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INVESTIGATION OF RADIATION DEFECTS IN SOLIDS USING THE EXAFS METHOD

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О ВОЗМОЖНОСТИ ПРИМЕНЕНИЯ ДАЛЬНЕЙ ТОНКОЙ СТРУКТУРЫ РЕНТГЕНОВСКОГО ПОГЛОЩЕНИЯ EXAFS В РАДИАЦИОННОЙ ФИЗИКЕ ТВЕРДОГО ТЕЛА

По анализу имеющихся методик исследований радиационных дефектов в твердых телах выдвинуто предложение об использовании EXAFS - методики для этих целей как более информативной и универсальной. Приводятся первые успешные результаты, полученные автором по применению EXAFS - измерения в сочетании с синхронным излучением, для изучения радиационных дефектов в кристаллах GaAsP, облученных электронами с энергией 50 МэВ.

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INVESTIGATION OF RADIATION DEFECTS IN SOLIDS USING THE EXAFS METHOD

The EXAFS method is proposed as a more informative, universal one to investigate the radiation defects in solids. The successful results as obtained by the author using the synchrotron radiation source are reported for the first time. The measurements were carried out in GaAsP crystals irradiated with 50-MeV electrons.

Yerevan Physics Institute

Yerevan 1983

Y E R E V A N   P H Y S I C S   I N S T I T U T E

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Different well-known methods are used in the investigation of solid state radiation physics, i.e. the Hall effect and electroconductivity temperature dependence, the optical absorption, the minority carrier lifetime, the ESR-measurement, thermoconductivity, etc. They allow one to describe the solid state electrophysical, optical and recombination parameters after irradiation, in general, and make the assumptions as to the nature of the radiation defects using "indirect" data.

The "direct" electromicroscopical and X-ray structural methods available are not effective to find out simple results because of orientation, dimension and other limitations. However the immediate observation and the measurement of the solid state radiation defects, particularly in crystals, are important since the radiation cluster properties are different in different regions of the crystal, being hence interpreted ambiguously in the literature.*

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* The idea of the edge absorption analysis as applied to the radiation defects was suggested by Prof. A.Ts.Amatuni to whom the author is deeply grateful.

The kinetics and distribution of the simple radiation defects even in the atomary single crystals need for a more detailed immediate measurement and explanation.

Therefore it is necessary, to our mind, to attract a "direct", more informative method for measuring the radiation defects to define the dimension, the form and the energy structure of the radiation damage. For this purpose, the EXAFS study is applied in our present work as a successful attempt on the basis of GaAsP solid solution irradiated with 50- Mev electrons [1,2].

Single crystals GaAsP epitaxy grown on the GaAs substrate were used. The substrate was polished out and the plates of GaAsP samples were reduced mechanically to the smooth (mirror) surface. The thickness of 20-40 10^3 nm was obtained optimal for observing EXAFS, the sensitivity was 15% of the edge absorption.

The experimental arrangement consists of an X-ray monochromator with the channel-cut Ge (111) crystal and the intensity was monitored by an ionization chamber [3]. The temperature of the samples was near the room temperature, the other conditions being equal.

The synchrotron radiation from VEPP-3 storage ring at the Novosibirsk Nuclear Physics Institute was used as the source.

In Fig.1 the absorption coefficients of $GaAs_xP_{1-x}$ (x = 32%) were compared before and after the irradiation with 50-MeV electrons and the fine structure after the irradiation (dotted line) was revealed.

The results were analyzed by the computer system. In Fig.2 the functions $\chi(K)=(\mu-\mu_o)/\mu_o$ (where μ, μ_o are the absorption coefficients at the given point and at the smooth spectral dependence region without oscillations) are given after the third-order polynomial approximation versus the photoelectron wave number K . Fig.3 presents the Fourier-transform, the comparison of the radial distribution functions shows that the radius of the first coordination sphere is increased by 2.6 nm (±0.2 nm) owing to the irradiation.

The Debye-Waller factor is calculated on the basis of the phase shift invariability (see the Table in Ref. [4]) and this gives rise to an increase of the Debye-Waller factor by 3, that testifies about a large mean square relative displacement of the atoms due to the irradiation. The atom distribution at the first coordination sphere is calculated by the curve fitting method. The most probable and experimentally reasonable result is obtained when the gallium central atom is surrounded by 3 atoms of phosphorus and one atom of arsenic in the diamond type GaAsP crystal lattice with coordination numbers 4+12+12+6+...

At present, works are being carried out to define the atomic distribution on the higher coordination spheres to determine the cluster radiation defects, its geometric and energetic structure of the radiation damage.

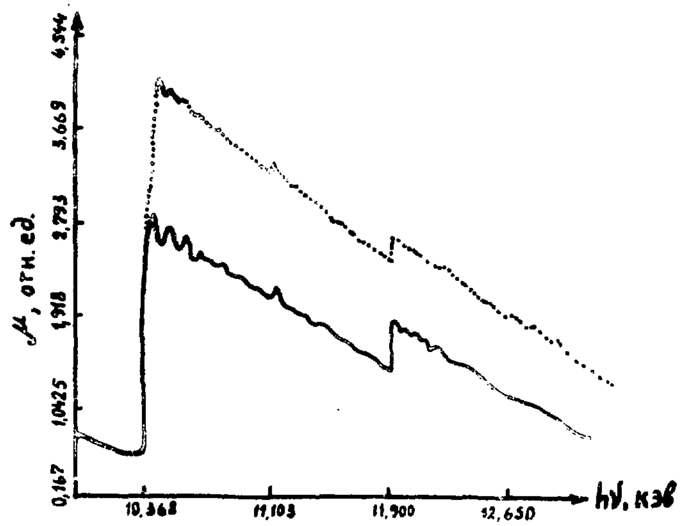
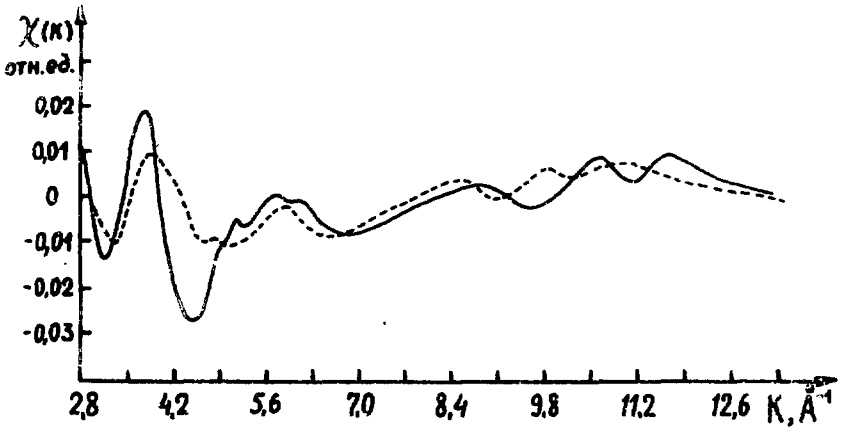


Fig.1. The absorption coefficient of single crystals $GaAs_xP_{1-x}$ (x = 32%) versus the energy of incident quanta above the K-edges of Ga and As. Solid line - before irradiation, dotted line - after irradiation with 50-MeV electrons.



The relative absorption coefficient of gallium atoms above the K-edge versus the wave vector in single crystals $GaAs_xP_{1-x}$ (x = 32%). Solid line - before irradiation, dotted line - after irradiation with 50-MeV electrons.

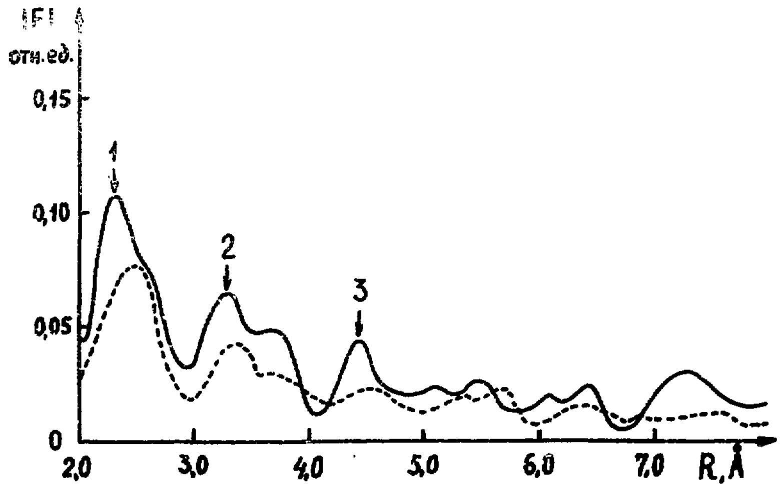


Fig.3. The radial distribution of the Fourier-function modulus after the Fourier-transform of data in Fig.2. Solid line - before irradiation, dotted line - after irradiation with 50-MeV electrons. (The arrows indicate the numbers of the coordination spheres).

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