Recent progress in self-organized growth of quantum dot and wire structures and their advanced device applications

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Epitaxial growth methods such as molecular beam epitaxy and organo-metallic vapor phase epitaxy have played important roles for the formation of quantum wells (QWs), superlattices (SLs), and selectively-doped heterojunctions, as they enable one to form these layered nanostructures. Two-dimensional (2D) carriers confined in these structures have been used to make a set of core semiconductor devices, such as QW lasers, heterostructure FETs, and quantum cascade lasers.

To explore further potentials of nanostructures, the use of 1D and 0D electrons in quantum wires (QWRs) and quantum dots (QDs) was proposed to make advanced devices [1], such as planar SLs [2], QWR FETs [3], and QD lasers [4]. Though QWRs and QDs could not readily be made, these proposals induced intensive efforts to develop various methods to fabricate these nanostructures.

While e-beam lithography was first used to form QWRs and QDs of about 100nm in size, several methods to form 10nm-scale QWRs and/or QDs have been realized; they include the overgrowth of an n-AlGaAs layer on the cleaved edge of GaAs QWs, the site-selective growth along bunched steps on tilted substrates, the facet-selective growth on patterned substrates and so on [1]. It has been also found that 10nm-scale QDs can be self-organized by using the Stranski-Krastanow (SK) growth of nanoparticles on lattice-mismatched substrates and by the droplet epitaxy, in which metal droplets are formed and transformed to QDs of intermetallic compounds [1]. In particular, the SK growth has been extensively used to make a variety of QD devices, such as QD lasers of excellent temperature stability [5], single-photon emitters, and interband /intersubband QD photodectors [1].

Moreover, self-organized growth methods of 10nm-scale QWRs and related nanostructures have been developed, such as the stacking of multiple SK QDs and the vapor-liquid-solid growth of nano- wires on catalytic nanoparticles; these methods have been extensively used to make such QWR/QD- based devices as QWR FETs, single-electron transistors, LEDs, photodetectors and so on.

In this talk, we review recent progress and discuss prospects of QD/QWR growth and devices.

References

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