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III-Nitride Based N-Polar Vertical Tunnel Transistors with High-Power Functionality

All electronic devices rely on power semiconductor devices to control or convert electrical energy in order to operate properly. Gallium nitride (GaN) materials are preferred because they have greater power conversion efficiency than silicon, resulting in smaller, faster transistors that can withstand higher electric fields and operate at higher temperatures. Current in a typical vertical transistor flows from source to drain through a designed aperture after being modulated by a gate, and a current blocking layer within the aperture region prevents excess current from leaking into the drain. In order to create apertures through current blocking layers, many existing designs use regrowth techniques or methods such as ion implantation that interrupt GaN single crystal growth of the aperture region. These fabrication processes are complicated and expensive, and can cause defects at regrowth locations that decrease the performance of the transistor.

Researchers at ASU have developed a high-power type-III-nitride vertical transistor with an active buried current blocking layer and aperture that can be grown in situ without a regrowth process. Multiple thin top layers below the transistor's source define two conductive GaN channels. This "multiple channel" architecture takes advantage of high aluminum compositions to create a very high charge, generating a polarization field that conveniently forms the current blocking layer and aperture. All functionality of the device is achieved by polarization engineering and not by doping or implementation, significantly simplifying fabrication. This eliminates the need for regrowth techniques or ion implantation, which lowers manufacturing costs and produces dependable transistors with greater performance.

Potential Applications

- Amplifiers and Oscillators
- DC-DC, DC-AC, AC-DC, AC-AC Power Converters
- High-Power Transistors
  - Low RON III-Nitride Vertical Transistors
  - Two-Channel Depletion Mode III-Nitride Vertical Transistors
- S-Band or Radio Frequency Devices

Benefits and Advantages

- Economical – Cuts manufacturing costs by simplifying fabrication and reducing product defects.
- High-Quality – No implantation steps or other confinement steps required that may degrade electrical performance.
- Innovative
  - Novel vertical III-Nitride based transistor with single crystal growth,

assisted and modulated by tunneling of electrons.
    - No interruption of the fabrication process to regrow epitaxial layers.
- Practical
    - Current blocking layer is obtained by polarization doped barrier.
    - The simplicity of the fabrication technique streamlines its implementation.

For more information about the inventor(s) and their research, please see

Dr. Srabanti Chowdhury's directory webpage