Growth and characterization of micro- and nanostructures of ZnO co-doped with Erbium and Lithium

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Introduction

Why ZnO?

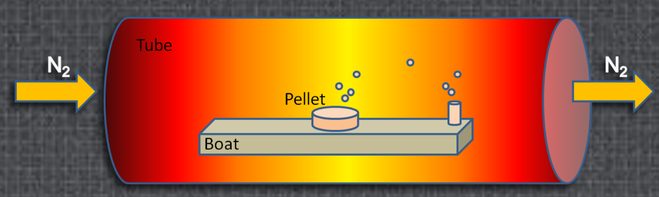
- Direct wide band gap semiconductor (3.37 eV)
- Large exciton binding energy (60 meV)
- Resistivity can be tailored between 10^{10} and 10^{-4} Ω·cm
- Refraction index > 2
- Biocompatible, piezoelectric, non-ohmic behaviour… Excellent candidate for optoelectronic devices, gas sensing, piezotronics and Transparent Conductive Oxide (TCO)

Why Er and Li?

- Er
  - Intense intraionic emissions (1.54 μm widely used in optical communications)
  - But at room temperature, the emission is strongly inhibited due to a non radiative transititon
- Li
  - Ionic radii: $Li^{+} \approx Zn^{+2} < Tb^{+3}$
  - Charge balance: $Li^{+} + RE^{+3}$ "=" Zn^{+2}

Experimental techniques

- ZnS + 5%wt Er_2O_3 + 1-10%wt Li_2O
- VS Method: 950°C, 10 h, 1.5 l/m N_2 flow

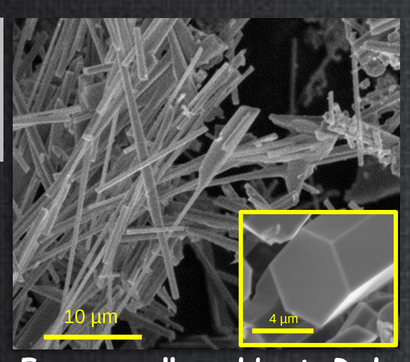


- Morphology: Scanning Electron Microscopy (SEM)
- Composition: X-Ray Microanalysis (EDS)
- Defect structure, optical properties: Cathodoluminescence (CL), Photoluminescence (PL), μ-Photoluminescence (μ-PL)

Morphology

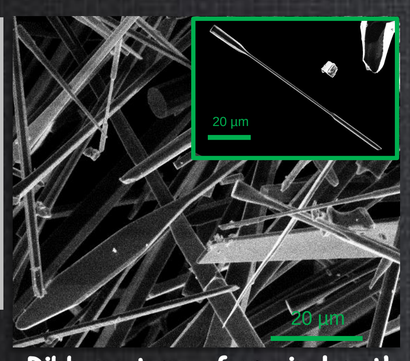
Amounts of erbium in a variable quantity are found in the different structures

5% wt Er_2O_3



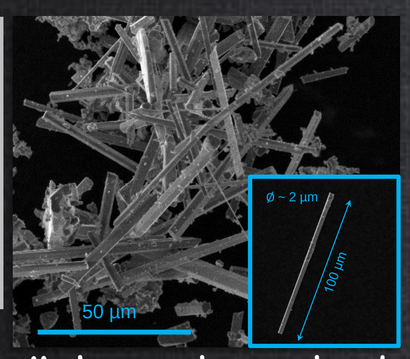
Furnace walls and boat. Rods tens of μm in length and 500 nm to 1 μm in diameter

5% wt Er_2O_3 + 1% wt Li_2O



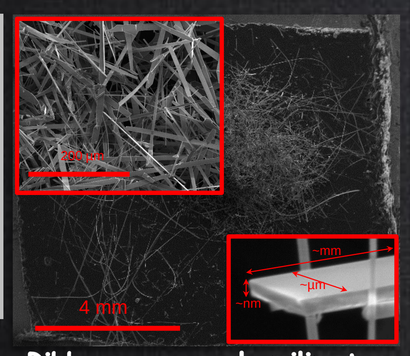
Ribbons tens of μm in length and widths of hundreds of nanometers. Some screw and hexagonal prisms began to appear

5% wt Er_2O_3 + 5% wt Li_2O



Much more hexagonal rods of tens to hundreds μm in length and few μm in width

5% wt Er_2O_3 + 10% wt Li_2O



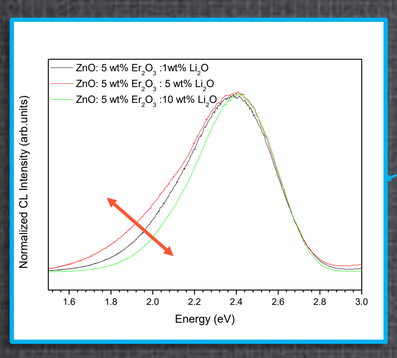
Ribbons, several milimeters in length, several microns width and hundreds of nanometers thick

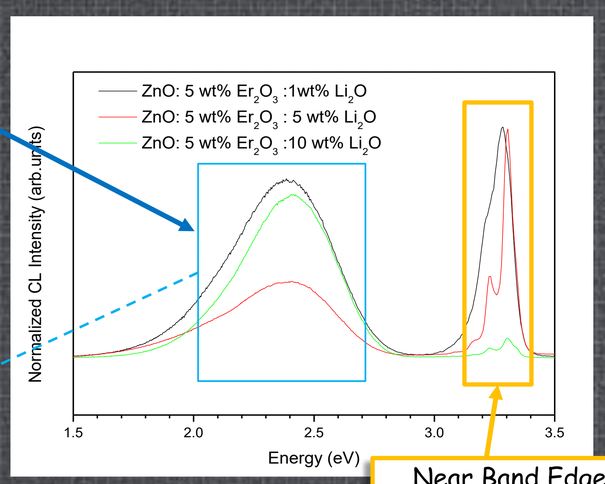
%Li_2O

Cathodoluminescence

UV-VIS CATHODOLUMINESCENT EMISSION

ZnO Green band (2.4 eV) plus alkaline related emission (2.1 eV)

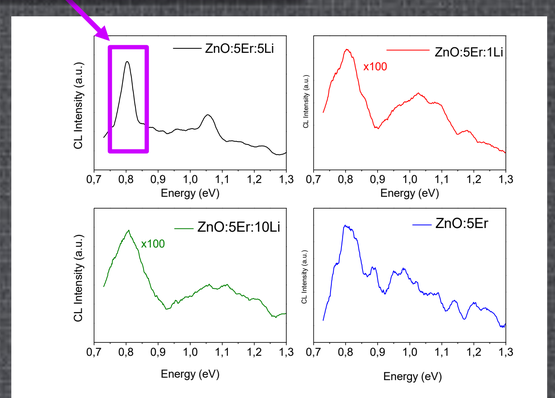




Near Band Edge: Band to band and shallow DAP

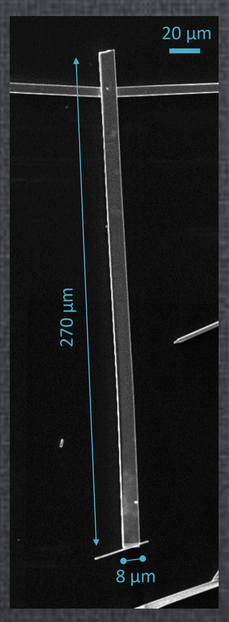
NIR CATHODOLUMINESCENT EMISSION

There is a optimal amount of Li -> clear 1,54 μm (0,8 eV) emission

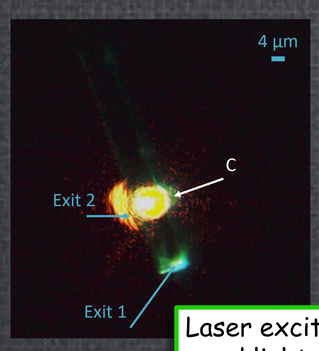


Light guiding

LIGHT GUIDING STRUCTURE EXAMPLE



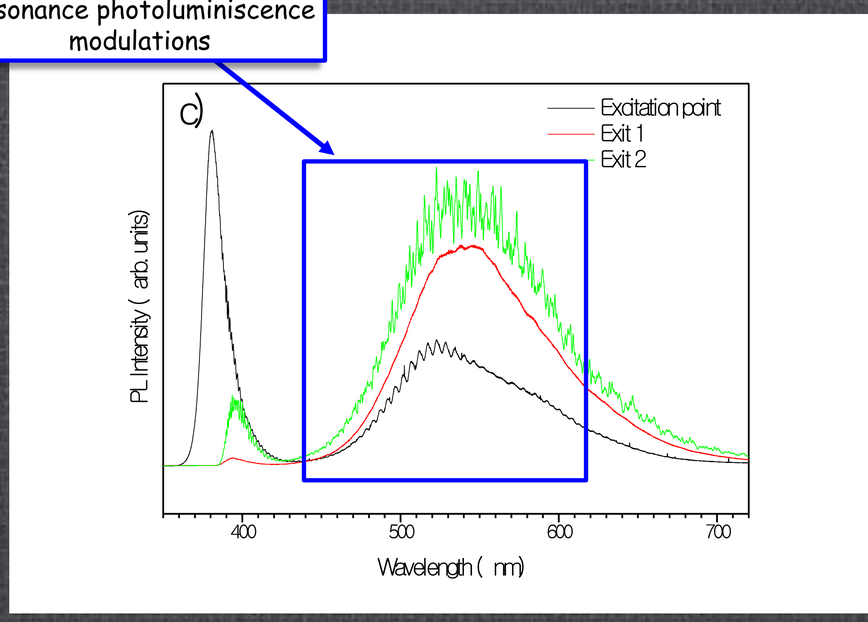
Resonance modes
Fabry-Pérot
Whispering Gallery



Laser excitation and light exit

PHOTOLUMINESCENCE SPECTRA

Resonance photoluminiscence modulations



Conclusions

- ✓ Er and Li doped ZnO nanowires have been grown by vapor-solid method. A large amount of nanostructures from ribbons to wires can be obtained in a very short time.
- ✓ The morphology of the structures changes depending on the dopant atom. Li addition allows a much better control of the obtained structures and 5% wt Li gets uniform in morphology.
- ✓ Luminescence emission changes in the doped structures. Much clearer 1,54 μm (0,8 eV) emission is obtained for 5% wt Li.
- ✓ Ligth guiding properties are tested and resonance modes are observed in photoluminescence measurement.