

Chapter 21

III–V Nitride Based Novel Solid–State Terahertz Power–Source: Application in Defense and Industry

Moumita Mukherjee

Centre for Millimeter-wave Semiconductor Devices & Systems (CMSDS), Institute of Radio Physics and Electronics, University of Calcutta, India

ABSTRACT

The static and dynamic characteristics of Wide Bandgap GaN having different structures and doping profiles are thoroughly investigated. The study has established the potential of this WBG semiconductor in fabricating high-power IMPATT devices in the above high frequency regimes. A comparison between the device performances of WZ- & ZB- GaN IMPATTs has shown that WZ-GaN IMPATTs are superior to ZB-GaN IMPATTs as far as output power density, efficiency, and high-temperature operation are concerned. Starting with brief review on state-of-the-art THz devices and on the conventional ATT devices, a details analysis of THz frequency performances of the novel III-V Nitride semiconductor based ATT devices will be presented in this chapter. Application possibilities of such devices in defence and industrial sectors will be presented in a nutshell. Emphasis will be given on the studies on their experimental realization. Photo-sensitivity studies of the new class of devices are also the scope the chapter.

INTRODUCTION

In recent years, the field of Terahertz (THz) science and technology has entered a completely new phase of unprecedented expansion that is generating every growing levels of broad-based

international attention. Indeed, the plethora of activities that have arisen recently in both the technology and scientific arenas associated with the THz frequency domain - i.e., between 1 millimeter (300 GHz) and 100 micrometers (3 THz), suggest that the field might be attempting to undergo a dramatic transition that could lead to long-awaited payoffs in a number of applica-

DOI: 10.4018/978-1-4666-0294-6.ch021

tion areas. The inherent advantages and potential payoffs of the THz regime for military & security as well as industry relevant applications have long stood as an important driver of interest in this science and technology area. This extremely expansive and spectrally unique portion of the EM spectrum had initial application in space-based communications, upper atmospheric sensing and potentially for short-range terrestrial communications and non-intrusive package screening. However, the very rapid growth in more recent years is arguably most closely linked to the potential payoffs of THz sensing and imaging for an array of military, security and industrial applications. These applications include the spectroscopic-based detection identification and characterization of chemical and biological agents and materials, remote and standoff early-warning for chemical-biological warfare threats, and imaging of concealed weapons and explosives, just to name a few. In addition, THz-regime finds its application possibilities in industry and private-sector areas as food-industry process control, pharmaceutical industry, biological science, medical diagnostics and security screening.

Systems for rapidly emerging applications at THz frequencies thus require reliable high-power sources. In the last few years, the development of suitable sources for this frequency regime is being extensively explored worldwide. There are broadly two technology roadmaps for THz semiconductor devices. Approaching from the lower frequency range in the THz regime, electronic devices such as, Gunn diode, Resonant Tunneling diode (RTD) and nanometer Field Effect Transistors (FET) based on plasma wave have been widely investigated for THz frequency generation. From higher portion of the THz frequency spectrum, the photonics-based device Quantum Cascade Laser (QCL) extends the emission wavelength to Terahertz spectral range. The other approach to THz generation is through femtosecond lasers incident on materials with non-linear optical properties

or on photoconductors such as InP. Parametric amplifiers are also being used for the purpose.

All the above efforts are to pursue the effective generation of THz signals. Most of the available THz sources are complex and bulky. QCL, on the other hand, has the advantage of small size, though they require low temperature operation to directly generate THz. Thus it seems that there is lack of availability of small-sized suitable THz source to serve a useful purpose. So, the development of high-power, low-cost and compact semiconductor sources in THz regime has attracted the recent attention of researchers working in this field.

Nowadays two-terminal solid-state Avalanche Transit-Time (ATT) devices are finding increasing applications in advanced RADAR, missile seekers and MM-wave communication systems. The performance of conventional Si (Silicon) and GaAs (Gallium Arsenide)-based IMPact ionization Avalanche Transit Time (IMPATT) devices are limited by power, operating temperature and especially by operating frequency. Recently, there is a global demand for THz-frequency applications and this warrants a new class of IMPATT oscillators which would outclass conventional Si and GaAs IMPATTs. Investigations on the prospects of Wide Bandgap (WBG) semiconductor materials, particularly III-V Nitride semiconductors, for developing devices for high-frequency, high-power and high-temperature applications have been started recently. Exploitation of the material properties of GaN, holds promise for revolutionary improvements in high-temperature and high-frequency performances of a broad range of military and commercial devices. The most attractive material property of GaN is its wide bandgap energy. WZ-GaN has direct room temperature bandgap of 3.4 eV, much higher than conventional Si (1.12 eV) and GaAs (1.42 eV). Owing to its wide bandgap, GaN is promising for high-temperature application as it goes intrinsic at much higher ambient temperature than materials like Si and GaAs. It means that GaN based devices can operate with less cooling and with less high

13 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage:

www.igi-global.com/chapter/iii-nitride-based-novel-solid/64734

Related Content

Process Optimization and NVA Reduction by Network Analysis and Resequencing

Anand Sunder (2019). *International Journal of Applied Industrial Engineering* (pp. 29-45).

www.irma-international.org/article/process-optimization-and-nva-reduction-by-network-analysis-and-resequencing/222794

Application and Evaluation of Bee-Based Algorithms in Scheduling: A Case Study on Project Scheduling

Ayşe Aycim Selamand Ercan Oztemel (2018). *Handbook of Research on Applied Optimization Methodologies in Manufacturing Systems* (pp. 20-42).

www.irma-international.org/chapter/application-and-evaluation-of-bee-based-algorithms-in-scheduling/191769

Developing Context Sensitive BIM Based Applications

Timo Hartmann (2010). *Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies* (pp. 254-269).

www.irma-international.org/chapter/developing-context-sensitive-bim-based/39476

Coping with Complexity: Exploring Modularity and Flexibility in IT Infrastructure Adaptation

Johan Sandberg (2010). *Industrial Informatics Design, Use and Innovation: Perspectives and Services* (pp. 85-101).

www.irma-international.org/chapter/coping-complexity-exploring-modularity-flexibility/44239

Firm-Specific Factors and the Degree of Innovation Openness

Valentina Lazzarotti, Raffaella Manziniand Luisa Pellegrini (2013). *Industrial Engineering: Concepts, Methodologies, Tools, and Applications* (pp. 1288-1310).

www.irma-international.org/chapter/firm-specific-factors-degree-innovation/69340