Introduction to the Special Issue on Physics and Applications of Semiconductor Quantum-Well Structures

REMARKABLE advances in semiconductor technology have made possible the fabrication of artificial microstructures with dimensions comparable to interatomic distances. The availability of this class of semiconductor structures creates new avenues for the investigation of the physics of condensed matter under conditions of greatly reduced dimensionality where ''quantum size'' phenomena become apparent. In the case of electrons, quantum size effects occur when the physical dimensions are comparable to the characteristic lengths that determine electron behavior: the wave packet de Broglie wavelength, the Bohr radii, and the mean free path. These lengths range between 10 Å and 1000 Å in the most common semiconductors. The great current interest in semiconductor microstructure research is stimulated by a continuous stream of discoveries and the potential to revolutionize the technology of solid state optoelectronics.

By growth with molecular beam epitaxy techniques and, more recently, by metal-organic-chemical-vapor deposition it is possible to obtain ultrathin semiconductor layers that are smooth on an atomic scale. New physics and novel devices are possible because of the excellent, angstroem-scale, control of composition, and doping. Single heterojunctions and multiple heterostructures based on two different semiconductors are now routinely grown in many laboratories. The closely lattice-matched GaAs-$(Al_xGa_{1-x})As$ heterostructures are fabricated to a high degree of perfection. In recent years, similar structures have been successfully grown in other semiconductors belonging to the III–V, II–VI, and IV groups.

These artificial structures have revealed a wealth of novel physical phenomena. Some of the most striking are the consequence of the existence of a ''unique axis'' along the direction normal to the layers. The unique axis represents the direction in which the electron motion is strongly altered by ultrathin layering. On the other hand the carriers motion parallel to the plane of the layers is not substantially modified. The semiconductor heterostructures can be fabricated with carefully tailored composition and doping profiles, such that the carriers are confined within one type of layers or quantum wells. This confers to carriers a quasi-two-dimensional character that is at the center of some of the most exciting recent developments in experimental and theoretical solid state physics. Two specific features that attract much attention are the extremely high mobility observed in ''modulation doped'' heterojunctions and the enhanced optical properties seen close to the bandgaps of quantum-well heterostructures. It is also possible to fabricate heterostructures in which carrier transport perpendicular to the layers is permitted. The behavior of carriers in these systems is three-dimensional, but with very anisotropic properties that can be tailored more or less continuously. In graded gap structures, internal electric fields, which are different for electrons and holes, introduce a new degree of freedom to modify charge transport. Periodic multilayer structures form superlattices in which the folding of the Brillouin zone strongly affects energy band structure and symmetry selection rules as compared to the bulk. These man-made quantum-layered semiconductors have already found applications in high-speed electronic, optoelectronic, and photonic devices.

This Special Issue of the IEEE JOURNAL OF QUANTUM ELECTRONICS presents a collection of invited articles and selected contributed papers that cover some of the most recent developments in the physics and applications of semiconductor quantum-well structures.

This field has seen an extraordinary growth during the last ten years. It is still far from being mature. Even greater progress and diversification can be expected in many areas of fundamental and applied research. We hope that the papers in this Special Issue will provide an up to date picture of the present status of the field. We also hope that it will serve as a useful source of ideas and reference for the future developments.

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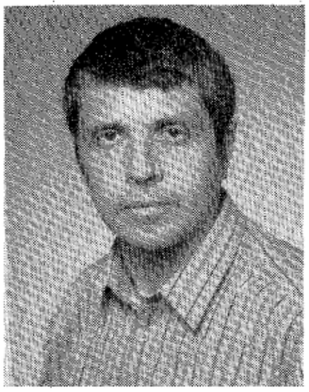

D. S. Chemla (M'84) was born in Tunis, Tunisia, on July 21, 1940. He graduated from the Ecole Nationale Superieure des Telecommunications, Paris, France, in 1965, and received the Doctorat Es-Sciences from the Faculty of Sciences of Paris in 1972.

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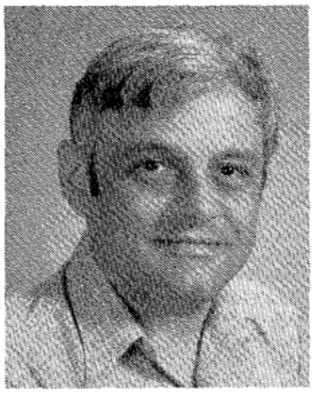

Aron Pinczuk was born in Argentina. He received the Licenciado degree from the University of Buenos Aires, Buenos Aires, Argentina in 1962, and the Ph.D. degree in physics from the University of Pennsylvania, Philadelphia, in 1969.

From 1969 to 1971 he was Research Assistant Professor at the University of Pennsylvania, where he carried out research on Raman scattering from semiconductors. This work led to applications of the light scattering method to fundamental studies of optical properties of semiconductors and of surface space charge layers. From 1971 to 1975 he worked at the Atomic Energy Commission and the National Research Council, Buenos Aires. In 1976 he was Visiting Scientist at the Max–Planck–Institute, Stuttgart, Federal Republic of Germany. In 1977 he worked as Visiting Scientist at the IBM T. J. Watson Research Center, Yorktown Heights, NY. He joined Bell Laboratories, Murray Hill, NJ, in 1978, where he began Raman scattering studies of semiconductor epitaxial layers. This research led to the development of new inelastic light scattering methods to study the novel properties of semiconductor superlattices. He is currently interested in the optical spectroscopy of two-dimensional electron systems in semiconductors.

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