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Evaluation of the Effect of Polishing Condition on Hydrogen Diffusion in Fluorapatite and Estimation of Diffusion Mechanism

CHIKASHI YOSHIMOTO[1], SHOICHI ITOH[1] AND ISAO SAKAGUCHI[2]

[1]Kyoto University
[2]National Institute for Materials Science

Hydrous minerals are important because their hydrogen isotopic compositions can reveal the origin and evolution of water in planetary materials. Because the hydrogen isotopic composition can change from the composition at the time of formation due to diffusion phenomena, experiments have been conducted to determine the hydrogen diffusivity in hydrous minerals [1]. The activation energies of hydrogen diffusion have mostly been less than 100 kJ/mol, and it has been argued that diffusion occurs as protons as the diffusing species. Fluorapatite is an even more important hydrous mineral because of its strength and ubiquity.

Vibrational chemical polishing was used to minimize the effects of fast diffusion due to surface damage caused by polishing [2]. Diffusion experiments were performed at 550-700°C using $^{2}H_2O$ as the diffusion source. The depth profiles obtained by SIMS fit the one-dimensional diffusion model well into low concentrations and gave accurate diffusion coefficients parallel to the c axis. The activation energy changed from ~80 kJ/mol to ~200 kJ/mol with removal of polishing damage (Fig. 1) [3], consistent with the activation energy of oxygen diffusion under wet conditions [4]. This suggests that hydrogen and oxygen diffusion in apatite is by the same mechanism and that OH^- is the diffusing species.

Additional experiments performed diffusion normal to the c-axis, but surface defects still prevented reliable fitting; pre-annealing at 700°C in $^{1}H_2O$ wet-flow was introduced to reduce dislocations and extend the fitting range of results. The activation energies agreed within error with //c [2], suggesting that a diffusion mechanism is responsible for the OH^-. The 3-fold difference in the coefficients was due to geometrical factors. These findings indicate the need to change our understanding of hydrogen diffusion in hydrous minerals. Therefore, we propose that the mechanism of hydrogen diffusion in other hydrous and/or anhydrous minerals can be systematically affected by polishing damage and defect density in the crystals, and that it should be investigated.

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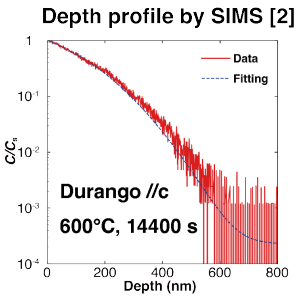


Fig. 1

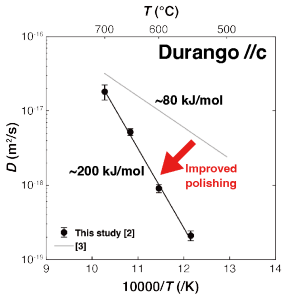


Fig. 2