ANNOTATION

of the dissertation for scientific degree of doctor philosophy (PhD)
6D060400 – Physics

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Color centers and nanodefects in LiF crystals, irradiated with fast ions

Topicality of the Work.

During for many years the alkali halide crystals (AHC) is actually objects not only basic research but also for different applications. On the basis of their proposed optical media for recording and storing information, laser materials, color - filter near and infrared band, thermoluminescent dosimeters. LiF crystals used in dosimetry(in radiobiology, radiation therapy, individual monitoring). Color centers in LiF crystals used for the development of new effective pulsed lasers. Thin films of LiF crystals with color centers are used for recording and information processing.

LiF crystals are model matrix in the study of a many problems in solid state physics. Lithium fluoride is also used for biological protection of nuclear reactors. At the present time we have perspective using lithium fluoride as an active element in thermonuclear fusion.

The purpose of the work

The purpose of this paper is the study process of electron color centers and nanodefects in LiF crystals after heavy and light ions. The defect formation process studied depending on loss of energy ions, power of ion beam and absorbed energy (fluence).

Objects of the Work

The object of the work was being LiF crystals. In these crystals has been studied the formation of color centers during irradiation by electrons and X-rays. All that can reveal features of processes of ion irradiation.

The subject of the research

1. Spectroscopic studies of color centers in LiF crystals by irradiation with different ions;
2. Investigation the kinetics of accumulation of simple and complex electron color centers in LiF crystals irradiated by swift heavy and light ions;
3. Development of complex methods investigation of radiation damages in irradiation LiF crystals with used optical and luminescent spectrometry, scanning electron and atomic force microscopy;
4. Identify the role of anion vacancies in the formation of complex color centers after irradiation and annealing;
5. Investigation nanodefects on the surface and in the bulk of lithium fluoride crystals after chemical etching with used scanning electron microscope and atomic force microscope.

Validity and reliability of the work:

1. Originality tasks and the choice of research methods.
2. Using well-proven techniques for measuring the optical properties of crystals and complementary methods of physical experiments, such as luminescence, electronic and atomic force microscopy, mechanical properties of crystals.
3. Volumes and statistics of experimental dates and their analysis.

Research methods.

In this paper we used absorption spectroscopy for assess the types and concentrations of color centers induced ion irradiation. We was used fluorescent spectroscopy for the separation of F_2 and F_3^+ color centers during irradiation and annealing of irradiated crystals. Nanostructure defects on surface were studied by scanning electron and atomic force microscopy. Mechanical properties were investigated using the nanoindentation.

Scientific novelty of the Work.

For the first time in this work experimentally demonstrated the role of F_2 and F_3^+ color centers and anion vacancies (V_a^+) after irradiation and annealing in LiF crystals. Peculiarities of formation of F and F_n color centers depending on the electron energy losses. Nanodefects studied on the surface and in the bulk irradiation crystals LiF.

The main provisions for the defense

1. Concentration of single F centers has saturated N_F^{sat} ~ 10^{19} cm^{-3} with increasing absorbed energy. N_F^{sat} saturation for heavy ions ^{84}Kr performed at lower absorbed energy than if irradiated by light ions ^{14}N.
2. Formation of complex F_n color centers depends of the loss of energy and the absorbed energy. The absorption spectrum the various F_n centers dominated is F_2 and F_3^+ color centers.
3. In LiF crystals irradiated with nitrogen (^{14}N) showed a decrease of concentration of single F and complex F_n centers for large absorbed energy due to the formation of larger aggregates.
4. In LiF crystals, irradiated by ^{84}Kr ions was a founded nanodefect (nanocrystallites, dislocation loops) on the surface and at depth along the track. In LiF crystals irradiated by nitrogen ions (^{14}N) are found only dislocation loops.

Scientific and practical significance of the Work

The results of the thesis can be used:

1. • For optimization dosimeters of ionization radiation;
2. • For modeling the effects caused by fission fragments in dielectric materials, including minerals for geology.
3. • For optimization the LiF crystals for color center lasers.
4. • For optimization the LiF crystals for recording and processing.

Conclusions.

1. It has been determined that the concentration of single color centers (F centers) saturates (N_F^{sat} ~ 10^{19} cm^{-3}) with the increase of the absorbed energy. Saturation occurs earlier for ions with a large value dE/dx.

2. It has been shown experimentally that for ^{14}N ions at high energy absorption is observed not only a decrease in the concentration of single *F* but also and complex F_n centers due to the formation of larger aggregates. This effect is absent in LiF crystals, irradiated by heavy ^{84}Kr ions.
3. It is found that the efficiency for luminescence for F_2 and F_3^+ color centers in LiF crystals irradiated with ^{14}N, ^{40}Ar and ^{84}Kr ions is lowering with an increase in both dE/dx ions, and the increase in the absorbed energy.
4. In crystals irradiated with ^{84}Kr ions ($F \geq 10^{13}$ ions/cm^2) found columnar nanostructures (size 30-90 nm) in the track areas with a critical loss of energy (dE/dx ≥ 10 keV/nm); in the last of the track formed only dislocation loops.
5. Experimentally confirmed that nanostructures are thermally stable up to a T = 500K temperature. At higher temperatures nanocrystals fall to fall to pieces into many dislocations which gradually annealed at T ≈ 830 K with the restoration of the original structure.
6. It has been shown that irradiation with an angle the decrease hardened layer with save structure retaining created nanodefects.
7. It has been shown that irradiation of LiF crystals with light ions (^{14}N and ^{40}Ar) formed a single-type structure, rich of dislocations and with enhanced hardness.

Personal contribution of the author. The author was direct participation in the statement of the problem in the dissertation and in the all studies presented in this paper, including the irradiation of the crystals with used DC-60cyclotron.

Approbation of the Work and Publications.

23 works including in 8 articles in reviewed journals (3 article in information base Web of Knowledge (Thomson Reuters), 2 articles in foreign journals, 3 articles in journals recommended by Comity of the Control in Education and Science of MES of the RK) and 15 abstracts and papers in proceedings of international conferences are published based on the materials of the dissertation.