- and shape orientation relationships (CORs, SORs) with the Pl host. The SORs of Mt leads to magnetic anisotropy which may bias the NRM of the Mt-Pl inclusion-host assemblage. Thus, the origin of the CORs and SORs between Mt and Pl is important for paleomagnetic reconstructions. In this context, the atomic structures of Mt-Pl interfaces are of particular interest.

The CORs and SORs between Mt and Pl were reported earlier and the underlying systematics was revealed from correlated optical and scanning electron microscopy (SEM) including electron back scattered diffraction (EBSD) analyses [1] (and references therein). The so-called plane normal type Mt micro-inclusions extend parallel to the Mt<111> direction, which is perpendicular to the densely packed Mt{222} oxygen layers that are parallel to one of seven Pl lattice planes with nearly identical d-spacings, namely Pl(112), Pl(-312), Pl(1-50), Pl(150), Pl(100), Pl(31-2) and Pl(1-12). Direct imaging of Mt-Pl interfaces has rarely been reported due to the beam sensitivity of Pl. Here we present the microscopic structure of a Mt-Pl interface along the inclusion elongation direction using high angle annular dark field scanning transmission electron microscopy (HAADF-STEM) and integrated differential phase contrast STEM (iDPC-STEM) techniques.

The TEM foil was prepared using a focused Ga-ion beam (Ga-FIB) from a lath-shaped Mt micro-inclusion of 23 μm x 17 μm x 0.1 μm extending perpendicular to Mt{111}/Pl(-312). The foil is oriented so that the Mt<111>/Pl(-312)-pole are parallel and Mt{110}/Pl(150) planes are perpendicular to the foil.

The STEM images show that the Mt-Pl interface is perfectly straight and parallel to Mt{110}/Pl(150) and that it is devoid of steps. Electron diffraction patterns confirm that the elongation direction of the micro-inclusions is determined by the good fit of oxygen layers across the Pl-Mt interface. A 2.4% difference in the d-spacings between Pl(-312) and Mt{222} is likely accommodated by every about 42nd Mt{222} plane forming an edge dislocation at the Mt-Pl interface. In addition, elastic strain is indicated by a deviation of d_{111}/d_{110} of Mt from the strain free reference lattice. Moreover, lattice fringes in iDPC-STEM images reveal coherence between Pl(22-1) and Mt{111} planes without misfit dislocations. This additional coherence may explain the particularly strong alignment of

Mt{111} and PI(-312) reflected by the EBSD data.

In summary, the elongation directions of the Mt inclusions are determined by the alignment of important oxygen layers of both phases across the Mt-PI interface, which is parallel to oxygen-rich lattice planes in both phases. Misfit dislocations are presumably introduced to compensate the 2.4% lattice misfit along the elongation direction. The well-organized interface structure ensures a low interfacial energy and is a viable explanation for the observed Mt-PI CORs and SORs.

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Reference

[1] Ageeva et al (2020) Contrib. Mineral. Petrol. 175(10), 1-16.