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FOREWORD

The physics of III-V nitrides

Guest Editor

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The evolution of semiconductor physics is driven by the increasing sophistication of the art of crystal growing and fabrication techniques. From Ge at the birth of the transistor, possibly the purest material ever grown, through Si, the work-horse of the crystal revolution, to the III-Vs, whose optical properties opened up a second front, namely, optoelectronics. Crystal growth with monolayer control gave us quantum wells, superlattices, quantum wires and quantum dots, along with the quantum Hall effect and quantized resistance. The potential for high-power devices triggered interest in the III-V nitrides with their large bandgaps. The nitrides mostly crystallize in the hexagonal form, and this has introduced the phenomenon of spontaneous polarization into mainstream semiconductor physics. Its effect manifests itself in huge electric fields in heterostructures like AlGaN/GaN which, in turn, causes the induction of substantial electron populations in the channel of a HFET without the need for doping. High-power microwave transistors have been successfully fabricated, even though there are features associated with spontaneous polarization that still needs clarifying. Another strange effect is the large electron population on the surface of InN. The lack of a suitable substrate for growing GaN has meant that the dislocation density is higher than we would wish, but that situation is expected to steadily improve.

Given the current interest in the physics of nitrides, it is natural to come across a special issue devoted to this topic. The difficulty presented by the surface layer in InN in the attempt to measure transport properties is discussed in the paper by King *et al*. A property that can affect transport is the lifetime of optical phonons and its dependence on electron density. Measurements of phonon lifetime in InN are reported by Tsen and Ferry, and in GaN channels, via the measure of hot-electron fluctuations, by Matulionis. The dependence on electron density is thought to be associated with the coupling of plasma and phonon modes, and this is discussed by Dyson. The intrinsic cause of phonon decay is the anharmonic interaction involving three phonons, and this process is described for zinc blende BN and hexagonal AlN, GaN and InN by Srivastava. The principal electron scattering mechanism at room temperature is associated with the interaction with polar optical modes. At high fields, transfer to the upper conduction-band valleys can take place and this involves the deformation-potential interaction. Deformation potentials have been derived by Yamakawa *et al* for GaN, and they have been incorporated into a cellular Monte Carlo simulation to describe high-field transport.

In high-power devices, thermal as well as electronic transport is important. The thermal conductivity of the substrate of devices is a vital factor, and the possible use of AlN ceramics is discussed by AlShaikhi and Srivastarva. A striking device based on a zinc blende superlattice is the quantum cascade laser. Exploiting intersubband transitions in the AlN/GaN superlattice for the high-speed detection of infrared light is described by Hofstetter *et al*, clearly a first step towards a nitride based quantum cascade laser.

In bulk material the displacement of As by N that transforms GaAs to GaN produces a huge change in properties. Adding a small amount of N to GaAs might be expected to produce a gradual more-or-less linear shift towards the properties of GaN, but this turns out to be far from the case. The strange

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properties of dilute nitrides have intrigued many workers in recent years. Its curious bandstructure suggested that hot-electron transport could exhibit a negative differential resistance, and a report on this topic can be found in the article by Patane *et al.* A comprehensive study of transport of electrons and holes in dilute nitride/GaAs quantum wells is reported by Sun *et al.* An unusual new device—a spin filter—is presaged by the work of Zhao *et al* on spin-dependent recombination, controllable by adjusting the N content.

Answers to a number of problems presented by the physics of III-V nitrides are to be found in the articles composing this edition, but there are still many that need clarifying. That clarification will have to await the future work that will form the contents of a future special edition.