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Effect of phase transformations on radiation resistance of lead tungstate (PWO) crystals

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A concept of the effect of valence changes in impurity tungsten oxides (WO_{3-x}) on radiation resistance and optical properties of PWO crystals has been developed. The action of ionizing irradiation (IOI) on the PWO crystal is shown to be similar to that of high-temperature annealing in oxygen-free atmosphere to a great extent. In both cases, the impurity tungsten oxides change their valence, thus changing the crystal properties and color. The radiation-induced bleaching under IOI and the photochromic effect in PWO crystals are related mainly to phase transitions of impurity tungsten oxide. The necessary thermodynamic conditions for the phase transitions of tungsten oxide have been determined.

Развита концепция о влиянии валентных изменений в примесных оксидах вольфрама (WO_{3-x}) на радиационно-оптические свойства кристаллов PWO. Показано, что действие ионизирующего облучения (ИО) на кристалл PWO во многом аналогично действию высокотемпературного отжига в бескислородной среде. И в том, и другом случае примесные оксиды вольфрама меняют свою валентность, меняя свойства и окраску кристалла. Указывается, что радиационное просветление при ИО и фотохромный эффект в кристалле PWO, главным образом, связаны с фазовыми переходами примесного оксида вольфрама. Указаны необходимые термодинамические условия фазовых превращений оксида вольфрама.

A large-scale use of PWO single crystals in high-energy physics experiments is possible only with the proviso that their optical and scintillation characteristics remain sufficiently stable under ionizing irradiation (IOI). In spite of considerable advances in this field, the characteristics of PWO scintillators are still depend heavily on the uncontrollable production regime variations and especially on the IOI. Starting from 1994, when the PWO crystal was approved as the basic scintillator for CMS and ALICE Projects at CERN, the improvement of its radiation resistance is among the main purposes for process engineers. A considerable breakthrough in this field was attained in 1996 when the PWO crystal doping with trivalent elements of lanthanum group has been reported [1]. Later, it was shown that an improved transparency and radiation resistance of PWO can be provided also by doping with Y, Sb, and some four-valence impurities (Th) [2]. At the same time, doping with Zr^{4+}, Si^{4+}, Sc^{3+}, Ti^{3+} does not result in any substantial improvements in PWO optical properties while that with Sn^{4+}, Yt^{3+} deteriorated those properties considerably [2, 3]. A photochromic effect has been found in PWO crystals. Irradiation at a wavelength exceeding 600 nm results in bleaching of the irradiated samples (bleaching) while the light at a wavelength near