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Gallium Nitride-Based Nanowire Radial Heterostructures for Nanophotonics

FANG QIAN, Harvard University

Semiconductor nanowires are attractive building blocks for the assembly of active photonics devices, providing a unique and flexible pathway for creating multicolor integrated nanophotonic systems beyond the limit of conventional planar structures. Realizing this potential will require novel electrically driven and interconnected nanowire building blocks with emission wavelengths that can be rationally tuned. To achieve this goal, we have exploited the controlled growth of well-defined GaN-based nanowire radial heterostructures, and their application as efficient and synthetically tunable multicolor light sources. Prepared by metal-organic chemical vapor deposition, these nanowire heterostructures consist of an n-GaN core and diverse multishells, including n-GaN/InGaN/p-GaN double heterostructures, n-GaN/InGaN/GaN/p-AlGaN/p-GaN single quantum well, and n-GaN/(InGaN/GaN)m/p-AlGaN/p-GaN multi-quantum well structures, where variation of indium mole fraction is used to tune emission wavelength. Transmission electron microscopy analysis shows that these nanowires are dislocation-free single crystals with triangular cross-sections and chemically distinct shells, while composition and thickness of individual shells are well controlled during synthesis. Under optical excitation, they exhibit strong photoluminescence consistent with bandgap emission of InGaN inner shell, and behave as freestanding Febry-Pérot optical cavities. Moreover, by contacting simultaneously n-GaN core and p-GaN shell, electroluminescence results demonstrate that in forward bias they function as high-brightness light-emitting diodes with tunable emission from 365 to 600 nm and high quantum efficiencies. The ability to synthesize rationally GaN-based nanowire radial heterostructures as electrically-driven, efficient and color-tunable light sources should open up significant potential for integrated photonics.