Scanning the Special Issue

Special Issue on Wide Bandgap Semiconductor Devices

The electronics revolution of the 20th century was driven by the invention of the transistor and integrated circuit employing silicon semiconductor technology. Hence, silicon can be considered the first generation semiconductor. The wireless and information revolution ignited at the turn of the 20th to 21st century was made possible by the utilization of the semiconductor laser and microwave transistor based on the second generation semiconductors, gallium arsenide, and indium phosphide. At the start of the 21st century, the wide bandgap semiconductors, SiC and GaN, are emerging as the third generation of semiconductors and promise to revolutionize both the optoelectronic and electronic device industries. These wide bandgap semiconductors offer properties that enable emitters [e.g., blue–green lasers and blue–green or white light-emitting diodes (LEDs)], solar-blind detectors, high-power solid-state switches and rectifiers, and high power density microwave transistors. These devices either out perform the comparable devices based on previous generation semiconductors or, in fact, could not be produced with the prior materials.

While these wide bandgap semiconductors have been recognized for over 30 years as being ideally suited for the applications mentioned above, until recently, the material quality was insufficient to allow high-performance devices to be produced. This has now dramatically changed based first on the invention and commercialization of the GaN-based LEDs in the early 1990s and the commercialization of large-diameter SiC substrates. These breakthroughs have driven the improvement in both SiC and GaN material quality and correspondingly allowed industry to create new products based on the enormous improvements in device performance.

The applications for these third-generation semiconductors are only beginning to be fully identified. The largest driver is expected to continue to be light emitters, the single-color LED, and laser (presently a ~$500 million/year market that is projected to grow to $4 billion by 2009) or as the basis for high-efficiency solid-state white lighting. The white lighting market is projected to exceed that of the single color sources. In addition, it is expected that high power switches and diodes for electrical power control and distribution will create a large commercial industry as the quality of epitaxy and substrates improve. The demonstration of high-power diodes with blocking voltages of 19 kV provide a preview of the type of performance that one can expect from these materials in the future. High-power microwave applications employed in future radar, electronics warfare, and communications systems drive the military market where these materials have already demonstrated performance superior to silicon and gallium arsenide. The commercial market for wide bandgap microwave components is evolving with third-generation wireless base stations being the first opportunity for SiC devices and GaN technology to find application at higher frequencies.

This Special Issue is divided into three sections that describe the excitement that is currently occurring in the development of wide bandgap materials and electronic and optoelectronic devices.

Silicon Carbide Materials and Devices

In this section, we present four invited papers that address the current "state of the art" and predict the future advances expected to occur in SiC Materials and Devices. In the first paper, Powell and Roland review the properties of SiC, assess the current status of substrate and epitaxial growth, and outline their expectations of SiC in the future. In the second paper, Cooper and Agarwal show why SiC offers significant advances for power-switching devices and they describe the remarkable progress that has occurred in power devices in the last five years with demonstrations of currents in excess of 100 A and blocking voltages of 19 000 V. In the third paper, Elasser and Chow look at the benefits of using SiC in power electronic applications, review the current "state of the art," and show how SiC can be a strong and viable candidate for future power electronics and systems applications. In the fourth paper, Clarke and Palmour describe the dramatic improvements made in power, efficiency, and linearity in SiC metal–semiconductor field-effect transistors and static induction transistors over recent years.

Nitride Materials and Devices

In this section, we present four invited papers that address the current "state of the art" and predict the future advances expected to occur in nitride based materials (AlGaN, GaN and InGaN) and the resulting electronic and optoelectronic

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devices. In the first paper, Davis and coauthors describe the state of the art in the materials characterization and growth of nitride alloys by organometallic chemical vapor deposition and molecular beam epitaxy. In the second paper, Razeghi describes the progress made in the development of ultraviolet photodetectors and future prospects for these detectors. In the third paper, Amano *et al.* present a historical overview and recent trends in the research and development of nitride-based light emitters with particular emphasis on describing the impact of low-temperature buffer layers on optoelectronic device performance. In the fourth paper, Mishra *et al.* describe the dramatic performance advances achieved in the last five years in GaN high-electron mobility transistors and provides the reader with the status of the technology and the market with a view of highlighting both the progress and remaining problems.

Other Applications and Issues

In this section, we present five invited papers that address the competition between SiC and GaN for microwave power applications, issues that impact the stability of output power from these devices and how this technology can impact the Department of Defense. In addition, the impact of wide bandgap power devices on high-temperature electronics and on naval applications is accessed. In the first paper, Trew compares the potential output powers and frequency ranges of both SiC and GaN microwave devices. He concludes that this technology is able to demonstrate performance that previously was only available from microwave tubes. In the second paper, Binari *et al.* describe materials and processing issues that limit the stability and microwave output powers for wide bandgap semiconductor transistors and how, like in GaAs microwave technologies, improvements in material properties and passivation techniques are starting to overcome these problems. In the third paper, Kemerley *et al.* describe the numerous electromagnetic systems of the Department of Defense that would be enhanced by the inclusion of wide bandgap microwave and millimeter devices, either as power amplifiers or receiver elements. In the fourth paper, Neudeck reviews the impact of wide bandgap semiconductor devices on high-temperature electronics. He describes thermal conditions under which current technologies fail and wide bandgap semiconductor devices can fill an unmet need. In the fifth paper, Ericsen reviews the potential impact of wide bandgap semiconductor power devices on the design of the next generation Naval Warship.

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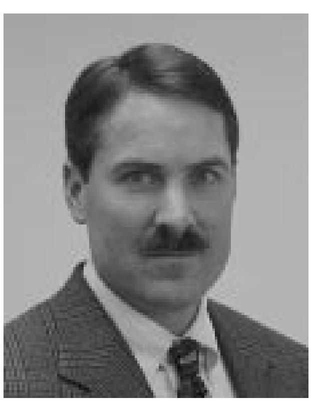

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