Name (Title): Hiroyuki Sakaki (Professor)

Affiliation: Institute of Industrial Science, Univ. of Tokyo

Address: 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505 Japan

Home Page: http://quanta.iis.u-tokyo.ac.jp/

Lecture Title:

From Superlattices to Quantum Dots : Evolution of Semiconductor Nanostructures and Their Device Applications

Abstract:

It is widely known that 1-10nm scale films of semiconductors are extensively used in the core parts of lasers, LEDs, field-efffect transistors (FETs), since the conductivity and the optical gain can be efficiently modulated by controlling the density of electrons in such film structures. Electrons confined in such nm-scale films begin to exhibit their quantum mechanical wave aspects, while their two-dimensional motions within the film plane retain their classical particle character. Although, discrete energy levels of electrons formed in such nano-scale films are not explicitly exploited in FETs and lasers, they are far more positively used in superlattices and resonant tunneling diode structures so as to realize a variety of device functions, as demonstrated in Bloch oscillators, quantum well infrared photodetectors and quantum cascade lasers. We review first the present state of such nano-scale layered structures and related devices to discuss a couple of unresolved problems to be tackled.

The precise control of in-plane motions of two-dimensional (2D) electrons in nm-scale film structures is another important issue in the present day electronics. For example, the down-scaling of FETs over the last several decades has brought forth huge progress in the LSI performance. As a result, the 10nm-scale lateral patterning is now considered as one of the core techniques for LSI. In parallel with the LSI scaling that has eventually entered into the sub-100nm range, the present author and colleagues started already in the mid 70's theoretical studies to confine electrons quantum mechanically with 10nm-scale semiconductor box (dot) and wire structures and explore unique properties of such confined electrons in order to create a family of new devices, such as planar superlattice FETs (1975), quantum wire (QWR) FETs (1980) and quantum dot (QD) lasers (1982). Inspired by these and other early proposals, a variety of methods have been developed to form QD- and QWR-based materials. As a result, QD and QWR based devices have been fabricated to demonstrate their attractive properties and functions. We discuss first the present state and future prospects of QD and QWR based transport devices, such as QWR FETs, quantum dot charge storage devices, single-electron transistors, and photo-detectors. We examine then QD and QWR-based lasers and single photon emitters and detectors.

In the final section, we discuss exploratory attempts on QDs and QWRs, including their possible uses for quantum information systems. We examine also a couple of advanced applications of nanostructures in such fields as medical diagnosis and environmental and energy-related technology.