Imaging 3D nanostructure of III-V on Si via cross-section SPM: quantum wells and nanowires - defects, polarity, local charges

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Resume : Merging unique performance of compound semiconductor (CS) III-V materials in optoelectronics, high frequency and power devices with mature Si manufacturing is a holy grail of modern semiconductor technology. The difference between lattice constants, processing, and chemistry are just a few major challenges to be resolved. With practically non-existing methods for studying nanoscale physical properties of these buried structures, we developed a new concept for fast and efficient 3D nanoscale resolution quantitative mapping of physical properties of CS materials and devices. We combine novel nano-sectioning using variable energy Ar ion beam targeted at the edge of the sample to create a perfectly flat oblique near-atomic flat section through all layers of interest, and the material sensitive scanning probe microscopy (SPM), to reveal 3D morphology, composition, strain and crystalline quality via local physical properties – mechanical and piezoelectric moduli, nanoscale heat conductance, workfunction and electrical conductivity. We can observe the propagation of antiphase domains (APD) from the GaAs-Si interface through the 3D structure, reporting for the first time APD effect on electronic properties of multiple quantum wells that are electrically short the structure evident on charge distribution nanomaps. In GaN nanowires, we directly observe NW/Si substrate interface, and unexpectedly find the in-NWs domains of the opposite polarity via piezoelectric moduli maps. The novel paradigm will make a disruptive change on how 3D structure and physical properties of CS and microelectronics materials and devices are currently studied.

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