Comparative study of Cr$^{3+}$ diffusion in chrysoberyl (BeAl$_2$O$_4$) irradiated by H$^+$ ions and electrons

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Abstract

Cr$^{3+}$ diffusion in chrysoberyl (BeAl$_2$O$_4$) irradiated by H$^+$ ions and electrons has been studied and compared with diffusion in non-irradiated samples. Chrysoberyl (BeAl$_2$O$_4$) crystals were irradiated with 6MeV H$^+$ ions to fluencies of $1 \times 10^{16}$ cm$^{-2}$ for 25 min and with 10 MeV electrons to fluences of $2 \times 10^{17}$ cm$^{-2}$ for 1 hour. Photoluminescence measurements with a 325nm He-Cd source showed that the electron beam irradiated sample formed more defects in the crystal lattices than the H$^+$ ions. Three different types of samples, which were doped with Cr$^{3+}$, were annealed in horizontal alumina tube furnaces by 50K intervals in the temperature range from 1773K to 1923K for 200 hours. SEM-EDAX was used to measure the diffusion.

Introduction

Chrysoberyl (BeAl$_2$O$_4$), which is isomorphous with olivine, has an orthorhombic structure with $a = 9.404$, $b = 5.476$, and $c = 4.427\text{Å}$ based on a hexagonal close-packed arrangement of oxygen with Al$^{3+}$ in the center of octahedral sites and interstitial Be$^{2+}$ tetrahedral sites. Alexandrite (BeAl$_2$O$_4$: doped Cr$^{3+}$) is a variety of chrysoberyl, which demonstrates a color change due to Cr$^{3+}$ ions in the crystal, which substitute for the Al$^{3+}$ ions of the chrysoberyl structure; 78% of the sites occupied by Cr$^{3+}$ ions have mirror symmetry (C$_s$) and 22% display inversion symmetry (C$_i$).

Result & Discussion

The concentration profile of Cr in the chrysoberyl after annealing at 1650$^\circ$C for 200 hours in the oxidation according the Gaussian type.

Arrhenius plot of Cr diffusion & Variation of structure in Al$_2$O$_3$ after irradiation

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Conclusions

We tried to diffuse chrysoberyl samples with Cr$_2$O$_3$ powder under by three methods (i.e. electron beam irradiation, H$^+$ ion beam irradiation and non-irradiation). When these were diffused in the presence of Cr$_2$O$_3$ powder, electron beam irradiation showed deepest penetration, followed by H$^+$ ion beam irradiation, and then non-irradiation. Also, equations for the Arrhenius diffusivities for the three cases were also developed.