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Experimental and Computational Studies of the Ultra-Fast Scintillators ZnO:Ga and CdS:In

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Abstract

We present experimental measurements and computational simulations of the ultra-fast scintillation mechanism that occurs in ZnO:Ga and CdS:In. These materials have measured rise times of <30 ps and exponential decay times of 660 and 190 ps, respectively, at room temperature. These scintillators are partially quenched at room temperature and have high luminous efficiencies at reduced temperatures. The scintillators are prepared by mixing 0.1 to 1 mol. % of the Ga_2O_3 or In_2O_3 into the melt and then reducing with H_2 or metal vapor. This process introduces an impurity band of donor electron states that overlaps the conduction band and is similar to n-doping in degenerate semiconductors. When a hole is created by ionizing radiation, one of the many donor band electrons can recombine with the hole in an allowed electric dipole transition to produce the scintillation light. [In many other scintillators, ionization electrons and holes form individual excitons whose radiative recombination is slow (spin-flip forbidden)]. We present band structure and molecular orbital cluster calculations supporting this picture of the scintillation process as well as providing guidance for the discovery of other scintillators for gamma ray and neutron detection that are both luminous and ultra-fast.

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