

# Piezotronic Effect Modulated Flexible AlGaN/GaN High-Electron-Mobility Transistors

Jiyuan Zhu<sup>1,2,#</sup>, Xingyu Zhou<sup>1,2,#</sup>, Liang Jing<sup>1,2</sup>, Qilin Hua<sup>1,2,3</sup>, Weiguo Hu<sup>1,2,3,\*</sup>, and Zhong Lin Wang<sup>1,2,3,4,\*</sup>

<sup>1</sup> CAS Center for Excellence in Nanoscience, Beijing Key Laboratory of Micro-Nano Energy and Sensor, Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences, Beijing 100083, China.

<sup>2</sup> School of Nanoscience and Technology, University of Chinese Academy of Sciences, Beijing 100049, China.

<sup>3</sup> Center on Nanoenergy Research, School of Physical Science and Technology, Guangxi University, Nanning, 530004, China.

<sup>4</sup> School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332-0245, USA.

<sup>#</sup>These authors contributed equally to this work

\*Correspondence to: [huweiguo@binn.cas.cn](mailto:huweiguo@binn.cas.cn), [zlwang@gatech.edu](mailto:zlwang@gatech.edu)

Table S1. The parameters on devices before and after transfer.

	Carrier Mobility ( $\mu$ )	Electron Density (n)
On silicon substrate	1626 cm <sup>2</sup> /V.s	$1.19 \times 10^{13}$ cm <sup>-2</sup>
On flexible substrate	1591 cm <sup>2</sup> /V.s	$1.15 \times 10^{13}$ cm <sup>-2</sup>

Table S2. The performances of our research among the previous studies.

	On flexible substrate	Ratio of drop (before and after the transfer process)
N. Defrance, et al. <sup>1</sup>	450 mA/mm	48%
S. Mhedhbi, et al. <sup>2</sup>	293 mA/mm	—
Our work	290 mA/mm	35%
M. Leseq, et al. <sup>3</sup>	280 mA/mm	40%
Seung Kyu Oh, et al. <sup>4</sup>	183 mA/mm	—

## REFERENCES

1. Defrance, N.; Lecourt, F.; Douvry, Y.; Leseq, M.; Hoel, V.; Lecavelier Des Etangs-Levallois, A.; Cordier, Y.; Ebongue, A.; De Jaeger, J. C. Fabrication, Characterization, and Physical Analysis of AlGaIn/GaN HEMTs on Flexible Substrates. *IEEE Trans. Electron Devices*. **2013**, *60*, 1054-1059.
2. Mhedhbi, S.; Leseq, M.; Altuntas, P.; Defrance, N.; Okada, E.; Cordier, Y.; Damilano, B.; Tabares-Jimenez, G.; Ebongue, A.; Hoel, V. First Power Performance Demonstration of Flexible AlGaIn/GaN High Electron Mobility Transistor. *IEEE Electron Device Lett.* **2016**, *37*, 553-555
3. Leseq, M.; Hoel, V.; Lecavelier des Etangs-Levallois, A.; Pichonat, E.; Douvry, Y.; De Jaeger, J. C. High Performance of AlGaIn/GaN HEMTs Reported on Adhesive Flexible Tape. *IEEE Electron Device Lett.* **2011**, *32*, 143-145.
4. Kyu Oh, S.; Cho, M. U.; Dallas, J.; Jang, T.; Lee, D. G.; Pouladi, S.; Chen, J.; Wang, W.; Shervin, S.; Kim, H.; Shin, S.; Choi, S.; Kwak, J. S.; Ryou, J-H. High-Power Flexible AlGaIn/GaN Heterostructure Field-Effect Transistors with Suppression of Negative Differential Conductance. *Appl. Phys. Lett.* **2017**, *111*, 133502.

Table S3. The physical parameters of wurtzite structure AlN and GaN

Physical Parameter	AlN	GaN	Reference
a (nm)	0.311	0.319	1
c (nm)	0.498	0.519	1
P <sub>sp</sub> (C/m <sup>2</sup> )	-0.081	-0.029	2
C <sub>11</sub> (GPa)	396	390	1
C <sub>12</sub> (GPa)	137	145	1
C <sub>13</sub> (GPa)	108	106	1

$C_{33}$ (GPa)	373	398	1
$e_{31}$ (C/m <sup>2</sup> )	-0.60	-0.49	2
$e_{33}$ (C/m <sup>2</sup> )	1.50	0.73	2
$e_{311}$ (C/m <sup>2</sup> )	5.850	6.185	2
$e_{333}$ (C/m <sup>2</sup> )	-10.750	-8.090	2
$e_{133}$ (C/m <sup>2</sup> )	4.533	1.543	2
$\epsilon_r$	8.5	10.4	3

#### REFERENCES

1. Vurgaftman, I.; Meyer, J. R. Band Parameters for Nitrogen-Containing Semiconductors. *J. Appl. Phys.* **2003**, *94*, 3675-3696.
2. Pal, J.; Tse, G.; Haxha, V.; Migliorato, M. A.; Tomić, S. Second-Order Piezoelectricity in Wurtzite III-N Semiconductors. *Phys. Rev. B.* **2011**, *84*, 085211.
3. Bernardini, F.; Fiorentini, V.; Vanderbilt, D. Spontaneous Polarization and Piezoelectric Constants of III-V Nitrides. *Phys. Rev. B.* **1997**, *56*, R10024.