GaN devices: Modes of degradation and technological counter measures

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Introduction

GaN based power devices for microwave applications and high efficiency switching applications in modern power electronics are rapidly moving into the focus of world wide research and development activities. Due to their unique material properties GaN devices are distinguished by featuring high breakdown voltages, low on-state resistances and fast switching properties at the same time. These properties are related to extremely high field and current densities possible per unit device volume or area. Therefore, in order to obtain very high performance, the material itself is stressed significantly during standard device operation and any imperfection may lead to reversible drift effects as well as to wear out and reliability problems. Thus material quality, the specific epitaxial design as well as the device topology directly influences device performance, reliability and mode of degradation. This presentation will mainly discuss degradation mechanisms that are especially due to the specific material combinations used in GaN device technology such as epitaxial layer design, chip metallization, passivation schemes and general device topology and layout. It will then discuss technological ways towards engineering reliability into these devices.

Structure of presentation

1) Overview on AlGaN/GaN HEMT technology for microwave and power switching applications
2) Reliability of GaN devices: State-of-the-art
    - Identification of operation conditions being particularly stressing for GaN devices
    - Identification of device regions facing particular stress during operation
    - Identification of degradation mechanisms
      (hot electron degradation, inverse piezoelectric effect, chemical pitting, degradation of passivation, ohmic and Schottky metals, premature vertical breakdown issues)
3) Reliability engineering
    - Considerations on how to design and realize improved devices
4) Overview on reliability data obtained from microwave and power electronic GaN devices
5) Conclusions