

# Compound semiconductor materials and devices and the fabrication of semiconductor nanostructures, search for new functions

## »» NOZAKI and UCHIDA Laboratory



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### Summary of Research

#### Fabrication of High-Performance Semiconductor Devices and Nanorods

Compound semiconductor materials and devices and the fabrication of semiconductor nanorods and their applications represent the two major research themes at our laboratory. We fabricate next-generation semiconductor materials and semiconductor nanorods through a metal organic vapor phase epitaxy (MOVPE) apparatus and chemical synthesis, developing high-performance electro-optic devices that strategically exploit the functions of the new materials we create.

#### Compound Semiconductor Materials and Devices

One of our most notable achievements in recent years has been the development of highly-reliable InP/InGaAs, InGaP/GaAs heterojunction bipolar transistors (HBT). These transistors, boasting high current drive and high-frequency operation capabilities, are expected to serve as power elements for cell phones and optical communication devices.

The problem with conventional bipolar transistors lies in the difficulty of achieving high-frequency operation due to limitations in base doping concentrations. We overcame this problem by using a wide-band-gap semiconductor as the emitter and carbon as the p-type impurity in the base. Another obstacle to the successful creation of a high-performance HBT is the need for a high-quality interface; different materials are generally used for the emitter and base. Our laboratory has independently developed defect evaluation methods for semiconductor elements using Laplace Deep Level Transient Spectroscopy (DLTS) and Charge Transient Spectroscopy (CTS), using them in our development of high-performance semiconductor devices.

We have also succeeded in improving the reliability of HBT characterized by high base doping concentrations, which typically tend to deteriorate under high current conditions. We accomplished this by introducing an emitter modified with a structure, called a passivation ledge, to the transistor.

In the area of optical devices, our laboratory is active in research and development involving powerful large-area LEDs for red, yellow, blue, and infrared. The semiconductors used for red and yellow LEDs are based on InGaP; for blue, InGaN; and for infrared, GaAs. Due to their long life and low power consumption, LEDs have gained popularity as environmentally-friendly illumination devices. The downside to conventional LED elements has been the small size of their effective surface areas, normally in the range of 0.3 to 0.5 mm<sup>2</sup>.

By using Indium Tin Oxide (ITO) as an electrode—the material offers high transmittance of 80-90% in the visible range and extremely low electrical resistance—our laboratory was able to expand the effective area to 1 cm<sup>2</sup>, as proudly demonstrated at SEMICON<sup>®</sup> Japan.

Research and development on ultraviolet (UV) LEDs has been gaining momentum both in Japan and abroad. In this area, our laboratory has independently developed an MOVPE apparatus that will enable the fabrication of a variety of high-quality metal oxide semiconductors suitable for use as wide-band-gap semiconductor materials. Our approach makes use of p-type nickel oxide (NiO)/ n-type zinc oxide (ZnO) heterojunctions to fabricate UV-LEDs.

We have also developed a UV oxidation method in which deposited silicon oxide thin films are oxidized at low temperatures under UV-irradiated conditions, allowing us to develop a low-temperature fabrication technique for the high-quality oxide thin films required for IC fabrication on the flexible substrates expected to become the material of choice for next-generation electronics. It has also resulted in the successful development of a fabrication technique for a high-quality gate oxide on semiconductor

### Keywords

Nanotechnology, compound semiconductors, LSI processing, metal organic vapor phase epitaxy (MOVPE), LED, heterojunction bipolar transistor (HBT), oxide semiconductors, deep-level transient spectroscopy (DLTS)

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# Nonstationary Modeling Of Iii-v Compound Semiconductor Materials And Devices

**Daniel F McAuley**



## **Nonstationary Modeling Of Iiiiv Compound Semiconductor Materials And Devices:**

**NON-STATIONARY MODELING OF III-IV COMPOUND SEMICONDUCTOR MATERIALS AND DEVICES** SAMUEL C. SOMEREN GREVE,1984     Compound Semiconductor Device Modelling Christopher M. Snowden,Robert E. Miles,2012-12-06 Compound semiconductor devices form the foundation of solid state microwave and optoelectronic technologies used in many modern communication systems In common with their low frequency counterparts these devices are often represented using equivalent circuit models but it is often necessary to resort to physical models in order to gain insight into the detailed operation of compound semiconductor devices Many of the earliest physical models were indeed developed to understand the unusual phenomena which occur at high frequencies Such was the case with the Gunn and IMPATI diodes which led to an increased interest in using numerical simulation methods Contemporary devices often have feature sizes so small that they no longer operate within the familiar traditional framework and hot electron or even quantum mechanical models are required The need for accurate and efficient models suitable for computer aided design has increased with the demand for a wider range of integrated devices for operation at microwave millimetre and optical frequencies The apparent complexity of equivalent circuit and physics based models distinguishes high frequency devices from their low frequency counterparts Over the past twenty years a wide range of modelling techniques have emerged suitable for describing the operation of compound semiconductor devices This book brings together for the first time the most popular techniques in everyday use by engineers and scientists The book specifically addresses the requirements and techniques suitable for modelling GaAs InP ternary and quaternary semiconductor devices found in modern technology     *Springer Handbook of Semiconductor Devices* Massimo Rudan,Rossella Brunetti,Susanna Reggiani,2022-11-10 This Springer Handbook comprehensively covers the topic of semiconductor devices embracing all aspects from theoretical background to fabrication modeling and applications Nearly 100 leading scientists from industry and academia were selected to write the handbook s chapters which were conceived for professionals and practitioners material scientists physicists and electrical engineers working at universities industrial R D and manufacturers Starting from the description of the relevant technological aspects and fabrication steps the handbook proceeds with a section fully devoted to the main conventional semiconductor devices like e g bipolar transistors and MOS capacitors and transistors used in the production of the standard integrated circuits and the corresponding physical models In the subsequent chapters the scaling issues of the semiconductor device technology are addressed followed by the description of novel concept based semiconductor devices The last section illustrates the numerical simulation methods ranging from the fabrication processes to the device performances Each chapter is self contained and refers to related topics treated in other chapters when necessary so that the reader interested in a specific subject can easily identify a personal reading path through the vast contents of the handbook

**Semiconductor Device Modelling** Christopher M. Snowden,2012-12-06 Semiconductor device modelling has

developed in recent years from being solely the domain of device physicists to span broader technological disciplines involved in device and electronic circuit design and development. The rapid emergence of very high speed high density integrated circuit technology and the drive towards high speed communications has meant that extremely small scale device structures are used in contemporary designs. The characterisation and analysis of these devices can no longer be satisfied by electrical measurements alone. Traditional equivalent circuit models and closed form analytical models cannot always provide consistently accurate results for all modes of operation of these very small devices. Furthermore the highly competitive nature of the semiconductor industry has led to the need to minimise development costs and lead time associated with introducing new designs. This has meant that there has been a greater demand for models capable of increasing our understanding of how these devices operate and capable of predicting accurate quantitative results. The desire to move towards computer aided design and expert systems has reinforced the need for models capable of representing device operation under DC small signal large signal and high frequency operation. It is also desirable to relate the physical structure of the device to the electrical performance. This demand for better models has led to the introduction of improved equivalent circuit models and a upsurge in interest in using physical models.

*Physics and Modeling of Tera- and Nano-devices* Maxim Ryzhii, Victor Ryzhii, 2008. *Physics and Modeling of Tera and Nano Devices* is a compilation of papers by well respected researchers working in the field of physics and modeling of novel electronic and optoelectronic devices. The topics covered include devices based on carbon nanotubes generation and detection of terahertz radiation in semiconductor structures including terahertz plasma oscillations and instabilities terahertz photomixing in semiconductor heterostructures spin and microwave induced phenomena in low dimensional systems and various computational aspects of device modeling. Researchers as well as graduate and postgraduate students working in this field will benefit from reading this book.

Sample Chapter s Semiconductor Device Scaling Physics Transport and the Role of Nanowires 784 KB Contents Semiconductor Device Scaling Physics Transport and the Role of Nanowires D K Ferry et al Polaronic Effects at the Field Effect Junctions for Unconventional Semiconductors N Kirova Cellular Monte Carlo Simulation of High Field Transport in Semiconductor Devices S M Goodnick Nanoelectronic Device Simulation Based on the Wigner Function Formalism H Kosina Quantum Simulations of Dual Gate MOSFET Devices Building and Deploying Community Nanotechnology Software Tools on nanoHUB.org S Ahmed et al Positive Magneto Resistance in a Point Contact Possible Manifestation of Interactions V T Renard et al Impact of Intrinsic Parameter Fluctuations in Nano CMOS Devices on Circuits and Systems S Roy et al HEMT Based Nanometer Devices Toward Terahertz Era E Sano Plasma Waves in Two Dimensional Electron Systems and Their Applications V Ryzhii et al Resonant Terahertz Detection Antenna Utilizing Plasma Oscillations in Lateral Schottky Diode A Satou et al Terahertz Polarization Controller Based on Electronic Dispersion Control of 2D Plasmons T Nishimura Higher Order Plasmon Resonances in GaN Based Field Effect Transistor Arrays V V Popov et al Ultra Highly Sensitive Terahertz Detection Using

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medicine is also provided Systems considerations including thermal mechanical reliability power management and safety are discussed in separate chapters Engineering processes are also explored in articles about corporate initiatives cost modeling and design reviews The book closes with a discussion of the underlying physics of electromagnetic propagation and interference In addition to new chapters on WiMAX and broadband cable nearly every existing chapter features extensive updates and several were completely rewritten to reflect the massive changes areas such as radio navigation and electronic warfare

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