Investigation of Zinc Oxide-Based Scintillators

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ZnO is a direct band-gap semiconductor that has displayed room-temperature, sub-nanosecond luminescence when doped with n-type dopants such as gallium and indium. Frequently ZnO scintillators suffer from relatively low light output, however. Recent testing of ZnO:Ga in both powder and single crystal form using pulsed x-rays and alpha particle excitation has demonstrated the promise for developing an outstanding inorganic scintillator based on ZnO that would combine fast timing characteristics, high light output, and robust thermal and mechanical properties. In order to realize the promise and potential of ZnO-based radiation detectors, we need to significantly increase our understanding of doping mechanisms and the role played by impurities or sample treatments that can produce improved scintillation characteristics in zinc oxide. A variety of scintillation schemes have been proposed in the case of ZnO radiation detectors, but at the present time, no consensus has been reached as to the exact nature of the luminescence center(s) or the energy transfer mechanisms actually responsible for scintillation.

Room-temperature alpha particle excitation of powder and single crystal samples. These measurements are useful for end-users but do not provide enough information to understand underlying mechanisms. Powder measurements are sensitive to particle size and powder layer thickness.

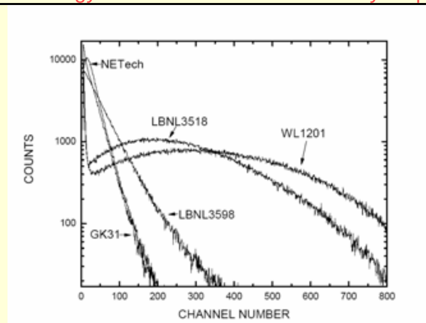

Fig. 1. Pulse height distributions for the five powder samples using alpha particle excitation.

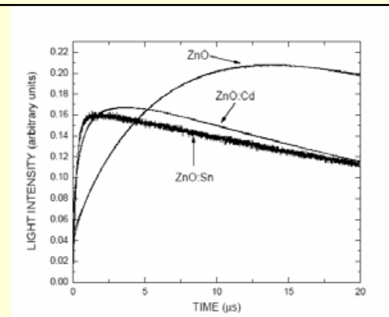

Fig. 2. Scintillator light output response to alpha particle excitation for ZnO (top), ZnO:Cd (middle), and ZnO:Sn (bottom) single crystal samples. Data and fitted curves shown for all samples.

Photoluminescence studies illustrate a bimodal emission spectrum for ZnO:Ga consisting of fast (sub-ns) UV and slow (~μs) visible emissions. Significant changes occur in the photoluminescence of ZnO:Ga as a function of temperature.

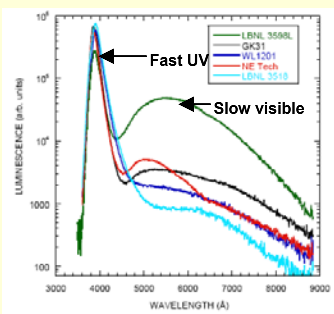

Fig. 3. Photoluminescence response to 325 nm laser excitation at 300 K.

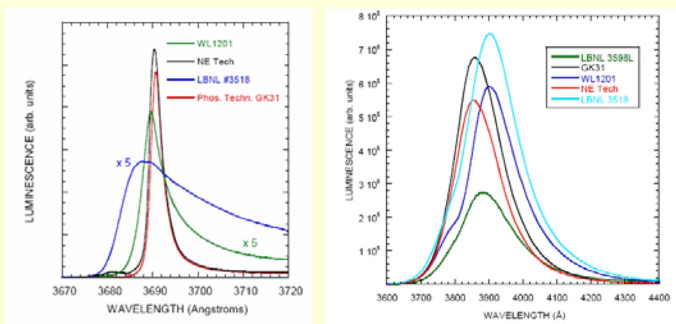

Fig. 4. UV photoluminescence response to 325 nm laser excitation at 5 K (left) and 300 K (right).

Temperature-dependent photoluminescence studies allow the tracking of free and bound excitonic components. The shift in the peak wavelength of the fast UV component can be explained using an excitonic model ► no need for an unknown component to explain ZnO:Ga luminescence. Micro-photoluminescence studies show deep-level emissions that prove the existence of recombination centers competing with excitionic edge emission. This model suggests using ultra-pure materials as a method for optimizing ZnO:Ga output.

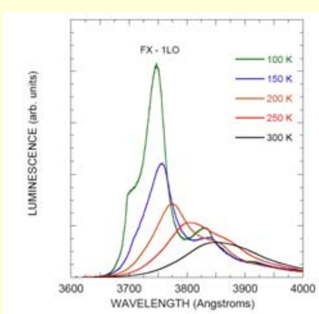

Fig. 5. Edge emission for NE Tech powder sample. The dominant emission at 100 K is the phonon replica of the free exciton emission (FX - 1LO). Excitation at 325 nm and 0.1 W/cm^2.

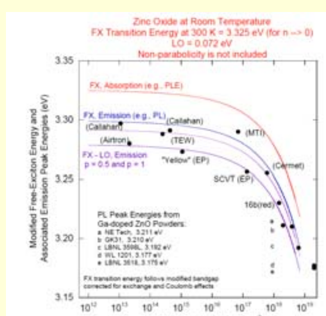

Fig. 6. Emission peak energies as a function of carrier concentration. Powder sample measurements made using anEPR technique and single crystal measurements made using the Hall technique.

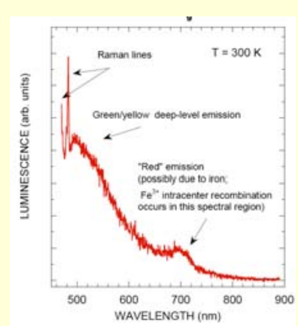

Fig. 7. Micro-photoluminescence measurement of LBNL 3518 ZnO:Ga powder using 485 nm (below E_g) excitation.