Abstract

Ph.D Thesis Initiation

Title: Synthesis and Characterization of Wide-Bandgap Semiconductor Nanostructures towards Opto-Electronic applications

Area of research: Material science, physics, chemistry, nano-photonics, fundamental electronics
Keywords: GaN, Graphene Quantum dot, hBN, CVD, nanowire, defect, Purcell enhancement

Semiconductor structures offer unique properties at the nanoscale. Mastering the growth of semiconductor crystals and fabrication processes is crucial towards developing better opto-electronic devices. Morphological variations at nanoscale have a direct effect on available electronics states, impacting fundamental electronic properties and photonic capabilities of the material. This thesis focuses on one-dimensional Gallium Nitride (GaN) nanowires, N Nitrogen-doped Graphene Quantum Dots (N-GQDs) and two-dimensional hexagonal-Boron Nitride (hBN).

First, optical capabilities of GQDs, GaN nanowires and hBN thin film have been studied for their optical emission in the ultraviolet and visible range. Inherent defects resulting from growth alter optical properties. GaN one-dimensional structures grown by Low Pressure Chemical Vapor Deposition system (LPCVD) show high concentration of surface states emitting yellow and green luminescence besides near-band edge emission. N-GQDs show better photoluminescence (PL) properties, compared to GQDs, as the emission can be tailored from green to yellow by adjusting the solvent in the hydrothermal reaction. Fluorescent properties of hBN monolayers with ultra violet emission and engineering defect-related luminescent centers is an aspiring goal for room temperature single photon emitters

Next, GaN nanowires growth kinetics and mechanisms were found to evolve by altering precursor concentration, temperature of growth or seed catalyst. PL and Raman spectroscopy characterizations show high concentration of defect states in LPCVD-grown GaN crystal while MBE-grown nanowires exhibit a strong near-band edge emission for as-grown and Mg-doped nanostructures. For N-GQDs the emission is modulated by changing the solvent in the hydrothermal reaction. The shortening of the emission lifetime is proportional to the increase in the emission wavelength from blue and yellow while the quantum yields approaches unity thanks to few hydroxyl and carboxyl groups acting as nonradiative electron–hole recombination centers.

Finally, fabrication of efficient micro- and nano-scale emitters is of crucial importance for optical nanodevices. In conventional semiconductors, such as Si or GaAs, fabrication processes can involve expensive and time consuming electron beam lithography and etching. We show an alternative, using femtosecond laser-based process, to fabricate efficient GaN and hBN-based localized micro- and nanometer-size light emitters based on intentionally induced points defects. Coupling these nano-emitters with surface plasmons of another nanostructure can improve the emission rate as shown by coupling N-GQDs to single Bi_2Te_3 nanoplates.