Zinc Oxide Nanostructures: An Idealistic Approach to Sensors, Phosphors and Optoelectronics

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Topics to be covered

- Introduction
- Sample preparation
- Theoretical Background
- Optical and Morphological characterizations
- Results and Discussion
- Conclusions

Introduction

- ZnO has wide band-gap (3.2 eV) and large exciton binding energy (60 meV).
- Applications of ZnO as Phosphor and Sensor.
- Synthesis of long nanobelts of ZnO.
- Nitrogen laser (337.1nm, 10ns) as pulsed excitation source.

ZnO as Phosphor

- ZnO is a wide band gap semiconductor compound exhibiting the phenomenon of phosphorescence, which has potential industrial applications such as coating material for fluorescent lamps, vacuum displays, picture tubes etc.

ZnO as Sensor

- Phosphorescence intensity and decay time both depend strongly on temperature and hence a good temperature sensor based on this concept can be made.
- ZnO act as a piezoelectric semiconductor because of asymmetries in its crystalline structure. Put under stress, piezoelectric materials produce an electric current or respond to an electric field by changing shape. This allows the ring to function as small scale pressure and force sensors. The ZnO can be employed as bio sensors in MEMS through some suitable fabrication techniques.
- Zinc oxide nanobelts grown by chemical precipitation technique can act as gas sensors. The gas adsorption takes place within the nanobelts because of the presence of so many pores leading to the change in resistance of nanobelts. Resistance of the ZnO nanostructures can be calculated in the presence of test gas at different temperatures and concentration of the test gas.

ZnO as Active Laser Medium

- Whenever the semiconductor is irradiated with radiations, there are trapping levels at different depths within the forbidden gap of the material, leading to transitions from the various traps. Selective excitation of the levels can make the ZnO as a best suited laser medium. When the scattering mean free path becomes equal to or less than the wavelength, light may return to scatterer from which it was scattered before, and thereby forming closed loop paths. If amplification in the loop exceeds the loss, laser oscillation could occur which serves as a laser resonator. Scattering merely increases path length of light in the gain region, but can not provide coherent feedback which is essential to laser action. Microcrystalline grain boundaries can provide optical feedback to promote amplified spontaneous emission

Sample Preparation

Four different routes have been opted to synthesize nanostructures (nanoparticles and nanobelts) by using zinc acetate as starting material. Methods are discussed in detail as below:

1. Zinc acetate + ethanol + water —(Reflux 1 hr, 80 °C)→ Drying.

2. Zinc acetate + absolute ethanol —(Reflux 3 hr, 80 °C)→ Precursor —(Add 0.1M LiOH)→
   Precipitates of ZnO → Centrifugation, Drying.

3. Zinc acetate + absolute ethanol —(Distillation 3 hrs 80 °C)→ Precursor —(Add 0.1M LiOH)→
   Precipitates of ZnO → Centrifugation, Drying.

4. Zinc acetate + absolute ethanol —(Distillation 3 hrs 80 °C)→ Precursor —(Add water)→
   Precipitates of ZnO → Centrifugation, Drying.

Theoretical

When samples are exposed to laser radiation, electrons are raised from valence band to excited states. These electrons may return to valence band with the emission of characteristic luminescent radiation. Intensity of phosphorescence radiation 'I' at time 't' is given by

$$I = Io\ e^{-pt} \qquad (i)$$

A plot of 'ln I vs t' will be a straight line in case of single lifetime. However, in most of the cases, when one comes across the interaction of radiation with solids, there are trapping levels at many different depths leading to multiple lifetime components from nonlinear plot of 'log I' verses 't'.

Scanning Electron Microscope Images

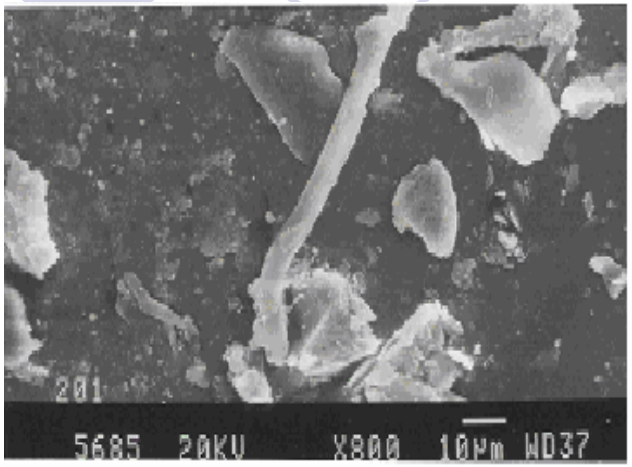


Figure 1 SEM of Zinc oxide nanobelt synthesized by method 1

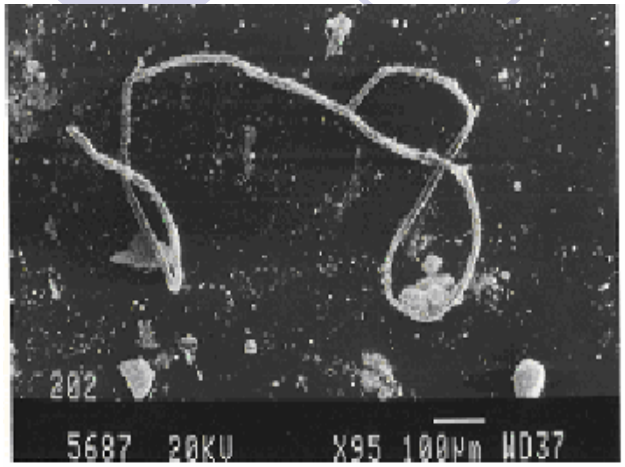


Figure 2 SEM of Zinc oxide nanobelt synthesized by method 2

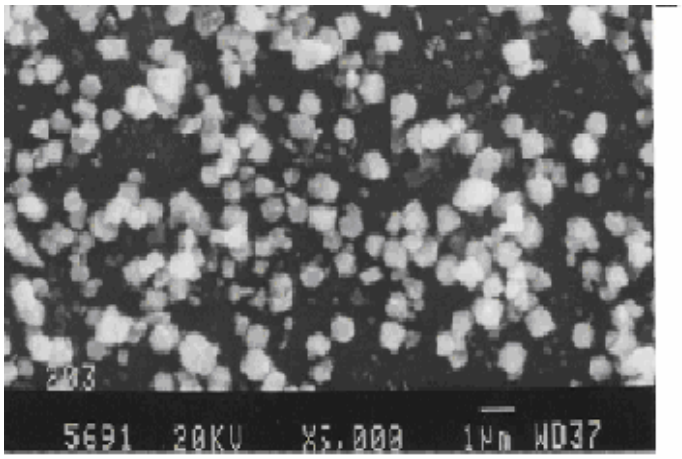


Figure 3 SEM of Zinc oxide particles synthesized by method 3

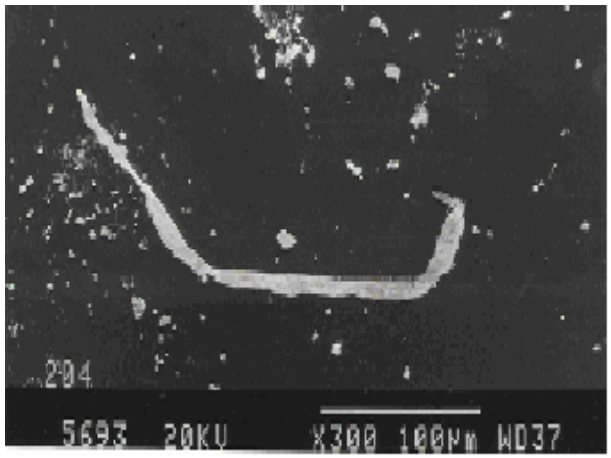
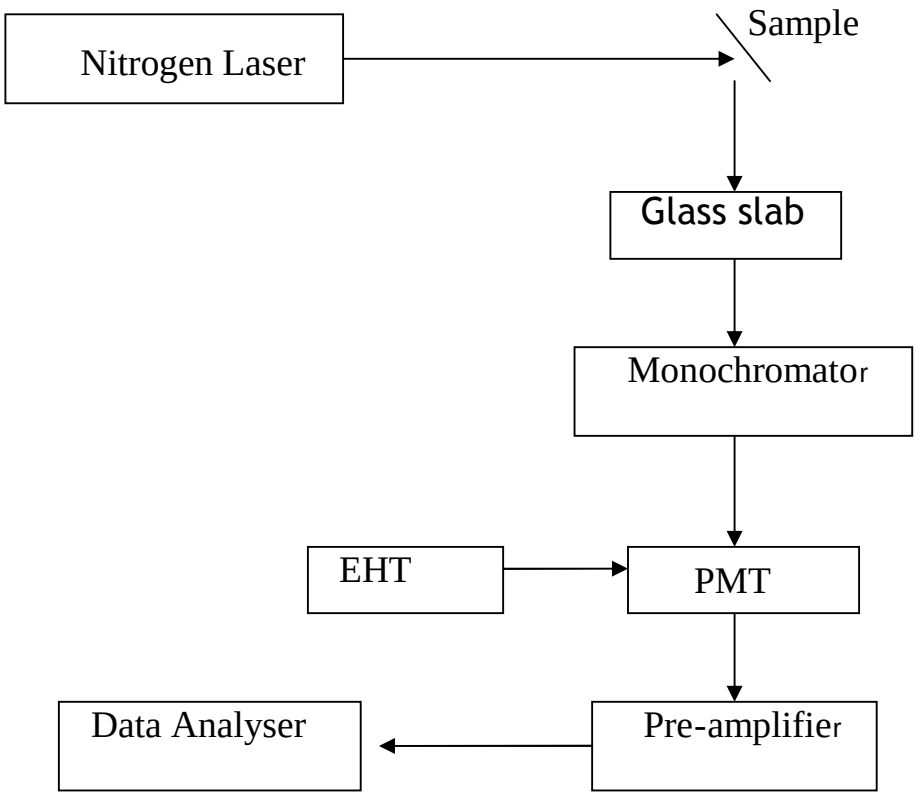
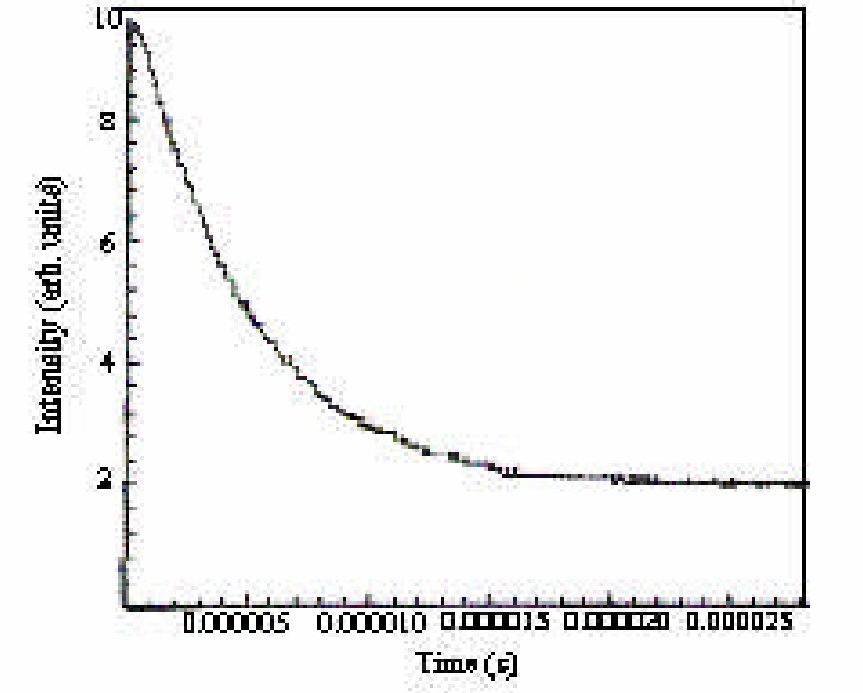


Figure 4 SEM of Zinc oxide nanobelt as synthesized by method 4

Experimental set up for Laser Induced Photoluminescence decay measurements



Hyperbolic Decay curve for Zinc oxide Nanocrystals synthesized by method 1



Excited state life-time values for Nanocrystals of Zinc oxide

Sample synthesized by method no.	Lifetime values (in micro-seconds)			Emission Wavelength (in nm)	Relative Intensity
	t_1	t_2	t_3		
1	6.8517	10.6383	19.3448	400	12.84%
2	5.1427	11.6869	22.3565	620	51.35%
3	6.2394	10.3859	22.3655	610	100%
4	6.2542	9.8652	19.2641	590	22.97%

Conclusions

- Intensity obtained from the ZnO nanostructures, synthesized by method 3, after excitation by means of nitrogen laser is very high.
- Excited state lifetime is of the order of microseconds.
- SEM image of Figure 2 reveals a very long nanobelt of the order of 2.8 mm of ZnO synthesized by the method 2.
- From excited state lifetimes and emission wavelength data, oscillator strength, dipole-moment, integrated cross-section, Einstein's spontaneous and stimulated coefficients for various strong and week transitions can be calculated.

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THANKS