Origin of light emission features of ZnO/polyvinylpyrrolidone nanocomposite

Isaieva O.F.[1,2], Rudko G.Yu. [1,2], V.I. Fediv[3], Dzhagan V.M. [1], E.G. Gule [1]

[1]*V. Lashkaryov Institute of Semiconductor Physics of National Academy of Sciences of Ukraine, 45, Pr. Nauky, Kiev, 03028, Ukraine.*
E-mail: oksana.isaieva@isp.kiev.ua
[2]*National University "Kyiv-Mohyla Academy", Skovorody, 2, Kiev, 04070, Ukraine.*
[3]*Department of Biophysics and Medical Informatics, Bukovinian State Medical University, 42 Kobylyanska st., 58000, Chernivtsi, Ukraine*

Motivation

✓ Organic-inorganic nanocomposites – new materials combining the advantages of polymers and nanoparticles;

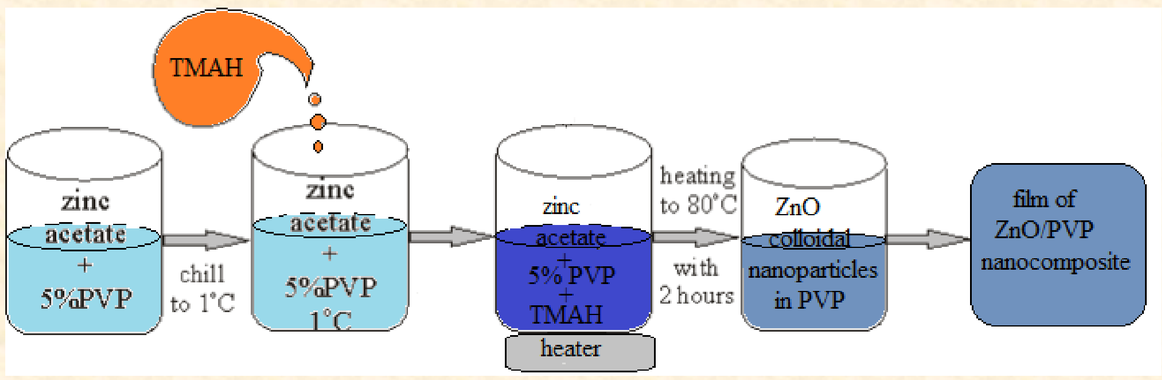
✓ ZnO nanoparticles are widely employed in the fundamental research and commercial applications;

✓The controlled synthesis of ZnO nanoparticles and in-depth understanding of the physical properties are the key issues for the future development of ZnO-based devices.

Goal

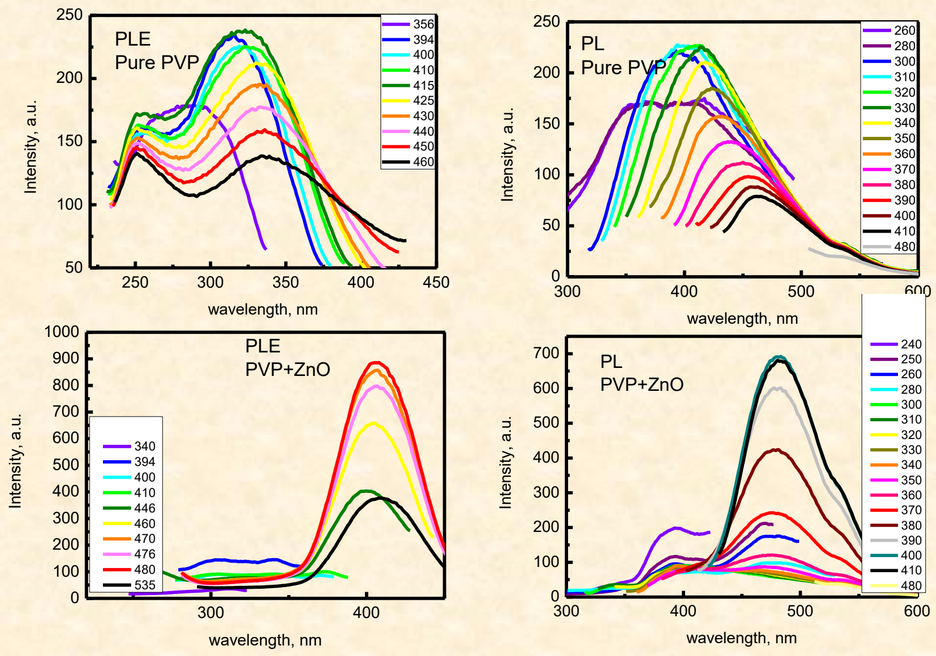
To fabricate ZnO nanoparticles embedded in polyvinylpyrrolidone (PVP) matrix by the in-situ colloidal technique at low temperature with environmentally friendly reaction conditions and to study the applicability of the nano-composite as a luminescent material.

Synthesis of ZnO/PVP nanocomposite film

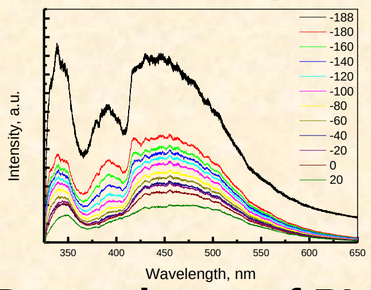


- ✓ Synthesis *in situ*;
- ✓ "Green" method;
- ✓ Precursors: zinc acetate ($Zn(CH_3COO)_2$), 5% water solution of PVP, tetramethyl hydroxide ((CH_3) 4NOH) (TMAH).

PLE and PL spectra

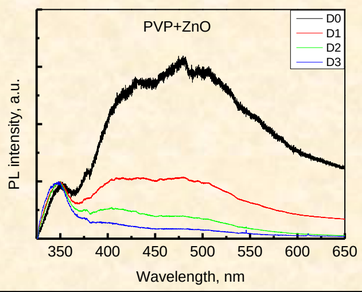


T-dependence of PVP/ZnO PL



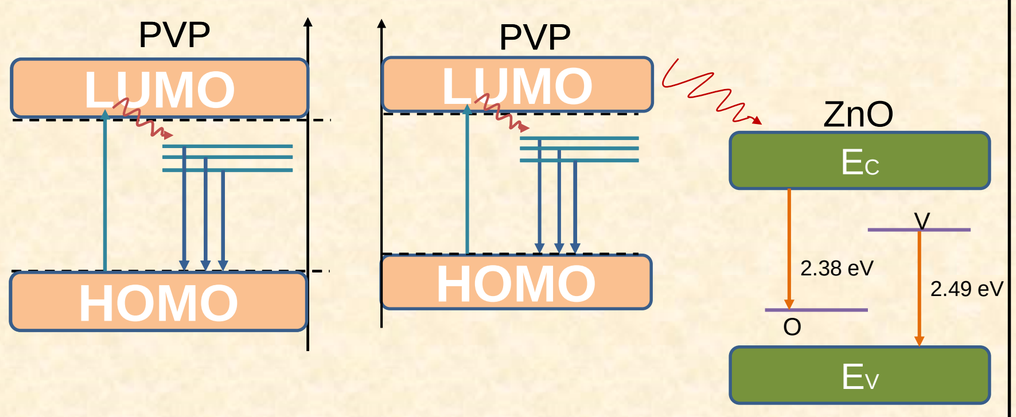
- ✓ 3 types of PL;
- ✓ T ↗ → I_{PL}(PVP) ↘;
- ✓ T ↗ → I_{PL}(PVP/ZnO, ZnAc) ↗;

Dependence of PL on the exciting light intensity



As the intensity of the exciting light increases, the contribution of nanoparticle emission to the PL spectrum of the sample increases.

Scheme of transitions in PVP and ZnO/PVP nanocomposite



PVP

- ✓ Either HOMO-LUMO excitation or excitation to intraband defect states;
- ✓ Emission via intraband defect states;

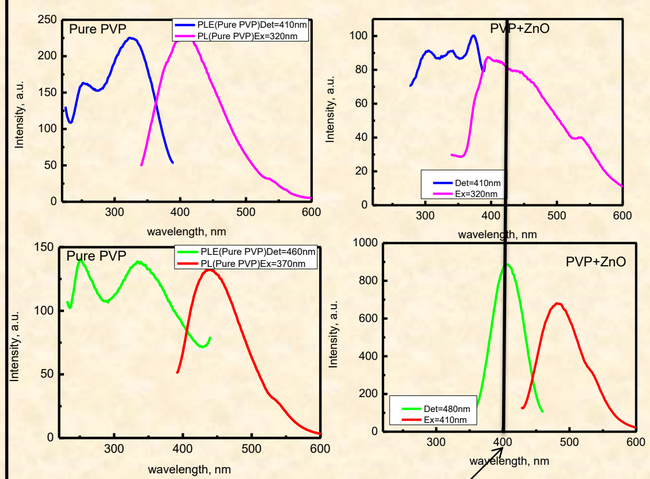
ZnO/PVP

- ✓ Excitation of intraband defects states in the matrix;
- ✓ Emission involving defects states in ZnO /PVP nanocomposite;
- ✓ Excitation transfer from matrix to nanocomposite

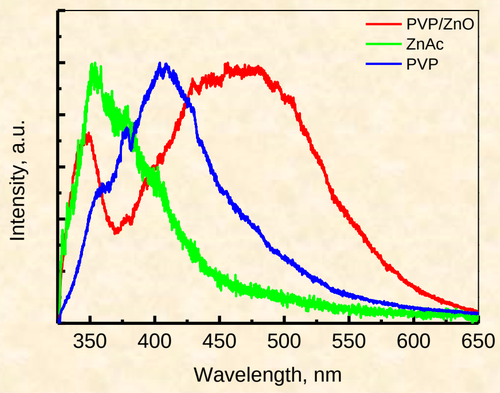
2.49 eV – emisssion of singly ionized oxygen vacancy V^{+}_{o}
2.38 eV – emission of antisite oxygen O_{zn}
[1,2]

Main spectroscopic results

- ✓ There are 3 types of emission in nanocomposite:
  - first originates from the unreacted zinc acetate residuals,
  - second – polymeric matrix,
  - third is related to ZnO nanoparticles (~485 nm);
- ✓ ZnO-related emission at ~485 nm (2.55 eV) is the defect-related emission;
- ✓ Luminescence excitation band at ~ 405 nm (3.06 eV) → its energy is lower than the band gap (3.3 eV) → excitation of nanoparticles occurs via intraband defects of polymer.



Max PL (Exc=320nm) =
Max PLE (Det=480nm)



At T=300K (red curve) emission of NPs dominates in PL spectra of nanocomposite.

1[Photoluminescence of ZnO nanocrystallites confined in sol–gel silica matrix / S Chakrabarti, D Ganguli and S Chaudhuri // J. Phys. D: Appl. Phys. 36 (2003) 146–151.]
2[Annealing effects on optical properties of low temperature grown ZnO nanorod arrays / L. L. Yang, Q. X. Zhao, M. Willander, J. H. Yang and I. Ivanov // J. Appl. Phys., 105 (2009) 053503.]

Conclusions

- ✓ Synthesis of the colloidal was carried out at low temperature, and the reaction conditions are environmentally friendly. It therefore has many advantages as compared with other vapor deposition and physical processes;
- ✓ Green-band emission originates from singly ionized oxygen vacancy and antisite oxygen O_{Zn};
- ✓ Spectral position of excitation peak of nanocomposite coincides with the long wavelength emission of polymer, thus, excitation is transferred from the matrix to nanoparticles;
- ✓ High-energy band is ascribed to unreacted zinc acetate residuals.