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SEED LAYER MEDIATED MODIFICATIONS IN STRUCTURAL AND PHOTOLUMINESCENCE PROPERTIES OF ZnO:Al NANOWIRES

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Abstract

In this work, we investigated the effect of variation in seed layer molar concentration on Al doped ZnO nanowires (ZnO:Al NW) on their structural and photoluminescence (PL) properties. Structural characterization on the seeded NWs reveals a successful fabrication of hexagonal wurtzite ZnO:Al NWs. A denser NWs growth was observed as we increased the molar concentration of the seed layer. Particle size of the as obtained ZnO: Al NWs was found to be inversely proportional to the molar concentration of the seed layer. This was attributed to a larger number of nucleation sites available in the seed layer precursor with higher molar concentration followed by growth of densely populated NWs with smaller dimensions. A blue shift in the PL emission spectra confirmed better crystallinity and smaller particle size of ZnO: Al NWs grown on seed layer prepared with higher molarity. ZnO:Al NWs exhibit enhancement in the UV PL intensity as compared to undoped ZnO NWs. This was attributed to the increase in the band gap of ZnO , after Al doping. The intensity of UV peak decreased and that of visible peaks broadened for bigger particles due to enhancement in the lattice constant and larger unit cell volume of the lattice for larger particles.

1.Introduction: ZnO is a versatile material with several important properties, e.g., strong room temperature UV photoluminescence (PL),piezoelectric, ferromagnetic, nonlinear optical properties, etc., has attracted the attention of the researchers. ZnO nanowires (NWs) are extensively studied for the ease of the devices fabrication process and have the ability to be integrated into the mainstream Si based electronics for optoelectronic device integration[1,2]. Without any intentional doping, ZnO is naturally n-type and can be extrinsically doped by introducing heteroatoms such as Al, Ga, In,B, or Sn into the ZnO crystal lattice .In solution phase process, the seed catalyst layer provides a base that initiates the growth of the NWs arrays through heterogeneous nucleation[3,4]. We observe the effect of concentration of seed layer in the structure morphology of NWs.[5,6]

2.Experimental Procedure: Al doped NWs (ZnO:Al) are prepared by using zinc nitrate, Aluminium nitrate (97%:3%) and HMT mixed in deionized water (DI) , the resultant solution was stirred on a magnetic stirrer for 30 min. at RT. The ZnO:Al NWs were grown by immersing the seeded substrate upside down in the as prepared aqueous solution in MW irradiations.It is prepared on 0.175M and 0.375M seeded substrate.This method consists of two-step procedure at first we prepared the seed layer, and than doped NWs was grown on them. Then the coated substrate was heated at 350◦C for 30 min to get ZnO seed layer. The ZnO NWs were synthesized by hydrolysis of zinc nitrate and Aluminium nitrate in water in presence of HMT on the above seeded substrate of different molar concentration.

3. Result and Discussion: The degree of alignment of ZnO NWs was strongly controlled by the orientation of the ZnO seed layer. During growth process, the doping of Al atoms inside the ZnO lattice may cause lattice distortion, which affects the initial growth orientation. It is known that the diameter of the as-grown NWs depends on the grain size of the ZnO seeds of 0.175M and 0.375 concentration and the reaction process. Structural characterization on the seeded NWs reveals a successful fabrication of hexagonal wurtzite ZnO:Al NWs. A denser NWs growth was observed as we increased the molar

concentration of the seed layer. Particle size of the as obtained ZnO: Al NWs was found to be inversely proportional to the molar concentration of the seed layer[7,8]. This was attributed to a larger number of nucleation sites available in the seed layer precursor with higher molar concentration followed by growth of densely populated NWs with smaller dimensions.

3.1 X-Ray Diffraction pattern: Information including sample composition, phase, particle size obtained from intensity versus 2θ.With the X-Ray Diffraction (XRD) (Instrument used:XRD- Bruker/LynxEye1D-PSD) particle size of 0.375M seed layer was obtained as 12.19nm and for 0.175M seed layer was obtained as 12.78nm. Fig.3.1 illustrates that Al-doping appreciably influence the ZnO crystallinity. The growth process of ZnO nanocrystal follows nucleation- absorption- orientation-coalescence a mechanism .By comparison, it can be found that the full width at half maximum (FWHM) of diffraction peaks of Al-doped ZnO nanowires slightly broaden as we increased the replenishing time. Al-doping can appreciably influence the ZnO crystallinity[9].

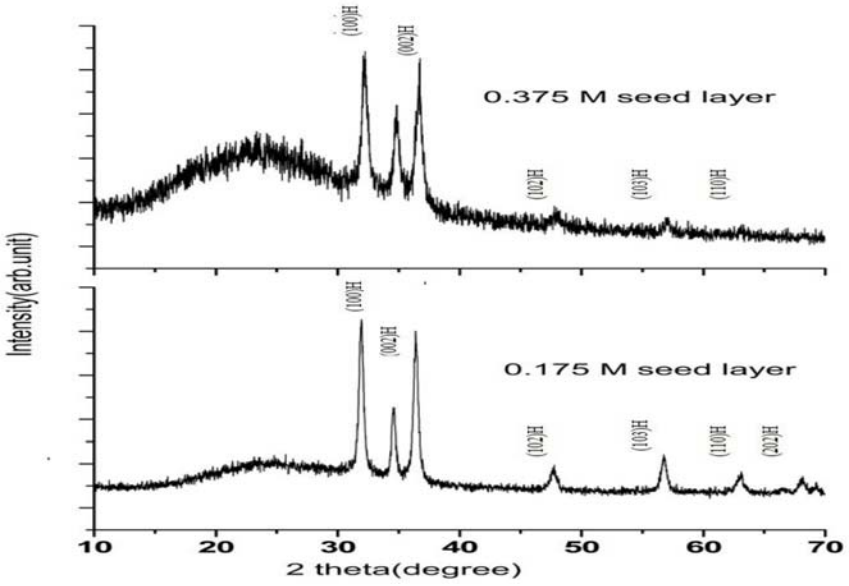

Fig 3.1:X-Ray Diffraction patterns of ZnO:Al NWs grown on different concentration of seed layer

3.2. SEM Studies: SEM in fig. 3.2(a) on 0.375M seeded substrate were observed as uniformly distributed some bunches of NWs and in fig.3.2(b) dense wires of smaller length and diameter was observed in the SEM of NWs grown on the 0.175 M seeded substrate.

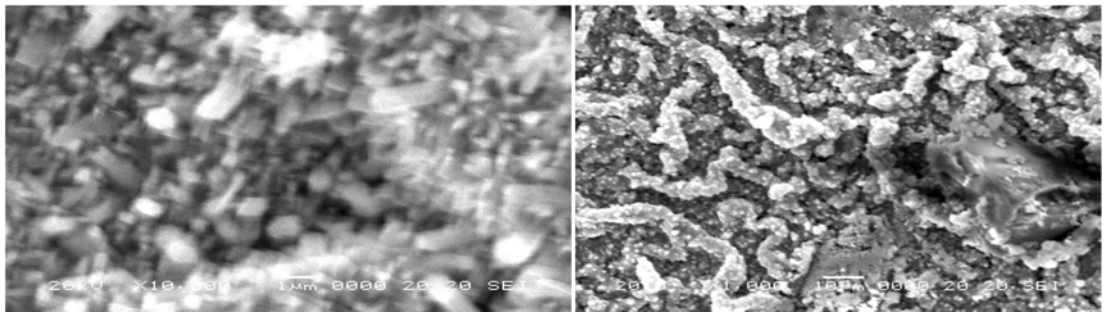

Fig.3.2 SEM of ZnO:Al NWs grown on (a) 0.175M and (b) 0.375 M seed layer

3.3. Photoluminescence: Fig 3.3(a) and (b) depicts the RT ,PL spectra of the ZnO:Al NWs on seed layer of 0.175M and 0.375M concentration .We observed each sample has two types of emission peak; at ultraviolet (UV, ~387nm) and visible peak centered (Vis, 560nm) ranges for more concentrated (0.375M) thin film . Thus, these UV emission peaks can be ascribed to near band-edge transitions of ZnO nanostructures with wide band gaps, namely, the recombination of free excitons through the exciton-exciton collision process [10,11].

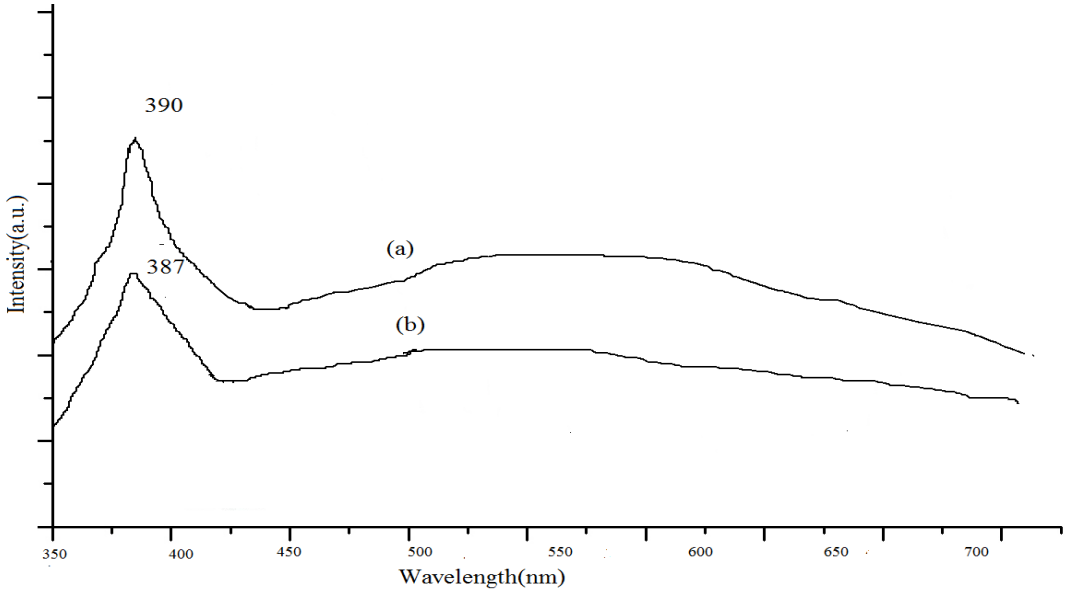

Fig.3.3: PL spectra of ZnO:Al NWs on seed layer of 0.175M and 0.375M concentration

We observed the blue shifting ,as we increase the seed layer molar concentration the intensity of UV peak decreased and visible peaks became broaden due to enhancement in the lattice constant and larger unit cell volume of the lattice .

4.Conclusions: The ZnO:Al NWs arrays were prepared on seed-layer of different concentration on the glass substrates. The XRD patterns indicate that the as-grown and annealed NWs arrays have a prominent peak for the wurtzite structure We observed the blue shifting ,as we increase the seed layer molar concentration.

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