Time-resolved luminescence of neutron irradiated and additively colored BeO crystals at core excitation

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F- and F⁺-centers in additively colored BeO crystals were studied in detail using time-resolved luminescence spectroscopy method at VUV-excitation [1]. At the same time it is known that irradiation of BeO crystals by fast neutrons (fluence of 3⋅10¹⁷ cm⁻²) as well as additively coloring resulted in effective generation of anion vacancies, too [2]. The peculiarities of core excitation of intrinsic luminescence in BeO crystals we have researched in [3]. In present study we compare the results of time-resolved luminescence investigation of additively colored and neutron irradiated BeO crystals at core excitation in the regions of K-edge of berullium and K-edge of oxygen.

Synthetic single crystals were colored in a metallic beryllium vapour at high pressure (2.5 kPa) and temperature (1900°C) or were irradiated in the internal cavity of fuel assembly established in a cell of reactor’s active zone (fluence of 4⋅10²⁰ cm⁻²). The luminescence spectra (2.5 – 8 eV), the luminescence excitation spectra (50-200 eV and 500-620 eV) as well as the decay kinetics of luminescence were recorded at temperatures 10 and 300 K using synchrotron radiation from the BW3 beam-line (HASYLAB, DESY) [4]. SR from the undulator was further monochromatized by a Zeiss SX700 monochromator. The luminescence spectra (LS) were measured by a 0.4 m vacuum monochromator (Seya-Namioka scheme) equipped with a microchannel plate-photomultiplier (MCP 1645, Hamamatsu). The luminescence excitation spectra (LES) were corrected for the equal number of the exciting photons but the LS are presented as they are measured. Time-resolved spectra were recorded within a time window (length Δt) correlated with respect to an exciting SR radiation pulse (delay δt). We made δt₁=0.2 ns, Δt₁= 3.4 ns for a first time window and δt₂=34 ns, Δt₂= 118 ns for a second time window at the BW3 beam-line.

The measured spectra (LS and LES) as well as decay kinetics are shown on Figures 1-4. Firstly, we should point the difference of LS of additively colored and neutron irradiated crystals (Fig.1). In LS of additively colored crystals there are three emission bands: known band of triplet F-luminescence (3.4 eV), self-trapped exciton luminescence VUV-band (6.7 eV) and host UV-band (4.9 eV). In our early investigations UV-luminescence peak at 4.9 eV was registered as intrinsic emission of self-trapped excitons in any BeO samples [5] or as singlet F-emission at inner-center excitation in additively colored crystals [1]. The decay kinetics of 4.9 eV in our case under core excitation (Fig.2, curve 2) points to first possibility, i.e. in our case we observed intrinsic UV-luminescence of self-trapped excitons. In neutron irradiated crystals VUV-luminescence of self-trapped excitons is suppressed significantly. This fact points to essential destruction of crystal lattice. From the other hand in LS of neutron irradiated crystals we have registered 3.9 eV emission band. In the decay kinetics of 3.9 eV luminescence there is a short component with τ~1 ns (Fig.2, curve 1). Accordingly [1] fast kinetic decay is typical for singlet F⁺-luminescence. More slow components in the decay kinetics of 3.9 eV luminescence of neutron irradiated BeO crystals could be caused by contribution of 4.9 eV luminescence.

LES of 3.4 eV and 4.9 eV emission bands in additively colored samples and those of 3.9 eV luminescence in neutron irradiated crystals are characterized by expressed structure with two minima at 119.2 eV and 124.5 eV. These peculiarities are in a good agreement with peculiarities of LES measured early for intrinsic luminescence of BeO in [3]. Observed LS structure is caused by transitions of electron from K-shell of Be after selective excitations. In present work we haven’t observed any shortening of kinetic decay discussed in [3]. At the excitation in the energy region 560-580 eV LES structure is caused by rise of absorption coefficient as a result of electron transitions from K-shell of oxygen. In both case (Fig.3 and Fig.4) LES are similar for intrinsic luminescence and emission of colour centers. Therefore we may conclude about similar (most possible volume) character of both types of luminescence.
Figure 1: Luminescence spectra of neutron irradiated (1) and additively colored (2) BeO crystals measured in fast (1) and slow (2) time windows at T=10 K. Energy of excitation 119.5 eV.

Figure 3: The luminescence excitation spectra (1 - $E_{\text{emis}}=3.4$ eV, 2 - $E_{\text{emis}}=3.9$ eV, 3 - $E_{\text{emis}}=3.9$ eV) measured in fast (1,3) and slow (2) time windows for additively colored (1,3) and neutron irradiated (2) BeO crystals at T=10 K.

Figure 2: Luminescence decay kinetics of neutron irradiated (1,2) and additively colored (3) BeO crystals (1 - $E_{\text{emis}}=3.9$ eV, 2,3 - $E_{\text{emis}}=4.9$ eV). Energy of excitation 119.5 eV. T=10 K.

Figure 4: The luminescence excitation spectra (1 - $E_{\text{emis}}=3.4$ eV, 2 - $E_{\text{emis}}=4.9$ eV) measured in fast time window for additively colored (1) and neutron irradiated (2) BeO crystals at T=10 K.

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References