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Coloration of natural beryl by iron ion implantation

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Abstract

Natural colorless crystals of Ural beryl were implanted at room temperature with 40 keV Fe^+ ions with fluences in the range of $0.5–1.5 \times 10^{17}$ ion/cm^2. As-implanted samples show dark-grey tone due to radiation damage of beryl crystal. Subsequent thermal annealing of irradiated crystals in oxygen at 600 °C for 30 min results in the color change, to yellowish or yellow–orange tones with golden luster, depending on value of iron fluence. The nature of beryl coloration was studied by optical absorption, Mössbauer and Rutherford backscattering (RBS) spectroscopes. It was established that the thermal treatment of iron-irradiated beryl lead to inward diffusive redistribution of iron ions. An appearance of optical absorption bands connected with charge-transfers $O^{2-} \rightarrow Fe^{3+}_{VI}$ and $O^{2-} \rightarrow Fe^{2+}_{IV}$, Fe^{3+}_{IV} determine the yellow tone in colored beryls. Most of implanted iron ions are founded in both tetrahedral Fe^{2+}_{IV} and octahedral Fe^{3+}_{VI} sites where they may substitute beryllium and aluminum host ions by isomorphic way.
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1. Introduction

Beryl, $Be_3Al_2(SiO_3)_6$, is a ring silicate mineral whose hexagonal crystalline structure was firstly described by Bragg et al. [1]. Pure beryl is colorless and transparent. However, beryl crystals may show various color tones if they contain transition metal ions as an impurity localized in crystalline sites [2,3]. For example, green color of emerald is caused by Cr^{3+} ions in aluminum sites, and pink beryl (morganite) is colored by Mn^{3+}_{Al} ions. Different correlation of the Fe^{2+} and Fe^{3+} ions in structural and interstitial positions of the crystal determine the color of the Fe-containing beryls from blue aquamarines to yellow–orange heliodors. Note that intensively colored yellow beryls with metallic luster are known in gemology as golden beryls.

Ion beam technology enables to introduce any chemical element in the near-surface layer of materials, and a possibility of coloring natural minerals by ion implantation may be an interesting issue. However, few works (e.g. [4,5]) have been

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