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Steep-Slope AlGaN/GaN Transistors with Threshold Switching Device

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Background

Conventional Si-based metal-oxide-semiconductor field-effect transistors (MOSFETs) are facing fundamental limitations as demands for increased power efficiency and integration density persist. The Boltzmann limit represents the minimum subthreshold change in gate voltage bias (VGS), 60 mV, required to effectuate a one-decade change in the drain-to-source current (IDS) at room temperature. Advancing transistor technology entails breaking through this limit and achieving "steep-slope" (<60 mV/decade) device operation.

Steep-slope operation has been achieved by recent research efforts involving tunnel field-effect transistors (TFETs) and the incorporation of ferroelectric materials for Si-based FET gates; however, average slopes were still above 30 mV/decade. Other approaches, such as those using Mott insulators, have demonstrated slopes of 8 mV/decade but suffer from thermal instabilities at high frequencies.

AlGaN/GaN high-electron-mobility transistors (HEMTs) have desirable properties for power switching and high-frequency applications such as radio-frequency and microwave. Since metal-insulator-semiconductor (MIS) gate configurations are known to decrease gate current leakage and improve gate-voltage swing capability, AlGaN/GaN MIS-HEMTs can combine both sets of advantages. For this reason, addressing the challenge of steep-slope operation in AlGaN/GaN MIS-HEMTs may hold the key to its commercial success.

Invention Description

Researchers at Arizona State University have developed an AlGaN/GaN MIS-HEMT with a threshold switching device integrated in series with the transistor source. This switching device is a SiO2-based metal-insulator-metal (MIM) structure originating from programmable metallization cell technology for resistive random-access memory (RRAM). Incorporating this threshold switching device in the AlGaN/GaN MIS-HEMT resulted in a subthreshold swing of ~5 mV/decade with a transition range of over five orders of magnitude in the transfer characteristics, at room temperature and in both VGS sweep directions. Low leakage current (~10-5 μA/μm) and high ION/IOFF ratio (>107), characteristic of the MIS-HEMT itself, were preserved when operated with the switching device.

Potential Applications

- Power switching and high-frequency transistors

Benefits and Advantages

- Effective – Steep-slope operation was demonstrated with subthreshold swings of ~5 mV/decade
- Efficient – Resulting device exhibited low leakage current (~10-5 μA/μm) and high ION/IOFF ratio (>107)
- Practical – Fabrication of MIM switching device with HEMT is compatible with back-end-of-line (BEOL) processing

Homepage of Professor Yuji Zhao