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ZnO nanorods, heterostructures and nanodevices

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ABSTRACT

One-dimensional nanorods open up many new device applications. As one of the semiconductor nanorods, ZnO-based nanorods have been studied for electronic and photonic nanodevice applications. Recently, we developed catalyst-free metal-organic chemical vapor deposition of ZnO nanorods and employed these ZnO nanorods for electrical and optical nanodevice applications. In this presentation, I will discuss a couple of advantages of the catalyst-free method over metal catalyst assisted vapor-liquid-solid (VLS) method which has widely been used for growths of many kinds of semiconductor nanowires. First, the catalyst-free method excludes possible incorporation of metal impurities which may occur in the catalyst-assisted VLS methods, which enables to minimize unintentional impurity incorporation and offer high purity nanorods. As evidence of the high purity ZnO nanorod growth using the catalyst-free method, free exciton emission peaks was observed in PL spectra of ZnO nanorods measured at low temperatures below 15 K. The high purity materials growth makes it easy to control conductivity by doping and fabricate high performance devices. I will demonstrate fabrication of high performance field effect transistors based on the ZnO nanorods exhibiting high field effect electron mobility above 1000 cm^2/Vs with a large turn ON/OFF ratio. Based on the nanorod Schottky diodes and field effect transistors, logic gates were also fabricated. Second, many kinds of nanorod heterostructures can be fabricated combining this catalyst-free method and conventional techniques already developed for growth of thin film heterostructure devices. For example, we demonstrated fabrications of metal/semiconductor nanorod heterostructures by simply evaporating metal on nanorod tips and nanorod quantum well structures and coaxial nanorod heterostructures by epitaxial growth. The heteroepitaxial nanostructures with well-defined crystalline interfaces are essential building blocks for the fabrication of devices on a single wire or a rod, which in principle permit extremely small size and ultrahigh density. Furthermore, embedding quantum structures in a single nanorod enables novel physical properties such as quantum confinement to be exploited, such as the continuous tuning of spectral wavelength by varying the well thickness. In this presentation, we demonstrate this to be the case by the fabrication of both ZnO/ZnMgO quantum well structures within individual ZnO nanorods and coaxial nanorod heterostructures. With precise thickness control down to the monolayer level, these heterostructures show the clear signature of quantum confinement, an increasing blue shift with decreasing layer thickness.