letter

SCIENCE CHINA
Information Sciences

• Supplementary File •

3.23 GW/cm^2 Power Figure of Merit and 0.69 V Turn-on Voltage β-Ga_2O_3 Heterojunction Barrier Schottky Diodes with P–I–N Junction Termination

Pengfei Dong[1,2†], Jianghan Zhao[1†], Chenlu Wang[1*], Anqi Ye[1], Xin Feng[1,2], Min Zhou[1], Kui Dang[1,2], Hong Zhou[1,2*], Yue Hao[1] & Jincheng Zhang[1,2*]

[1]*Key Lab of Wide Band Gap Semiconductor Materials and Devices, School of Microelectronics, Xidian University, Xi'an* 710071, *China*
[2]*2 Guangzhou Wide Bandgap Semiconductor Innovation Center, Guangzhou Institute of Technology, Xidian University, Guangzhou* 510555, *China*

Appendix A Expand data

Devices with varying anode radii (r = 30, 50 and 75 μm) were fabricated to investigate the influence of anode size on device characteristics. Fig. A1 presents the forward J–V characteristics of devices with different radii. The $R_{on,sp}$ are 4.75/5.48/7.32 mΩ·cm^2, and I_F@3 V are 425/370/278 A/cm^2 for devices with radii of 30, 50, and 75 μm, respectively.

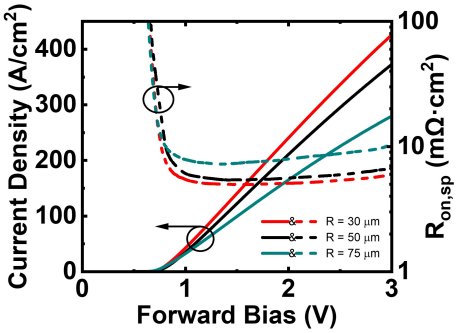


Figure A1 (a)The forward J–V characteristics of devices with different radii, showing that current density decreases as the radius increases

In main text, the width of each NiO_x ring was designed to be 6 μm, with an interspacing of 5 μm ("SP1"). Additionally, structures with increased NiO_x ring widths (W_{NiO} = 8 μm, "SP2") were also fabricated to explore the influence of W_{NiO}.

Fig. A2(a) shows the linear-scale current density–voltage (J–V) curves and log-scale $R_{on,sp}$ for SP1 and SP2, while a β-Ga_2O_3 SBD and a basic HJBS diode (without any terminal) are also included for comparison. The $R_{on,sp}$ and I_F@3 V for SBD, basic HJBS diode, SP1, and SP2 are extracted to be 3.75/4.74/4.75/5.39 mΩ·cm^2 and 510/431/425/391 A/cm^2, respectively. The log-scale forward J–V characteristics is plotted in Fig. A2(b). The η calculated from overall slope of the subthreshold region of the J–V curve were 1.00, 1.09, 1.07, and 1.03 for SBD, basic HJBS diode, SP1, and SP2, respectively.The η calculated by the differential method being slightly less than 1.0 may stem from measured noise fluctuations at $V_F < V_{on}$. The V_{on}, defined as the forward current density reaching 1 A/cm^2, is determined to be 0.69 V for all SP1, SP2, SBD, and the basic HJBS diode.V_{on} is negligibly affected by the implementation of the n-β-Ga_2O_3/p-NiO_x heterojunction, which is most likely attributed to the carefully designed fin interspacing.

* Corresponding author (email: chenluwang@stu.xidian.edu.cn, hongzhou@xidian.edu.cn, Jincheng Zhang, jchzhang@xidian.edu.cn)

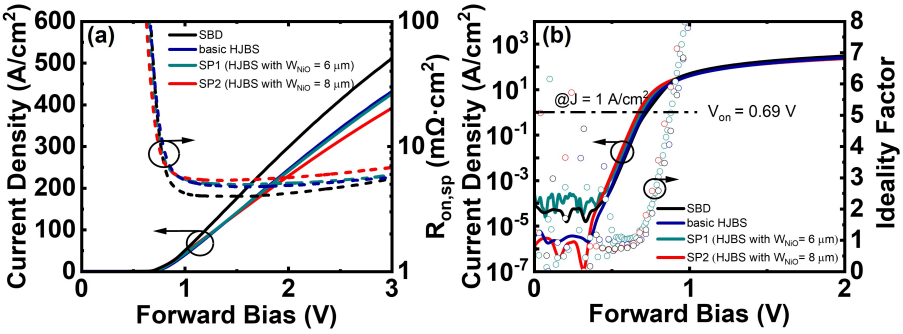


Figure A2 (a) Comparison of the linear-scale J–V curves and log-scale $R_{\mathrm{on,sp}}$ for SP1 ($W_{\mathrm{NiO}} = 6$ μm), SP2 ($W_{\mathrm{NiO}} = 8$ μm), basic HJBS diode, and SBD. (b) Log-scale J–V characteristics and the extracted ideality factors. The V_{on} was extracted to be 0.69 V for all SP1, SP2, basic HJBS diode, and SBD. (c)The forward J–V characteristics of devices with different radii on SP1 show that current density decreases as the radius increases

Appendix B TCAD simulation

To further investigate the electric field distribution of the HJBS diode, Sentaurus TCAD simulations were carried out at the breakdown voltage of 3.9 kV.

Figure B1(a) and (b) depict the simulated electric field distributions for devices with and without the ion-implanted termination structure, respectively. As illustrated in Fig. B1(a), a horizontal cutline CL1 was positioned just below the Ga_2O_3/NiO_x interface, while a vertical cutline CL2 was defined at the edge of the outermost NiO_x ring.

The electric field distribution along CL1 and CL2 was presented in Fig. B1(c) and Fig. B1(d). It should be pointed out that the advanced p-i-n termination can effectively suppress the peak electric field from 8.5 MV/cm to approximately 6.8 MV/cm, resulting in a more uniform electric field distribution across the whole device.

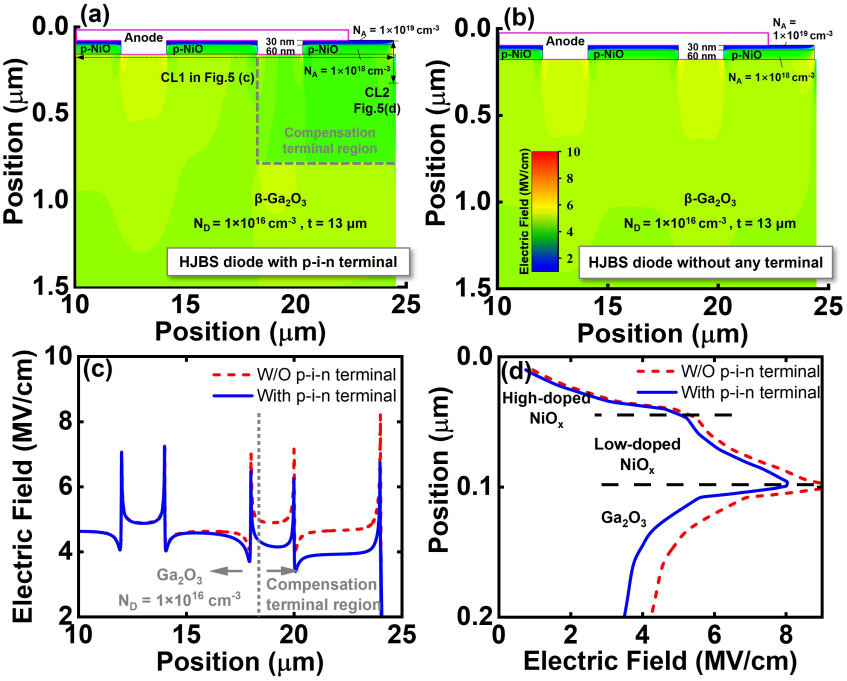


Figure B1 Simulation of the electric field distribution at a BV of −3.9 kV for the HJBS diode: (a) with p-i-n termination and (b) without p-i-n termination. The electric field distribution along the cutlines CL1 and CL2 are shown in (c) and (d), respectively. The p-i-n termination can effectively suppress the peak electric field from ∼ 8.5 MV/cm to approximately 6.8 MV/cm, resulting in a uniform electric field distribution across the whole device.