

Comparative study of Cr³⁺ diffusion in chrysoberyl (BeAl₂O₄) irradiated by H⁺ ions and electrons

Yong-Kil Ahn and Jong-Wan Park

Division of Materials Science and Engineering, Hanyang University
17 Haengdang-Dong, Seongdong-Gu, Seoul, 133-791, Korea

Abstract

Cr³⁺ diffusion in chrysoberyl (BeAl₂O₄) irradiated by H⁺ ions and electrons has been studied and compared with diffusion in non-irradiated samples. Chrysoberyl (BeAl₂O₄) crystals were irradiated with 6MeV H⁺ ions to fluencies of 1 × 10¹⁶ cm⁻² for 25 min and with 10 MeV electrons to fluencies of 2 × 10¹⁷ cm⁻² for 1 hour. Photoluminescence measurements with a 325nm He-Cd source showed that the electron beam irradiated samples formed more defects in the crystal lattices than the H⁺ ions. Three different types of samples, which were doped with Cr³⁺, 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 (BeAl₂O₄), which is isomorphous with olivine, has an orthorhombic structure with a = 9.404, b = 5.476, and c = 4.427Å based on a hexagonal close-packed arrangement of oxygen with Al³⁺ in the center of octahedral sites and interstitial Be²⁺ tetrahedral sites. Alexandrite (BeAl₂O₄:doped Cr³⁺) is a variety of chrysoberyl, which demonstrates a color change due to Cr³⁺ ions in the crystal, which substitute for the Al³⁺ ions of the chrysoberyl structure; 78% of the sites occupied by Cr³⁺ ions have mirror symmetry (C_v) and 22% display inversion symmetry (C_i).

Structure of chrysoberyl

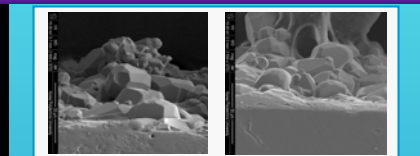


Result & Discussion

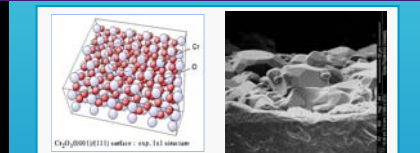
Nova nano Scanning electronic microscope image



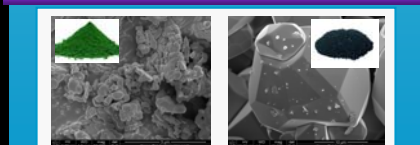
Cr-rich and Al-rich layer of diffused Surface before diffusion



Heated at 1500°C for 200hours Heated at 1550°C for 200hours

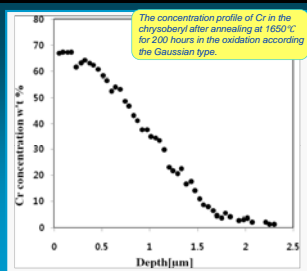


Structure of Cr₂O₃ Heated at 1600°C for 200hours

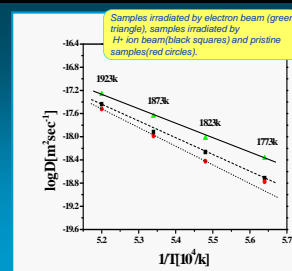


Cr₂O₃ powder before heating Cr₂O₃ powder after heated

Arrhenius plot of Cr diffusion & Variation of structure in Al₂O₃ after irradiation



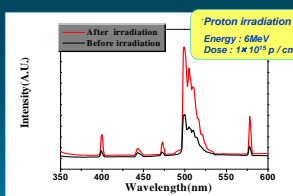
The concentration profile of Cr in the chrysoberyl after annealing at 1650°C for 200 hours in the oxidation according to the Gaussian type.



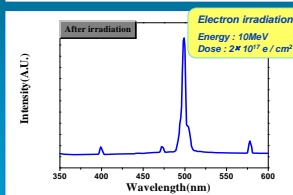
Samples irradiated by electron beam (green triangle), samples irradiated by H+ ion beam (black squares) and pristine samples (red circles).

The concentration profile of Cr

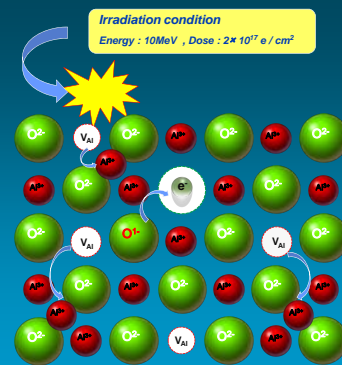
Arrhenius plot of Cr diffusion



Proton irradiation
Energy : 6MeV
Dose : 1 × 10¹⁶ p / cm²



Electron irradiation
Energy : 10MeV
Dose : 2 × 10¹⁷ e / cm²



Irradiation condition
Energy : 10MeV , Dose : 2 × 10¹⁷ e / cm²

Variation of photoluminescence spectra & structure in Al₂O₃ after irradiation

Conclusions

We tried to diffuse chrysoberyl samples with Cr₂O₃ 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 Cr₂O₃ 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.



First Author : Yong-Kil Ahn +82-2-2220-1165
Hanyang University , Seoul, Korea
E-mail to ykahn@hanyang.ac.kr