Point defect production by monochromatic x-rays above and below the K-absorption edges in KBr and RbBr

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Introduction

It is well known that ionizing radiation such as x-rays, vacuum ultraviolet or fast electrons, cause radiation damage in the alkali halides mainly through the efficient formation of F-centers (electrons trapped at negative ion vacancies) and H-centers (interstitial halogen atoms). Thus point defects or color centers are formed in the volume of the crystals largely through the recombination of electron-hole pairs across the valence band. In the case of x-rays the initial stage coloration efficiency turns out to be about 1 keV per F-center and this efficiency varies slowly, if at all, with x-ray energy. The question arises as to whether or not significant new channels for defect formation arise, due to Auger and other processes, when the ionizing x-ray radiation is capable of producing holes within the inner core levels. Suggestions that this occurs above the K-absorption edges appear in the early and recent literature. Here we extend this search to KBr and RbBr.

Methods and Materials

The materials KBr and RbBr are of special interest since the relative ion sizes in these ionic crystals lead to fairly efficient formation of F-centers (the Rabin-Klick criterion). Rubidium bromide is also a material of possible interest in connection with x-ray image plate technology. We have therefore carried out experiments on the initial stages of coloration using highly monochromatic x-rays at the PNC-CAT beamline on the APS Sector 20. The results on KBr were obtained within the beamline's FOE in late 1997 and reported as an invited paper in Il Nuovo Cimento [1]. The work on RbBr was carried out in the experimental hutch for the undulator in late 1998 and recently reported in Physical Review[2].

A sensitive laser-induced F-center luminescence technique was used to detect the point defects as they were produced in the single crystals of KBr or RbBr mounted within a cryostat at 77K. Before the radiation damage experiments the K-absorption edges at 13.48 keV for Br and at 15.21 keV for Rb were measured on relatively pure material. The near edge structure was well resolved, including the white lines at or below the edges. Exposure of the single crystals was then carried out at different wavelengths below and above the absorption edges, detecting the F-centers by their laser-induced luminescence as they were produced during the initial stages of coloration. Experiments were carried using relatively high x-ray intensity, and also with very low intensity, by detuning the undulator gap so that the incoming radiation was well down the side of the first undulator harmonic.

Results

A large increase in F-center formation efficiency was not found upon crossing the bromine K-edge in either material. Similarly, little or no increase was found upon crossing the rubidium K-edge in RbBr. Some decrease in efficiency occurs above the edges, but this can largely be explained in terms of the loss of x-ray fluorescence energy when in the incoming radiation is above the absorption edge.

Discussion

These results indicate that above the edges Auger-cascade and other possible mechanisms do not effectively compete with the usual multiple ionization electron-hole recombination processes known to generate point defects. This is in reasonable agreement with theoretical estimates of the number of electron-hole pairs produced by the ionizing radiation and estimates of the Auger processes. In the course of the work it was found that the laser-induced luminescence method for detecting F-centers is especially useful over a wide dynamic range in pure crystals such as KBr and RbBr. The method might well compliment studies of photo-stimulated luminescence in in RbBr:Tl as well as other image plate materials such as BaFBr:Eu.

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References

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