Growth Technique Yields P-Type ZnO

A multi-institution research effort in Japan has resulted in the production of P-type ZnO using a variant of molecular beam epitaxy that the participants suggest may find application in blue-violet LEDs and laser diodes. In the technique, the temperature in the growth process is rapidly modulated to enable high crystallinity and high concentrations of the nitrogen dopant.

Despite its advantages as a material for short-wavelength emitters, including its room-temperature bandgap of 3.37 eV and an exciton binding energy of 60 meV, ZnO has tended to resist P-type doping. It remains a matter of debate whether this is the result of native defects or of the preferential incorporation of hydrogen, which acts as a donor material in ZnO.

The scientists employ molecular beam epitaxy on a $ZnO/ScAlMgO_4$ substrate, periodically heating the back side of the target during deposition using a laser diode so the temperature varies between 400 and 950 °C. The lower temperature is selected for the growth of 10- to 15-nm-thick nitrogen-doped layers, at which acceptor concentrations on the order of 10^{20}/cm are obtained. Nitrogen cannot be incorporated at such concentrations at the higher temperature, at which another 1-nm-thick layer of ZnO is deposited, but the conditions enable the recovery of surface smoothness and the elimination of any hydrogen that had been introduced into the deposited films.

To investigate the suitability of the technique for fabricating emitters, the researchers produced a PIN-junction LED, featuring 400-nm-thick N-type and 50-nm-thick undoped layers of ZnO grown at 950 °C and a 300-nm-thick layer of the P-type. Operating at room temperature under 20 mA of direct current, the device had an output spectrum with a peak at approximately 430 nm — but also a redshifted peak at approximately 570 nm, which the scientists partly attribute to the relatively low, 2×10^{16}/cm hole concentration in the P-type layer. Further work will focus on optimizing the technique to increase the hole concentration in P-type ZnO.

The team includes members from Tohoku University and Riken research institute's Photodynamics Research Center, both in Sendai; the University of Tsukuba; Shizuoka University in Hamamatsu; Tokyo Institute of Technology in Yokohama; and Combinatorial Material Science and Technology in Tsukuba. □

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