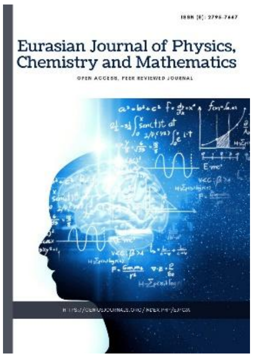

Generation And Aggregation Of Radiation Defects In Lif Crystals Under Gamma Irradiation

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ABSTRACT

The absorption spectra of LiF crystals irradiated with gamma radiation in a ^{60}Co source at a power of 1200 R/s in the dose range of 10^5–10^8 R and a temperature of 320 K were studied. Gamma irradiation initially produces F-centers in the crystal, with an absorption band peaking at 250 nm and increasing in intensity with increasing dose across the entire range of doses studied. Increasing the irradiation dose leads to interactions between F-centers and the formation of more complex complexes, such as F_2 - and F_2^+ - centers. The increase in the intensity of these bands, especially those of the R - and N- centers, at doses above 10^7 R indicates defect aggregation and the formation of stable color centers, which are the basis for the formation of nanoparticles in the crystal structure.

Keywords: LiF crystal, optical absorption, color centers, gamma-ray irradiation

Introduction

LiF crystals are widely used in optics, radiobiology, and medicine as ionizing radiation dosimeters, as well as model objects for studying radiation defects in ionic crystals. Under the influence of gamma radiation, point defects such as F-centers (vacancies that have captured electrons) and more complex aggregates arise in LiF, which significantly affect its optical properties [1]. The accumulation of various types of defects in pure alkali halide crystals, including LiF, is based on the creation and transformation of intrinsic primary structural defects in ionic crystals: F-, H-, V_k-, I- and other centers [2]. The probability of radiation accumulation of F-centers in pure alkali halide crystals can be represented as the product of the probabilities of generation, separation and stabilization of primary defects (F, H-pairs):

$$P_{acc}(D,T) = P_{gen}(D,T) \cdot P_{sep}(D,T) \cdot P_{stab}(D,T)$$

These three probabilities depend on the type, dose, and temperature of irradiation, and their effectiveness is determined by the motion of the H-center, which leads either to the annihilation of Frenkel pairs or to the spatial separation of the pair components [3]. Later, the authors of [4] studied the formation of metal lithium nanoparticles and their optical characteristics after high-dose (5Ч10^8 R) γ-irradiation of LiF crystals 0.3 mm thick and their subsequent annealing at 600–650 K. Atomic-force microscopy images showed the presence of chaotically distributed bulges formed by lithium nanoparticles from 10 to 30 nm in size, to which the authors assigned the absorption band near 290 nm (unresolved from the 250 nm band of the *F* - center).We have shown by X-ray diffraction that radiolysis (dose 10^8 R, ^{60}Co source of ~1.25 MeV γ - quanta with 765 R/s in water) leads to twinning of the LiF crystal lattice with the {100} orientation and to formation of LiOH nanocrystals (reflection 112) with an average size of 28 nm [5]. Then, we studied electro conductivity within the temperature range of 190–400 K in LiF crystals before and after irradiation with doses of 7.8Ч10^5–10^8 R with 406 R/s at 300 K [6]. Characteristic hopping conductivity over localized states with a peak around 300 K was observed only after irradiation, which leads to the formation of aggregates of two or more electronic *F* centers and Li nanocolloids [7,5,6, 8–10].

Therefore, the study of defect formation processes depending on the type, dose, and temperature of irradiation is of great importance. Based on this, the aim of this work is to investigate the effect of γ - radiation dose on the creation and transformation of radiation defects in LiF crystals.

Materials and methods

The objects of the study were nominally pure LiF crystals, manufactured in the form of 1Ч1Ч0.2 cm^3 plates. Irradiation was carried out using a gamma setup of the Institute of Nuclear Physics of the Academy of Sciences of the Republic of Uzbekistan with a ^{60}Co source with a power of 1200 R/s in the dose range of $10^5 \times 10^8$ R at a temperature of 320 K. Optical absorption spectra were measured using a Spectromom-202 optical spectrometer in the spectral range of 200–800 nm at room temperature of 320 K.

Results and discussion

Figure 1 shows the absorption spectra of gamma-irradiated LiF crystals, which shows that under the influence of gamma rays, *F*-centers with an absorption band with a maximum at 250 nm are first created in the crystal, the intensity of which increases with dose over the entire range of doses studied.

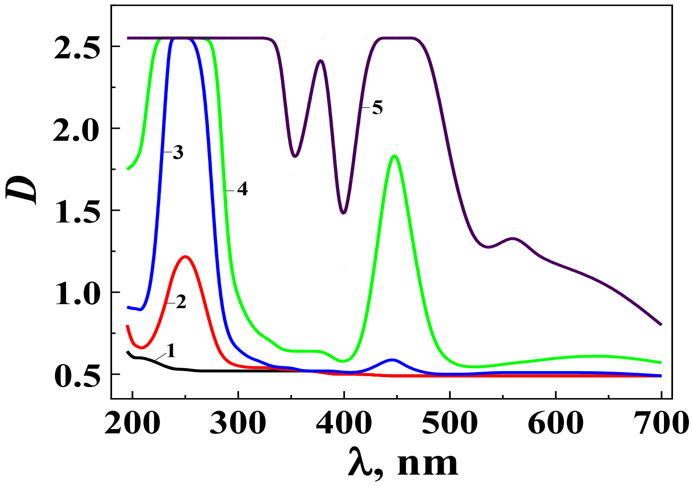

Fig. 1. Absorption spectra of non-irradiated (1) and irradiated with γ-radiation doses of 10^5 P (2), 10^6 P (3), 10^7 P (4) and 10^8 P (5) LiF crystals

Starting with a dose of 10^6 R, in the spectrum, along with the *F*-band, a band of *M*-centers with a maximum at 445 nm appears (Figure1, curve 3), starting with a dose of 7Ч10^6 R, bands of *R*-centers (maximum at 378 nm) and M^+-centers (maximum at 630–640 nm) are detected in the spectrum (Figure1, curve 4), and at a dose of 10^7 R, bands of *N*-centers with a maximum at 550 nm are also visible (Figure 1, curve 5). With a further increase in the irradiation dose, the intensity of 445 nm increases very strongly (Figure 2, curve 2). At the same time, the rate of increase in the intensity of the *F*-center band slows down (Figure 2, curve 1).

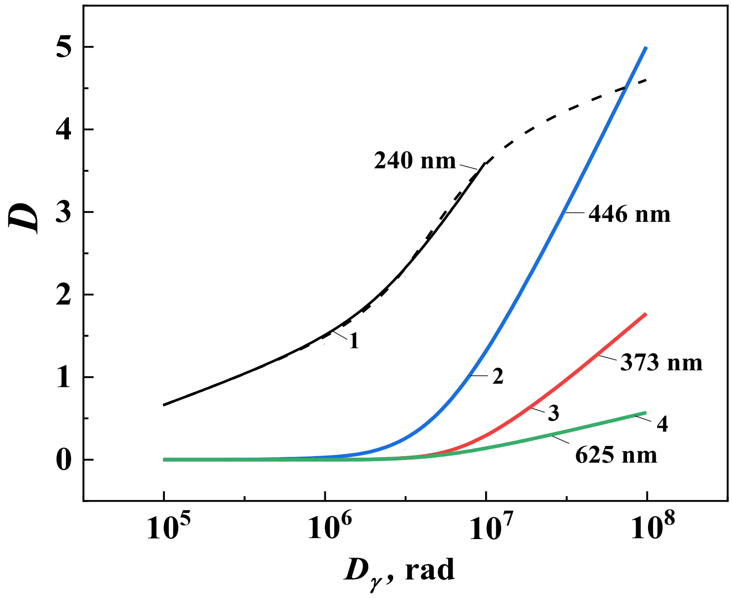

Fig. 2. Dose dependence of the change in the absorption intensity of *F*- (1), *M*- (2), *R*- (3) and *N*- centers (4) in a gamma-irradiated LiF crystal

The above experimental data show that in the dose range of 10^5–10^8 R, an intense increase in the absorption band of *F*-centers is observed in the region of about 250 nm, corresponding to single anion vacancies that have captured an electron. An increase in the irradiation dose leads to the interaction of *F*-centers with each other and the formation of more complex complexes, such as F_2 -, F_2^+ -centers.

Conclusion

The increase in the intensity of these bands, especially the bands of *R*- and *N*-centers at doses above 10^7 R, indicates the aggregation of defects and the formation of stable color centers, which are the basis for the formation of nanoparticles in the crystal structure [8, 10]. With a further increase in the dose (above 10^8 R), partial saturation or redistribution of defects is possible, which is expressed in changes in the dose dependences of the absorption bands shown in Fig. 2.

The results can be useful in optimizing the conditions of radiation dosing and studying defect formation in ionic crystals.

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