E. Compound Semiconductors 분과

O25_[TM2-E] WBG Semiconductor-II

좌장: 차호영 교수(홍익대학교), 권혁민 교수(한경대학교)

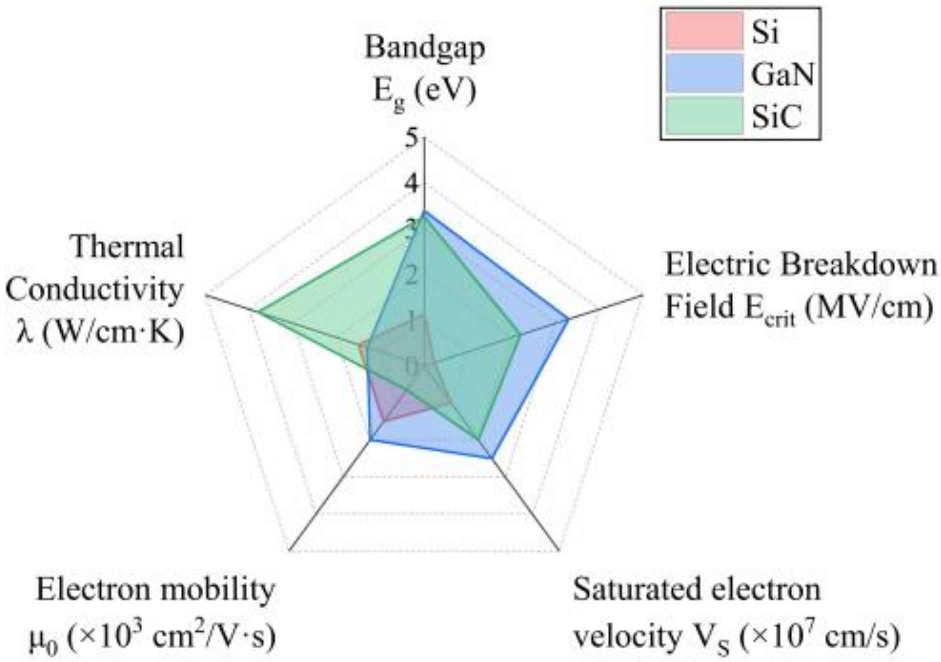
TM2-E-1 10:55-11:10	**Sub-100 nm $Al_{0.4}Ga_{0.6}N$/GaN HEMTs with f_{max} = 490 GHz** Su-Min Choi[1], Hyeok-Jun Lee[1], Wan-Soo Park[1], Hyo-Jin Kim[1], Young-Hun Han[2], June-O Song[2], Jae-Hak Lee[1], Kyounghoon Yang[3], and Dae-Hyun Kim[1] [1]School of Electronic and Electrical Engineering, Kyungpook National University, [2]WaveLord, [3]KAIST
TM2-E-2 11:10-11:25	**Fabrication and Characterization of GaN FinFETs for Power Devices** Hyun Woo Lee[1,2], Hyeon Tak Kwak[1], Jae Won Park[1], Dong Han Kim[1], Hoe Min Kwak[1], Sung Bum Bae[1], Sang Mo Koo[2], and Hyung Seok Lee[1] [1]ETRI, [2]Department of Electrical Material Engineering, Kwangwoon University
TM2-E-3 11:25-11:40	**Enhancement of AlGaN/GaN HEMTs through N_2 treatment on SiN Passivation** Hyo-Jin Kim[1], Su-Min Choi[1], Hyeok-Jun Lee[1], Min-Seo Yoo[1], Yu-Jeong Lee[1] Jae-Hak Lee[1], Kyounghoon Yang[2] and Dae-Hyun Kim[1] [1]Kyungpook National University, [2]KAIST
TM2-E-4 11:40-11:55	**E-mode AlGaN/GaN HEMTs의 드레인 전압에 의한 문턱전압 열화 분석** 채명수, 김형탁 홍익대학교 전자전기공학부
TM2-E-5 11:55-12:10	**Device Performance Improvement in GaN-Based HEMTs Using Extremely Thin h-BN Passivation Layer and Air Spacer** S.-J. Chang[1], S. Moon[2], D.-S. Kim[3], H.-Y. Jung[1], J. Jeong[1], J. Song[2], J. Kim[2], H.-K. Ahn[1], Y.-S. Noh[1], J.-W. Lim[1], J. K. Kim[2], and D.-M. Kang[1] [1]ETRI, [2]POSTECH, [3]KAERI
TM2-E-6 12:10-12:25	**Reducing Thermal Crosstalk in Multi-Finger AlGaN/GaN HEMTs Through Central Source Length Modulation** Chae-Yun Lim, Jae-Hun Lee, Tae-Sung Kim, Yeong-Hyun Won, and Hyun-Seok Kim Division of Electronics and Electrical Engineering, Dongguk University
TM2-E-7 12:25-12:40	**Effect of Al-rich AlGaN Channel Composition Variation on HEMT Performance** Joon-Hyuk Lee, Joocheol Jeong, Shyam Mohan, Jooyong Park, Jaejin Heo, and Okhyun Nam Convergence Center for Advanced Nano Semiconductor (CANS), Department of Nano-Semiconductor, Tech University of Korea

Reducing Thermal Crosstalk in Multi-Finger AlGaN/GaN HEMTs Through Central Source Length Modulation

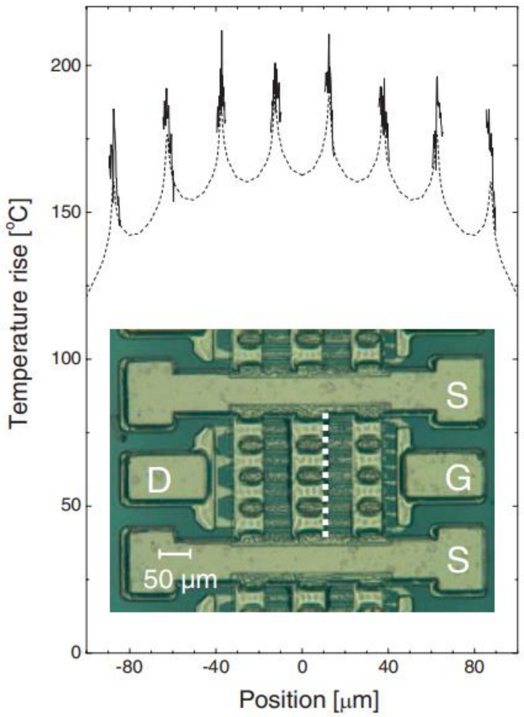
*임채윤, 이재훈, 김태성, 원영현, 김현석©
동국대학교 전자전기공학부

Table of Contents

(1) Multi-Finger AlGaN/GaN HEMTs and It's Challenges



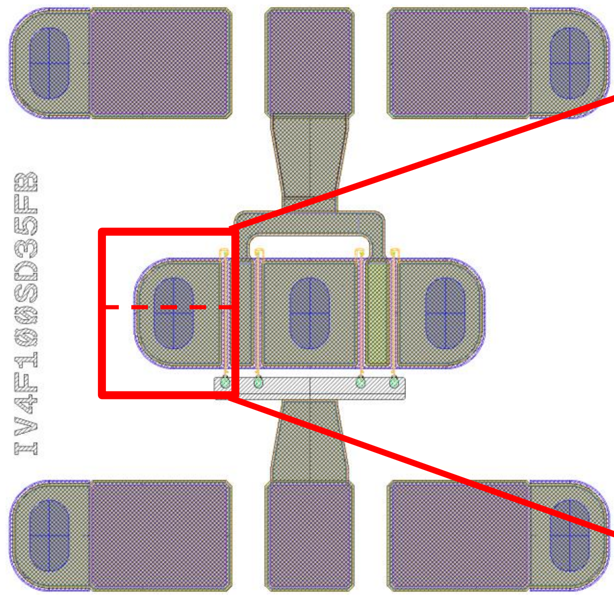
Zhiyuan Qi, *et al.*, IEEE Trans. Power Electron, 2021



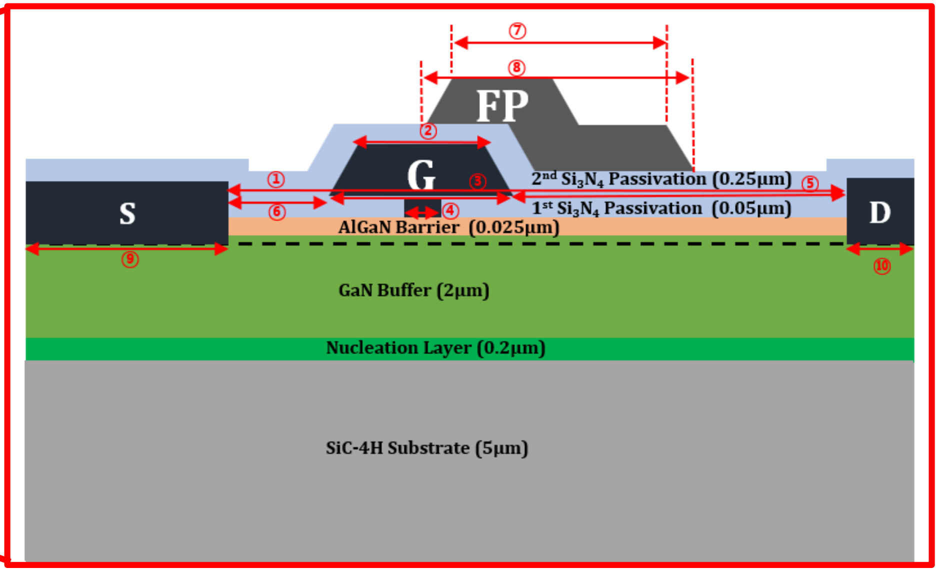
M.Kuball, *et al.*, phys. stat. sol, 2005

- GaN: High thermal stability, superior RF performance
- Multi-Finger structure: Reduces gate resistance, ideal for RF, but faces thermal issues
- Thermal challenges: **Heat variation and thermal crosstalk** increase device failure rate

2. Device Structure Modeling and Reliability Assurance
(1) Modeling Based on the Layout of 0.15μm Planar-gate HEMT Device



<Layout of 0.15 μm Planar-gate HEMT>

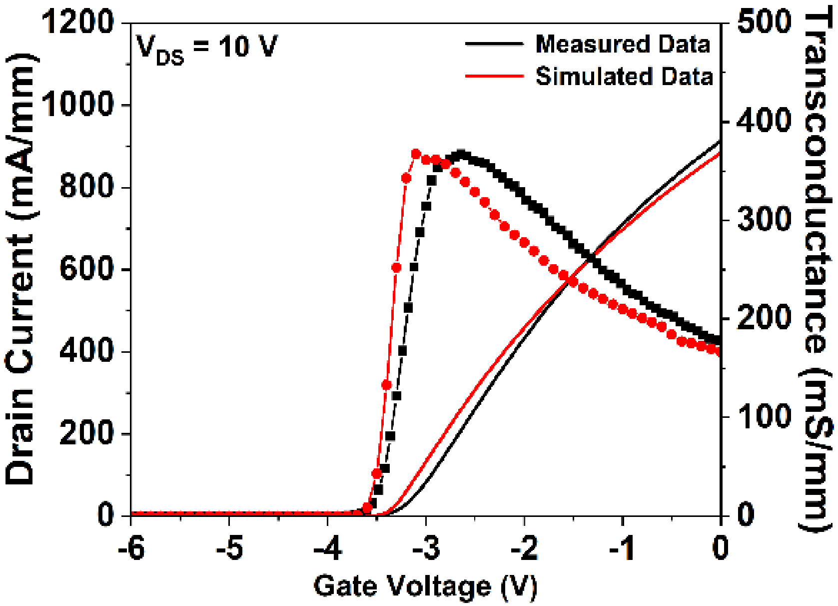


< 0.15 μm Planar-gate HEMT>

Parameters	Values (μm)	Parameters	Values (μm)
① L_{SD}	3	⑥ L_{SG}	0.5
② $L_{G.HEAD\_TOP}$	0.8	⑦ $L_{FP.TOP}$	1.4
③ $L_{G.HEAD\_BOTTOM}$	1.0	⑧ $L_{FP.BOTTOM}$	1.6
④ $L_{G.FOOT}$	0.15	⑨ L_{SOURCE}	3.0
⑤ L_{GD}	1.5	⑩ L_{DRAIN}	1.0

dongguk UNIVERSITY

2. Device Structure Modeling and Reliability Assurance
(2) Simulation Reliability Assurance



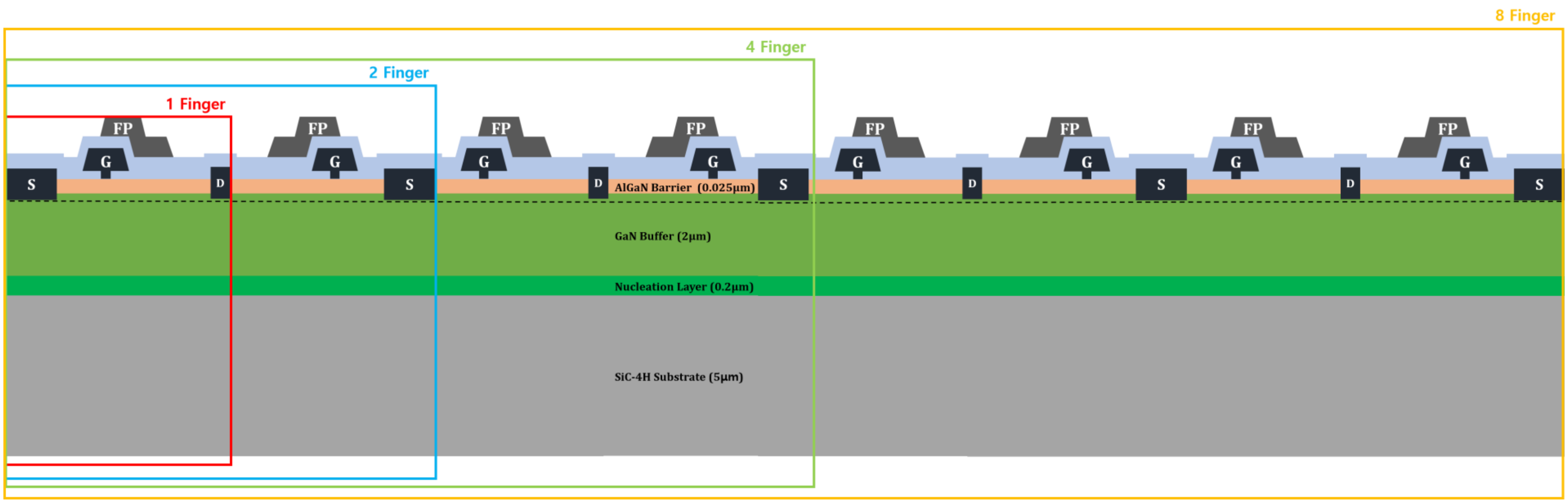
	I_{dss} (mA/mm)	G_m (mS/mm)	V_{th} (V)
Measured Data	913.80	367.34	-3.5
Simulated Data	884.32	367.17	-3.5
Error Rate	3.32%	0.04%	0%

※ I_{dss} : Drain Current @ V_{GS} = 0 V G_m : Maximum Transconductance V_{th} : Threshold Voltage

- Simulation reliability : Simulation data were matched with the measured data of AlGaN/GaN HEMT devices fabricated through actual processes
- **Error rates : 3.32% for I_{dss}, 0.04% for G_m, and 0% for V_{th}**

dongguk UNIVERSITY

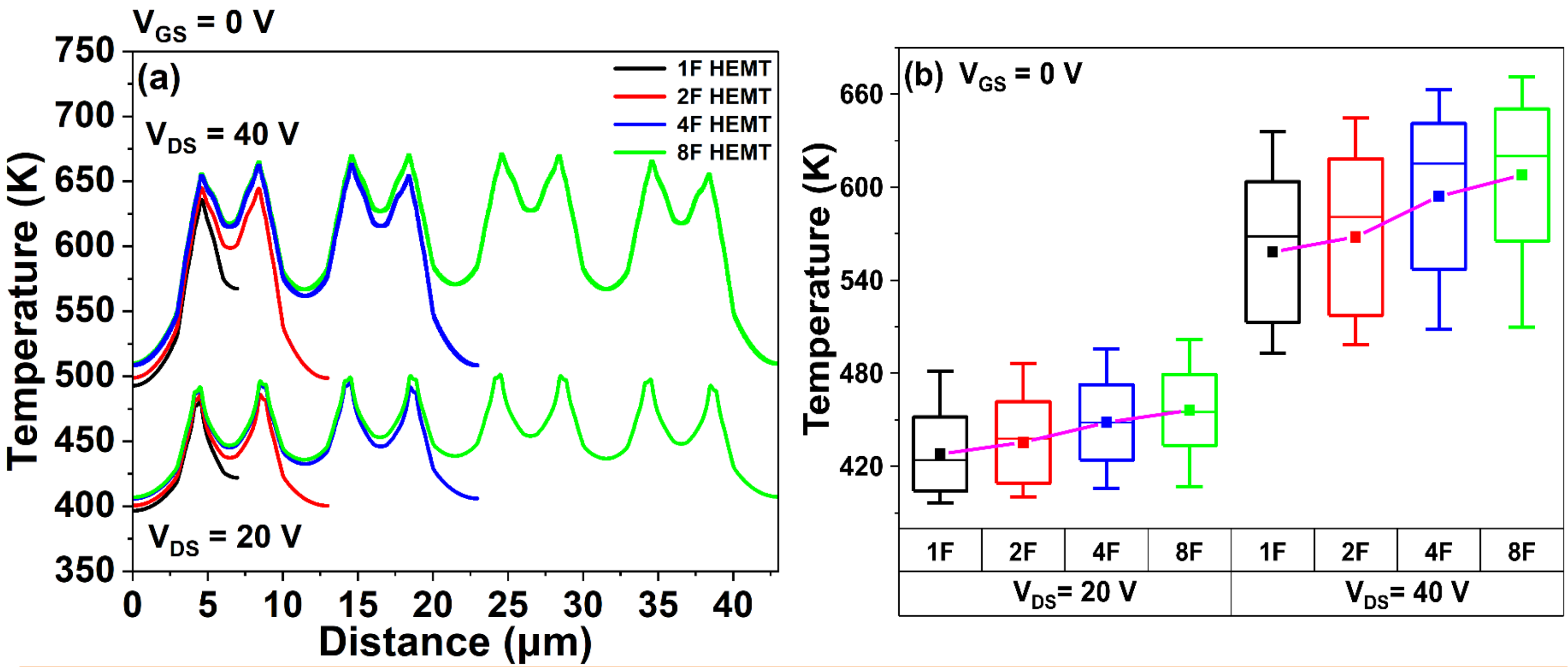
3. Thermal and Operational Characteristics Analysis in Multi-Finger HEMTs
(1) Device Structure Analysis



< Schematic Cross-Section of AlGaN/GaN HEMT Devices>

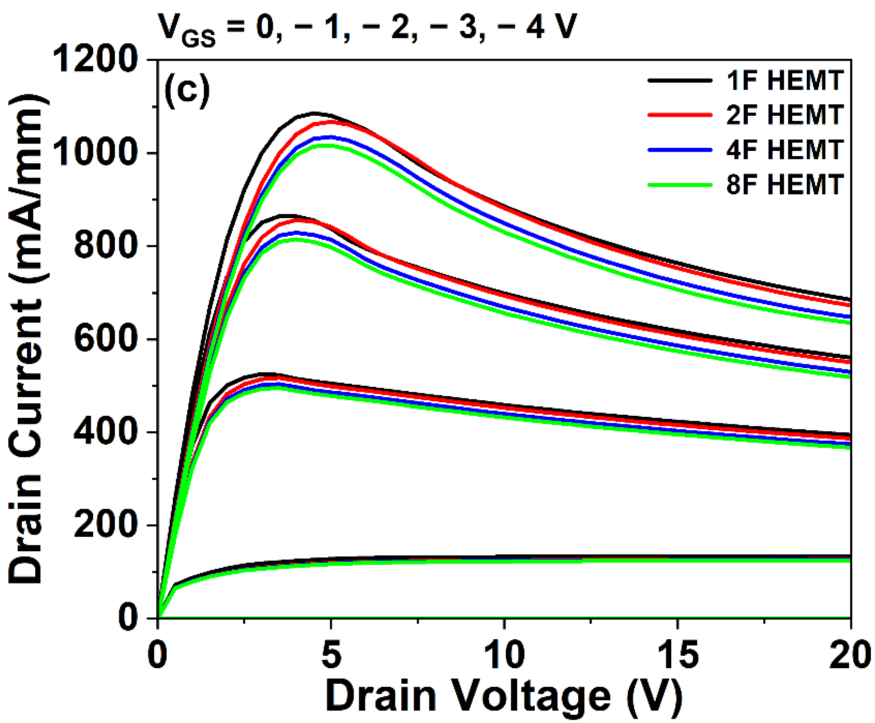
dongguk UNIVERSITY

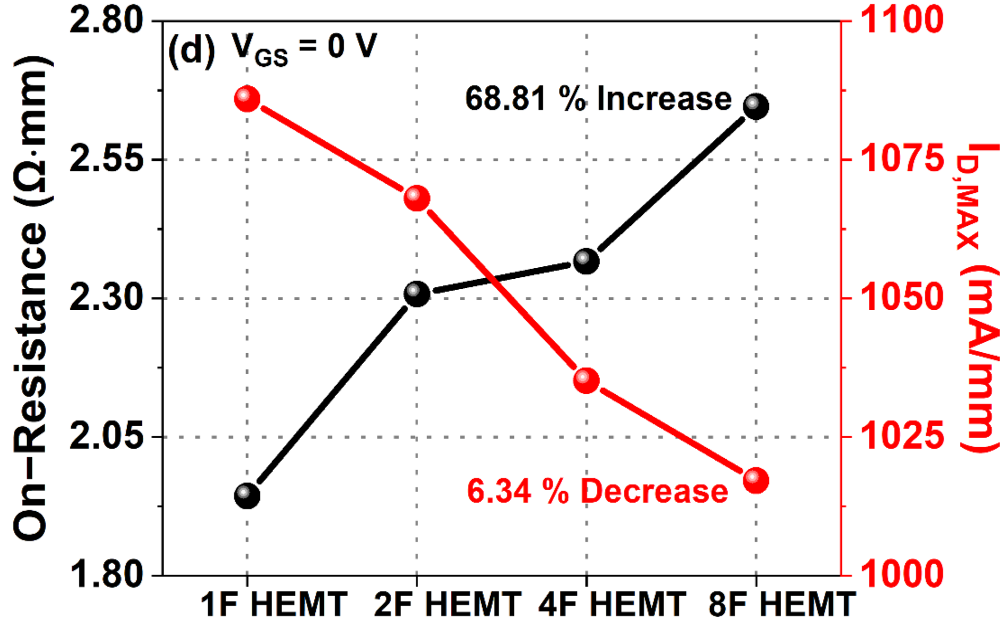
(2) Thermal Degradation of Multi-Finger HEMTs



- **Thermal crosstalk:** Peak finger temperature differences between 1F HEMT & Multi-Finger HEMTs
- **Maximum thermal crosstalk** at V_{DS} = 40 V: **9.03 K (2F), 27.03 K (4F), and 34.98 K (8F)**
- **Average temperature** at V_{DS} = 40 V: **9.58 K (2F), 35.77 K (4F), and 49.53 K (8F)**

(3) Degradation of DC Characteristics in Multi-Finger HEMTs



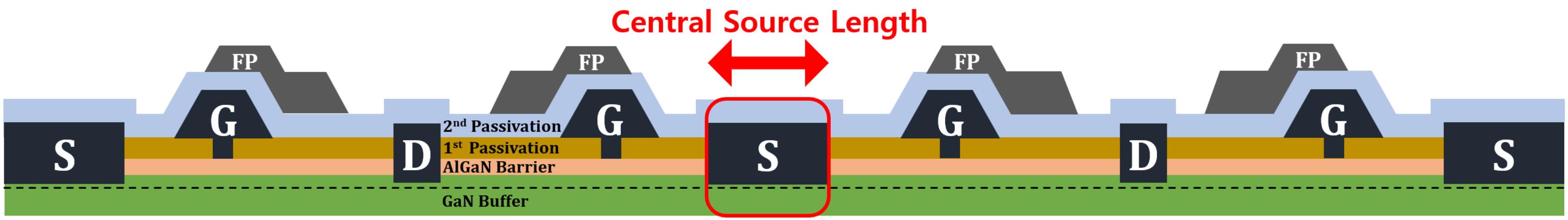


※ $I_{D,MAX}$: Maximum Drain Current @ V_{GS} = 0 V
R_{ON} : Slope of the I_{DS}-V_{DS} curve @ V_{DS} = 0 V V_{GS} = 0 V

- Thermal crosstalk degrades R_{ON} and $I_{D,MAX}$ as the number of fingers increases
- 68.81% increase in R_{ON} , 6.34% decrease in $I_{D,MAX}$ (1F HEMT ➔ 8F HEMT)

dongguk UNIVERSITY

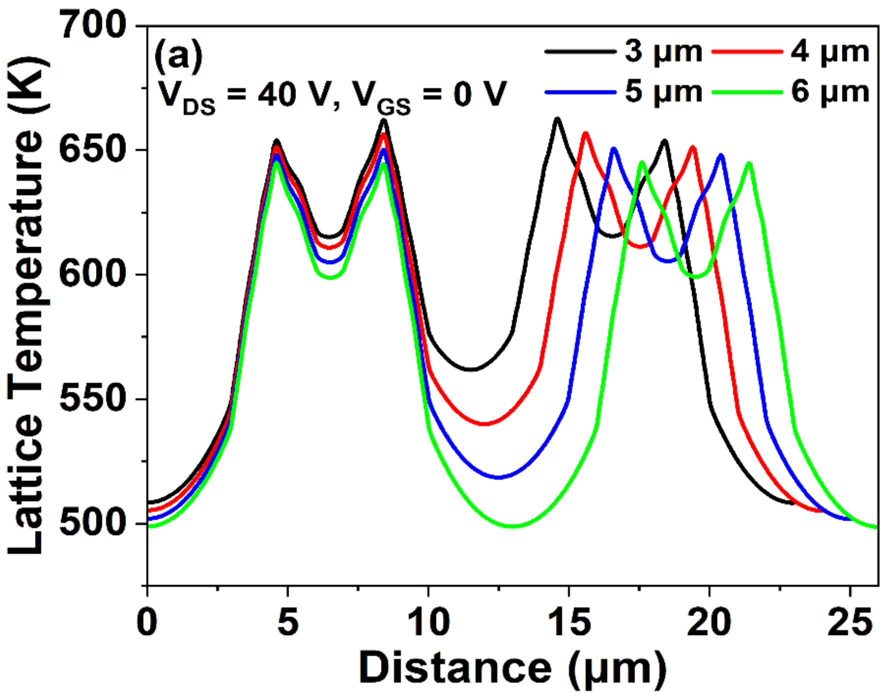
3. Thermal and Operational Characteristics Analysis in Multi-Finger HEMTs
(4) Widening the Central Source Contact Length

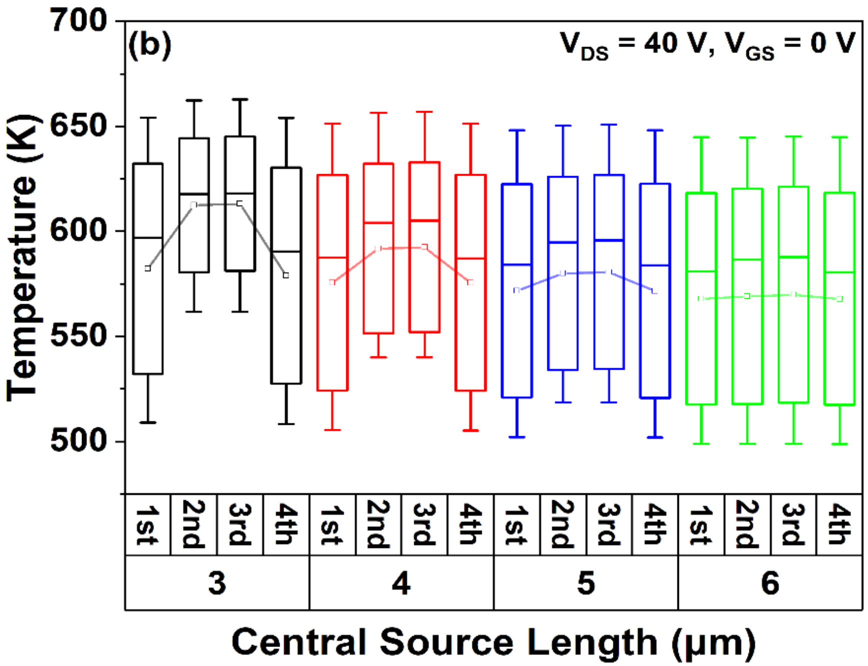


< Schematic Cross-Section of 4F HEMT Device>

Variable Parameters	Units	Values	Note
Central Source Contact	**μm**	3.0 ~ 6.0	Simulation performed with 1 μm increments

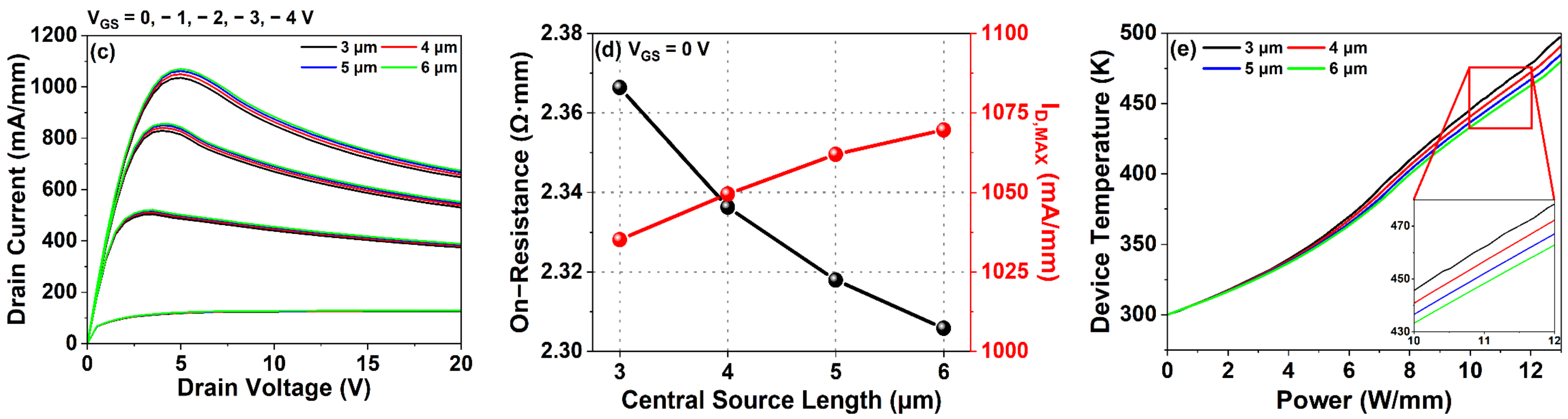
(5) Thermal Characteristics of Widened Central Source Contact Multi-Finger HEMTs





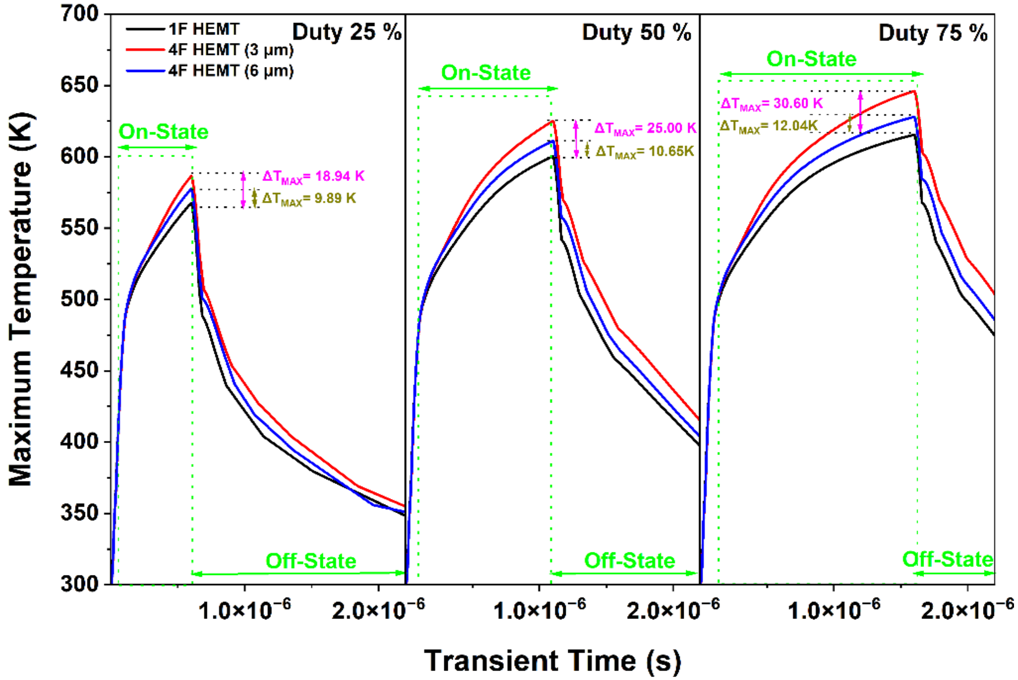
- Maximum thermal crosstalk decreased by **27.03 K (3 μm) to 9.39 K (6 μm)**
- Average temperature differences between outer **(1, 4)** and center fingers **(2, 3)** decreased from **32.27 K (3 μm) to 1.59 K (6 μm)**

3. Thermal and Operational Characteristics Analysis in Multi-Finger HEMTs
(6) DC Characteristics of Widened Central Source Contact Multi-Finger HEMTs



- Extending the central source contact alleviates R_{ON} degradation and $I_{D,MAX}$ with 6 μm delivering optimal performance
- 6 μm central source contact shows clear temperature benefits at higher power densities
- At 12 W/mm, the device temperature for the 6 μm is **17.45 K lower than the 3 μm 4F HEMT**

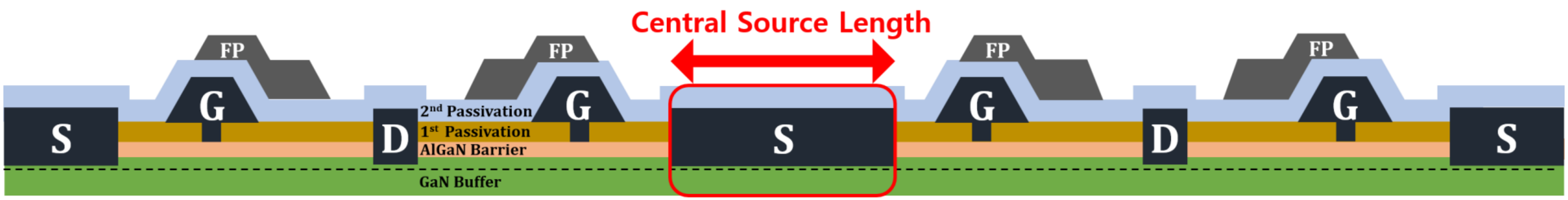
(7) Thermal Transient Analysis of Multi-Finger HEMTs



Central Source Length (μm)	Duty (%)	ΔT_{MAX} (K)
3	25	18.94
	50	25.00
	75	30.60
6	25	9.89
	50	10.65
	75	12.04

- Transient analysis shows ΔT_{MAX} as the maximum thermal crosstalk during the on-state of a single pulse (On-off duration : 2 μm)
- For the 3 μm configuration, ΔT_{MAX} increased from **18.94 K (25% duty cycle) to 30.60 K (75% duty cycle)**
- The 6 μm configuration exhibited smaller increases, from **9.89 K (25% duty cycle) to 12.04 K (75% duty cycle), mitigating heat accumulation**

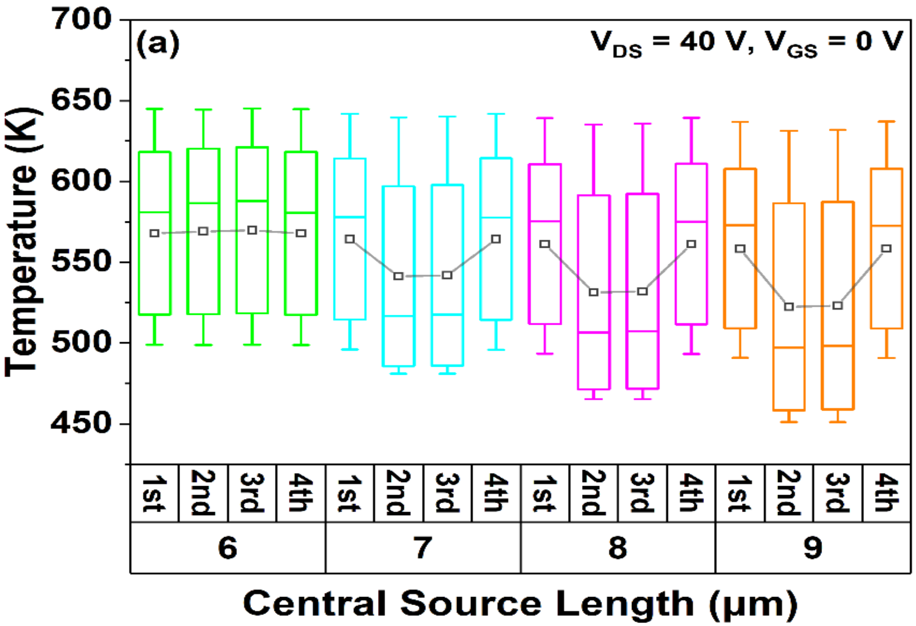
3. Thermal and Operational Characteristics Analysis in Multi-Finger HEMTs
(8) Central Source Contact Length Exceeding 6 μm

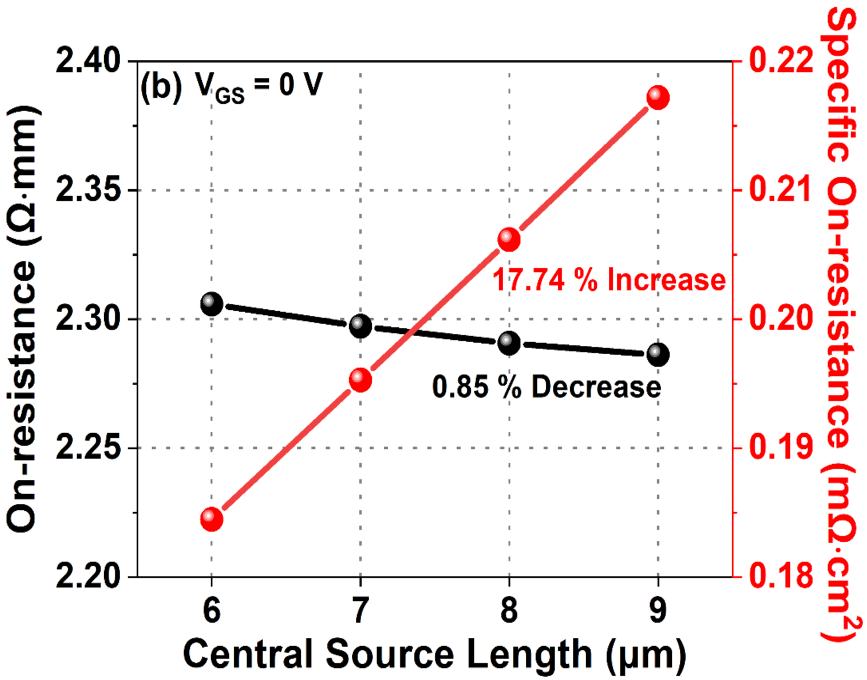


< Schematic Cross-Section of 4F HEMT Device>

Variable Parameters	Units	Values	Note
Central Source Contact	**μm**	6.0 ~ 9.0	Simulation performed with 1 μm increments

(9) Temperature Non-uniformity and Reduced Area Efficiency





- Extending the central source contact length beyond 6 μm reduces thermal coupling but increases temperature variation (T_{OUTER} -T_{INNER} = 35.66 K at 9 μm)
- **R_{ON} improves by only 0.85%, but specific on-resistance (R_{ON} · A) rises by 17.74%**, reducing area efficiency

4. Research Summary and Conclusion

Research Summary

Central Source Length (μm)	Maximum Thermal Crosstalk	ΔT_{MAX} (K) @ Duty (75%)	T_{OUTER} -T_{INNER} (K)
3	27.03	30.60	32.27
6	9.39	12.04	1.59

Conclusion

- This study investigates thermal crosstalk in multi-finger GaN HEMTs by proposing a four-finger structure with a modulation of central source contact length. As a result, the maximum thermal crosstalk is reduced by 65% in 6 μm central source contact. The optimized design reduces thermal crosstalk and improves temperature uniformity for high-power applications.

Thank You

Acknowledgement:
This work was supported by the Institute of Information and Communications Technology Planning and Evaluation (IITP) through the Korea government (MSIT) under Grant 2021-0-00760.