Ion-induced luminescence of radiation defects in ZnO

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Ion-induced luminescence (IL) experiments and photoluminescence investigations (PL) were performed to study the properties of irradiation induced intrinsic point defects in ZnO single crystals.

In these experiments, we irradiated vapour phase grown n-type ZnO single crystals perpendicular to the c-axis with 4.8 MeV/amu Ti^{12+} ions up to a fluence of 2.5×10^{10} ions/cm^2. The ion beam had a frequency of 1 Hz and a pulse length of 5 ms corresponding to 6×10^7 ions/cm^2 per pulse. The samples were mounted on a closed-cycle He-cryostat and kept at constant temperatures between T = 25 and 140 K. The luminescence was analyzed with a fixed grating outside the vacuum chamber and detected with a CCD detector. The PL was excited by the 355 nm line of a frequency tripled Nd:YAG laser. After each IL measurement a PL spectrum was recorded at the same temperature within 30 s.

The PL and IL spectra at T=25 K and T=75 K are shown in Fig. 1 and 2, respectively. At a temperature of T=25 K the PL spectrum shows a dominant peak at 3.360 eV which is caused by aluminium donor bound exciton transitions. At higher energies, smaller peaks caused by hydrogen (H) and free exciton transitions (FX) are visible. The IL spectrum has a dominant peak at 3.355 eV (I_x), and a correlated two-phonon transition at 3.210 eV (I_x-2LO).

At higher temperatures, the FX transition and its phonon replica increase in intensity (Fig. 2). While the phonon-related transitions are visible in PL and IL as well, the FX zero-phonon transition is only visible in the PL spectra. The difference between the PL and IL spectra can be understood, if one considers the different electronic excitation volumes in both cases. In PL the excitation is located in the surface region, while in IL the excitation is distributed along the ion track. In the latter case the emission has to pass a thicker layer of material before reaching the surface, which leads to a stronger absorption of luminescence close to the band-edge.

The temperature dependence of the emission intensity of I_x was measured in the range of 50 to 90 K. A two-level model of free and bound excitons is used to fit the measured intensity at increasing temperatures. As preliminary result, we obtain a localization energy of 23 meV, and under the assumption of a donor bound exciton transition, a donor binding energy of 74 meV. These values are comparable with the so far unidentified I_{10} defect in ZnO (Tab. 1).

Possible candidates for the I_x defect are generally all native point defects. Based on literature data, vacancies and oxygen interstitials can be excluded as origin of the I_x defect. The zinc interstitial, however, seems to be a reasonable candidate for the observed defect.

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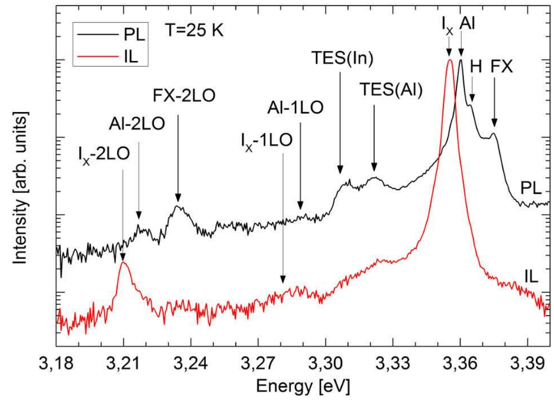

Figure 1: PL and IL spectra of ZnO crystals at T=25K.

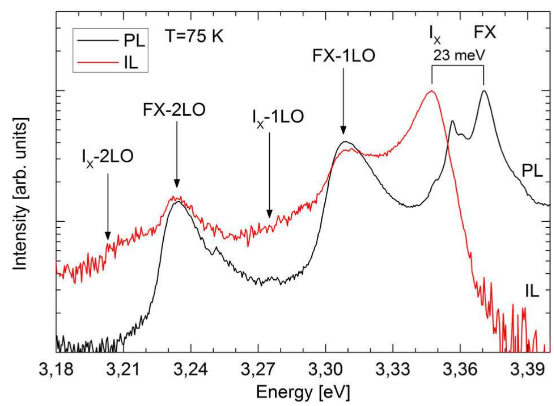

Figure 2: PL and IL spectra of ZnO crystals at T=75K.

Defect	E_{loc}	E_D (meV)	Ref.
I_x	23 meV	74	This work
I_{10}	22.8 meV	72.6	[1]
I_{10}	23.1 meV		[2]
IID*		75	[3]
I_{10}	23.5 meV	76.7	[4]

* Irradiation induced donor

Table 1: Measured values and literature data.

References

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