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Effects of annealing in zinc vapor upon the electron spectrum formation of ZnSe(Te)-based scintillators

V.Ryzhikov, N.Starzhinskiy, K.Katrunov, L.Gal'chinetskii, I.Rybalka

Institute for Single Crystals, National Academy of Sciences of Ukraine, 60 Lenin Ave., 61001 Kharkiv, Ukraine

Effect of the post-growth annealing in zinc vapor on optical transmission and photoluminescence spectra of ZnSe(Te) scintillators has been presented. Such an annealing results in formation of a broad absorption band in the 2.15–2.55 eV interval with a maximum at $E = 2.35$ eV as well as in absorption on free charge carriers in IR spectral region. The results obtained show that the annealing in zinc gives rise to a broad donor extrinsic band near the conductivity band bottom associated with the zinc introduction into the interstitial lattice positions (Zn_i). Formation of that extrinsic band is a necessary condition for the formation of working bands of ZnSe(Te) scintillators.

Представлены результаты влияния послеростового термического отжига в парах цинка на спектры оптического пропускания и фотолюминесценции сцинтилляторов на основе ZnSe(Te). Определено, что такой отжиг приводит к образованию широкой полосы поглощения в пределах 2.15–2.55 эВ с максимумами $E = 2.35$ эВ и поглощению на свободных носителях заряда в ИК-области спектра. Полученные результаты показывают, что отжиг в цинке приводит к образованию широкой донорной примесной зоны вблизи дна зоны проводимости, связанной с введением в решетку цинка в междоузлии Zn_i. Образование такой примесной полосы является необходимым условием формирования рабочих полос сцинтилляторов ZnSe(Te).

Zinc selenide based scintillators are ZnSe crystals doped with an isovalent dopant Te and/or O grown by the Bridgman technique and then subjected to the heat treatment (annealing) in zinc vapor (1300 K, 24–48 hours). The post-growth heat treatment is a very important stage of the scintillator production technology. At this stage, formation of luminescence centers is completed, and possible channels of non-radiative recombination are suppressed as well as the levels responsible for the afterglow. Annealing of ZnSe(Te) crystals in Zn gives rise to the crystal lattice defects related to the interstitial zinc [1]. This brings about a donor band close to the bottom of the conductivity band. As a result of such an annealing, resistivity of the crystals is substantially lowered (by about 10 orders of magnitude), while the light yield is increased.

Two types of ZnSe-based scintillators are known, the peculiar features of which are related to the growth and post-growth treatment procedures. The first type are just ZnSe(Te) crystals grown by the standard technology with post-growth annealing in hydrogen atmosphere. These scintillators show a high light yield (up to 140 % as compared to CsI(Tl)), their luminescence spectrum is characterized by a maximum in the 630–640 nm region and decay times are up to 100 ms [1, 2]. As for the second type, its production technology is related to additional doping of the crystals with oxygen resulting formation of new radiative levels [3, 4]. Scintillators of this type exhibit lower light yields, their luminescence spectrum is shifted toward shorter wavelengths