Chapter 1
Development of the Bulk GaN Substrate Market

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Abstract Near- and long-term market applications for bulk GaN substrates are examined, along with motivations and challenges for adopting the substrate technology for specific device applications. The near-term demand for bulk GaN is driven primarily by laser diodes, while solid state lighting and power electronics will drive the long-term demand. Challenges to achieving broad market penetration include increased volume production and reduced manufacturing cost, which are needed to penetrate incumbent GaN device technologies based on foreign substrates.

1.1 Introduction

Technology is pervasive throughout most of today’s society. Around the world, many of us are mass consumers of technology and vast industries have been created to meet our growing technological needs. Even in the third world, technology is increasingly being introduced in various forms including wireless communications, solar power, and modern pharmaceuticals. Advanced technologies have benefitted our lives in countless ways, but have also extracted a price in terms of resource and energy consumption and waste generation. A growing challenge is to employ technologies that advance our standard of living while addressing an increasingly important need to do more with less energy in order to reduce the negative impact on our environment.

In the ongoing development and application of new technologies, every so often there appears a fundamental technology that can shift the way the world operates. The development of silicon semiconductor materials, which enabled transistors, integrated circuits, microprocessors, the computer, and the information age, has influenced virtually every aspect of modern life. In a similar manner, the III-Nitride (III-N) semiconductor materials are poised in such a way to fundamentally change our lives. These materials, which include aluminum nitride (AlN), gallium nitride (GaN), and indium nitride (InN), will enable semiconductor devices with new capabilities and will make possible the reinvention of existing technologies. While there are many possible and even likely applications for these materials, their impact over
the next decade will focus on two main applications: light generation and the control of electrical power. These applications can anticipate large new commercial markets and this possibility is already stimulating aggressive development of supporting materials and device technologies. The great promise arising from these innovations is the ability to do more (more light, more power) with less (higher energy efficiency, less electricity, less waste heat). In this chapter, we discuss the opportunities and the challenges GaN-based materials face in addressing these markets and applications, and, in particular, we examine how GaN substrates will be used in new market applications. We present how GaN substrates will be introduced into near-term market opportunities that will create the driving force for manufacturing improvements and will allow GaN substrates to effectively address future market opportunities.

1.2 III-N Device Market Drivers and Forecast

1.2.1 Light Generation and Solid State Lighting in the III-Ns

One of the unique properties of the III-Ns is that they can enable efficient light emission from deep ultraviolet to infrared wavelengths. Accessing these wavelengths makes possible the development of highly efficient semiconductor-based white light sources. Solid-state lighting (SSL) based on light-emitting diodes (LEDs) allows the consumer to replace less efficient and less reliable lighting technologies, such as incandescent, fluorescent, and metal halide light sources.

A tremendous amount of energy goes into generating light for our everyday lives. For example, in the United States, about 22% of the nation’s electrical energy is used for lighting [1]. This equals the output of about 100 large power plants, but more than three times this amount is needed to produce the electricity due to electrical inefficiencies in lighting systems. The cost of this electricity is about $55 billion and growing, as energy costs increase, populations grow, and technology penetration throughout the world rises. Today, the need for lighting translates into a global market for lamps (light bulbs), ballasts, lighting fixtures, and lighting controls that is valued at about $40 billion annually [1]. Highly efficient lighting systems based on SSL are being developed to replace many of these low efficiency lighting technologies. As one considers the penetration of SSL into lighting applications and the energy savings resulting from these changes, it is easily seen how this technology can bring a significant benefit to our lives: improved energy efficiency and reduced energy consumption, carbon emission reduction, and lower total cost to the consumer. These benefits create the impetus for the development of the new GaN-based technologies for SSL.

According to the U.S. Department of Energy (US DOE), the long-term research and development goals for SSL call for a luminous efficiency of 160 lm/W in cost-effective, market-ready systems in 2025 [2]. This efficiency level of