

GaN Vertical Nanowires with Self-Aligned Gates for Field Emission Applications

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Field emitters (FE), or namely vacuum transistors, are promising for harsh-environments and high-frequency electronics thanks to their radiation hardness and scattering-free electron transport. However, the stability and operating voltage still need improvement to enable circuit applications. To overcome these issues, III-Nitrides are excellent candidates due to their strong bonding energies and tunable electron affinities. Though the material properties of III-Nitrides are promising, so far, there are few works demonstrating sub-100 V turn on as most III-N FEs are still two-terminal structures.

In this work, we demonstrate a novel GaN nanowire (NW) FEs based on self-aligned gates to reduce the gate-emitter turn-on voltage ($V_{GE, ON}$) below 30 V. The

GaN on Si wafer was grown by Enkris Semiconductor, Inc. With carefully fabrication, we successfully fabricate GaN NWs with width of 60 nm and aspect-ratio of 5 (Figure 1 (a)). The gate stack is then conformally deposited. We then finish the device fabrication by dry etching to open FEs' tips (Figure 1 (b)).

We measure the transfer characteristics with a suspending 0.5-mm-diameter tungsten ball biased at +500 V as an anode (Fig. 2(a)). Device turns on at 27 V. This device demonstrates low turn-on voltage and high current density among GaN field emitters in literature (Fig. 2 (b)) and shows potentials for integrated circuit applications with further future improvement.

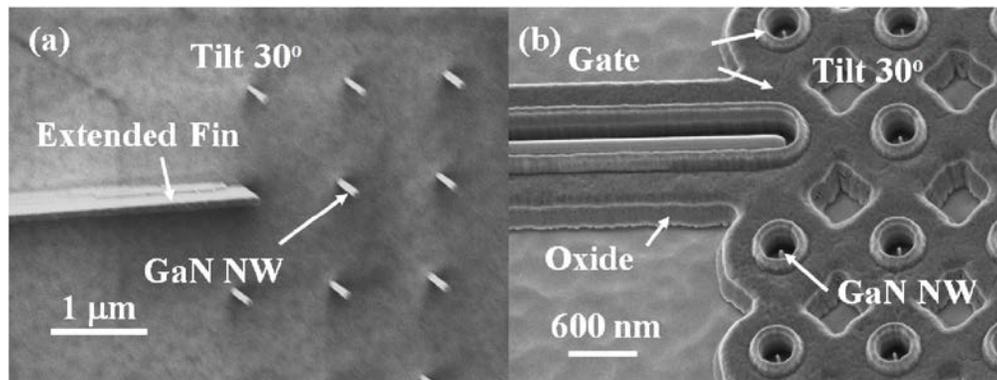


Fig. 1. Scanning electron microscope (SEM) images of (a) GaN NWs with extended fin and (b) finished self-aligned gate FEs. The “extended fin” is used to extend out the gate metal to a large metal pad.

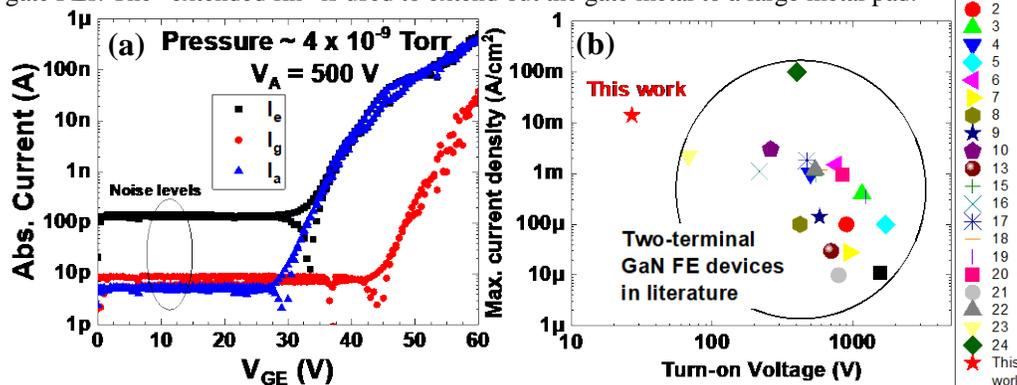


Fig. 2. (a) Transfer characteristics with a 50×50 NW arrays with NW width of 60 nm and NW height of 300 nm. (b) The benchmark of different GaN FE devices.

Further Reading

- P.-C. Shih, G. Rughoobur, P. Xiang, K. Liu, K. Cheng, A. I. Akinwande, and T. Palacios, “GaN Nanowire Field Emitters with a Self-Aligned Gate Process,” to be presented at 78th Device Research Conference, Columbus, Ohio, June 2020.

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Electronics, vacuum electronics, III-Nitrides, Field emitter devices, Nanofabrication

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PDF:

https://mtlresume.mit.edu/system/files/resumes/cv_shih_04-07-2020.pdf