NANO-OPTOELECTRONICS BASED ON III-V SEMICONDUCTOR QUANTUM DOTS

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ABSTRACT

In this talk, I discuss the new physics and device applications provided by self-assembled quantum dots, in particular, with III-V compound semiconductor materials system. The quantum dots are the structures three-dimensionally confined and therefore provide quasi zero-dimensional electron gas system, where novel physics can be studied and improved device performance can be achieved, in particular, in optoelectronics. As an example, I introduce the research activities at Nano Device Research Center, on the nanophotonics based on III-V compound semiconductor quantum dots. The activities include the growth of quantum dots, study of carrier dynamics, development of photonic devices such as quantum dot laser diodes, superluminescent diodes, and quantum dot infrared photodetectors. In the growth of self-assembled quantum dots, with InGa(As)/GaAs structures, the migration-enhanced (or atomic layer growth) mode of molecular beam epitaxy was employed, which provides larger and more uniform quantum dots with reduced wetting layer thickness, compared to the conventional Stransli-Krastanov mode. Recently, quantum dot laser diodes lasing at room temperature and at 1,300 nm wavelength, which is important in optical communication, have been developed utilizing modulated p-doping and high-temperature growth of spacer layers. Although further optimization is necessary in device processes, theses laser diodes exhibit quite state-of-the-art quality. Superluminescent diodes have been also developed employing chirped structure for wider bandwiths. Quantum dot infrared photodetectors were also developed, which have potential advantages over conventional quantum well infrared photodetectors, such as the possibilities of response to the normal incidence, which is important for implementation of focal plane array, and higher temperature operation, which can replace the liquid nitrogen dewer to simple and less expensive cryogenic circuit. Employing an asymmetric potential structure we developed photovoltaic photodetectors where the maximum responsivity occurs at zero bias, where the dark current is reduced to the minimum value and the detectivity can be enhanced. Also, the effects of post-growth treatments such as hydrogenation and thermal annealing, on the device performance will be presented. Issues of passivation of non-radiative recombination centers and intermixing will be discussed. Finally, I propose possible cooperation schemes between Korea and USA with selected research topics.