Development of ZnO Plasmonics as Novel Materials for Enhanced Florescence Light-emitters

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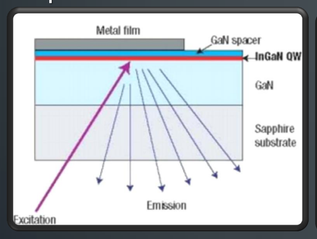
Abstract

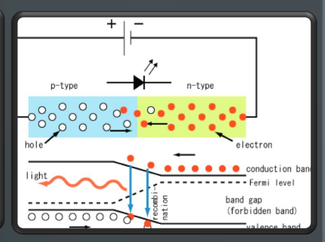
The aim of this project is to study ZnO-based structures as an emission enhancing material. The work is based on synthesizing, fabrication and measurement. Results show that ZnO-plasmonics can play an important role in emission enhancement.

Background

- LEDs produce light (photons) as a result of the radiative recombinations that occur when working in forward bias mode.
- Plasmons are collective oscillations of the free electron gas density waves that are produced of the incident of photons on metal surfaces under specific conditions.



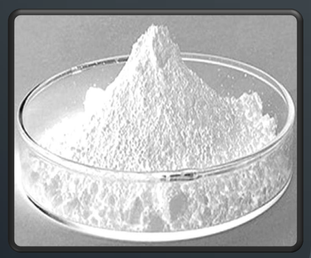
Plasmonic enhancement



LED Operation Mechanism

- ZnO possesses several properties that make it an ideal material for several optical applications and we use ZnO-plasmonics as a powder and as a thin film to enhance the emission of light emitters.

ZnO Thin Film



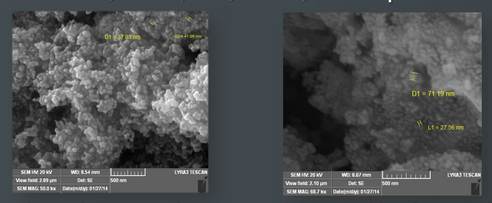
ZnO Powder

ZnO Nanoparticles

First, we synthesized two sample of ZnO nanoparticles using two different techniques.

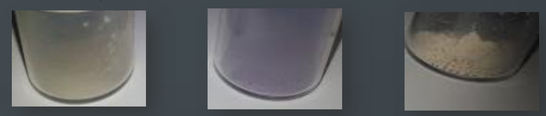
Synthesized ZnO nano-particles

Then, we characterized both of them using several tests; XRD, PL, SEM, and Spectroscopy.



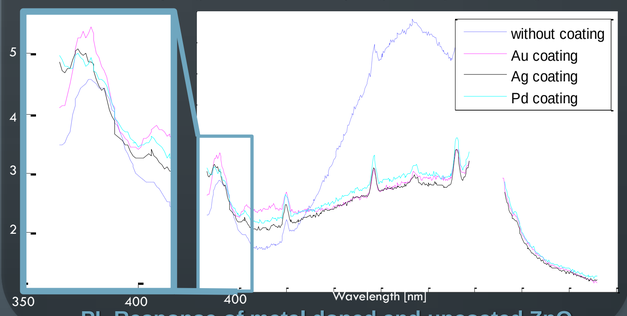
Scanning Electron Microscope image of both samples

Those tests confirmed that our samples were, indeed, ZnO powder nano-scale. Thereafter, we used them and compared them with different ZnO samples that are coated with Au, Pd and Ag.



ZnO + Ag | ZnO + Au | ZnO + Pd

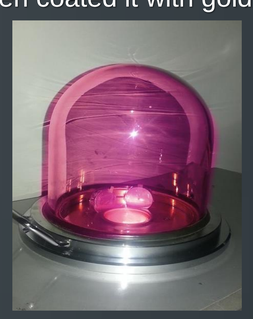
And by plotting the PL results, we see that the emission of ZnO at 381 nm was enhanced by 11%, 11% and 20% after doping with Silver (Ag), Palladium (Pd), and Gold (Au), respectively.



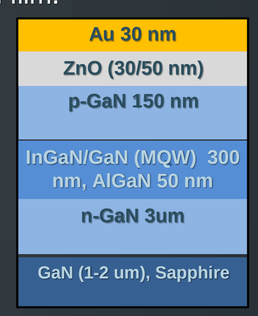
PL Response of metal doped and uncoated ZnO

GaN LED with Quantum Wells

Quantum wells are thin layers of semiconductor which gives quantum mechanical effects. The layer could be 40 atoms thick sandwiched between other semiconductors. There special properties are driven from the quantum confinement of charge carriers. The light emitter that we used was a GaN LED with a quantum well structure. To study the effect of ZnO plasmonic we, first, coated it with ZnO with two different thickness values, 30 nm and 50 nm, and then coated it with gold thin film.

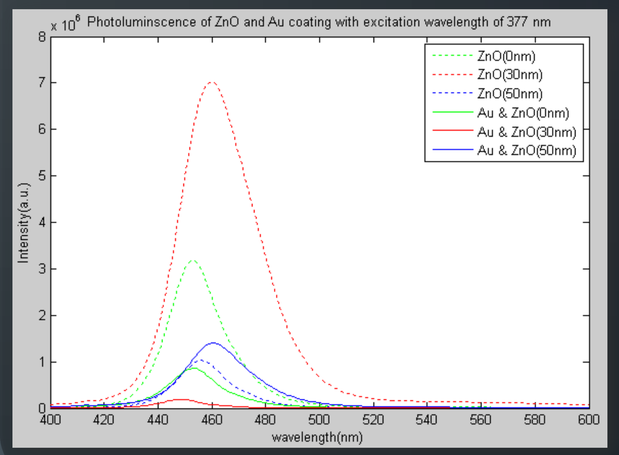


Gold Sputtering Machine



LED quantum Well Structure

After analyzing the coated Light emitters using the PL test, we were able to producing the following summarizing plot of all different cases:



Photoluminescence results of all different cases

Conclusion

- Ag, Au, Pd doping of ZnO nanoparticles enhance its emission.
- Materials used for plasmonics have resonance wavelengths that need to be matched.
- ZnO is a great tool for emission and efficiency enhancement of QWs and LEDs in general.
- There is an optimal thickness of ZnO coating.

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References

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- W. Lai, J. An, and H. C. Ong , “Surface-plasmon-mediated emission from metal-capped ZnO thin films,Applied Physics Letters.