Challenges of Manufacturing Vertical GaN™ Technology of Future: Now a Reality with NexGen Power Systems

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Abstract

Recent developmental advances have allowed silicon (Si) semiconductor technology to improve and reach the theoretical limits of the Si material. However, power device requirements for many applications have exceeded what Si-based power devices can do. The requirements include higher blocking voltages, higher switching frequencies, efficiency, and reliability. To overcome these limitations, new semiconductor materials for power device applications are needed. Wide bandgap semiconductors with their superior electrical properties, are likely candidates to replace Si in the near future and GaN has the widest bandgap of any commercially available material. This paper reviews recent progress and key challenges in manufacturing process for high-performance vertical GaN transistors.

INTRODUCTION

GaN power devices have been widely recognized as promising candidates for next generation power electronics. High voltage blocking capability is key for efficiency gains in GaN power electronics. Currently, both lateral GaN HEMT and vertical GaN devices are considered for achieving high breakdown voltage beyond 650V. When aiming at high voltage, lateral GaN devices are limited by the area and surface trap related reliability concerns. Contrary to the lateral GaN devices, vertical GaN devices do not require enlarged chip size for increased breakdown voltage. The breakdown voltage in vertical GaN devices can be increased by increasing the thickness of the drift region while keeping a compact chip size. Moving the peak electric field from the surface into the GaN bulk potentially minimizes the surface trapping effect and eliminates dynamic Ron variations in the vertical devices

ADVANTAGES OF GAN-ON-GAN SEMICONDUCTORS

GaN power transistors can be created via epitaxially grown GaN layers on different types of carrier wafers. There are significant impacts in the choice of substrate material to realize the full potential GaN's superior material properties. When compared against other substrate material, by maintaining a GaN-only structure via homoepitaxy, GaN-on-GaN power semiconductors offer the simpler approach for fabricating vertical power devices. The NexGen Vertical GaN™ technology is based on growing GaN on GaN wafers as opposed to Si, SiC or sapphire.

The NexGen Vertical GaN™ is the world's first commercially available GaN-on-GaN technology which unlocks the full potential of this advanced power semiconductor material with the following advantages:

- A normally-off, enhancement-mode junction field-effect transistor (JFET)
- Reduced defect density in the GaN-on-GaN homoepitaxial layers
- Superior breakdown voltage (BV) and current capability for a given chip area than any other GaN device up to 4kV
- Reduced dynamic on-resistance variation due to less reliance on surface passivation
- Smallest size compared to other power semiconductors for a given current rating
- Lowest Capacitance and Lowest Switching Losses
- Best-in-class temperature coefficient
- Has a P-N junction and this enables the device to show both single and repeated cycle avalanche robustness[2]
- Best in class short circuit protection >10µs, for the SC duration and BV

GAN-ON-GAN MANUFACTURING CHALLENGES

GaN-on-GaN has always held the promise as the technology of the future but had various manufacturing challenges that NexGen Power Systems has addressed:

#	Challenge	Solution
1	Compatibility with HVM	Use of widely available manufacturing tools in fab equipment set (no specialized custom tools)
2	Tool handling/processing of GaN substrates (transparency, fragility)	Modify tools for handling Work with substrate vendors and tool vendors to ensure compatibility
3	High quality GaN substrates (surface finish, flatness, macro-defect levels)	Work with substrate vendors on specs
4	High quality epi	Internal epi development, substrate specs
5	Regrown junction quality	Optimization of etches, cleans and epi growth
6	Electrical and SPC control	Novel PCM test structures, novel metrology structures