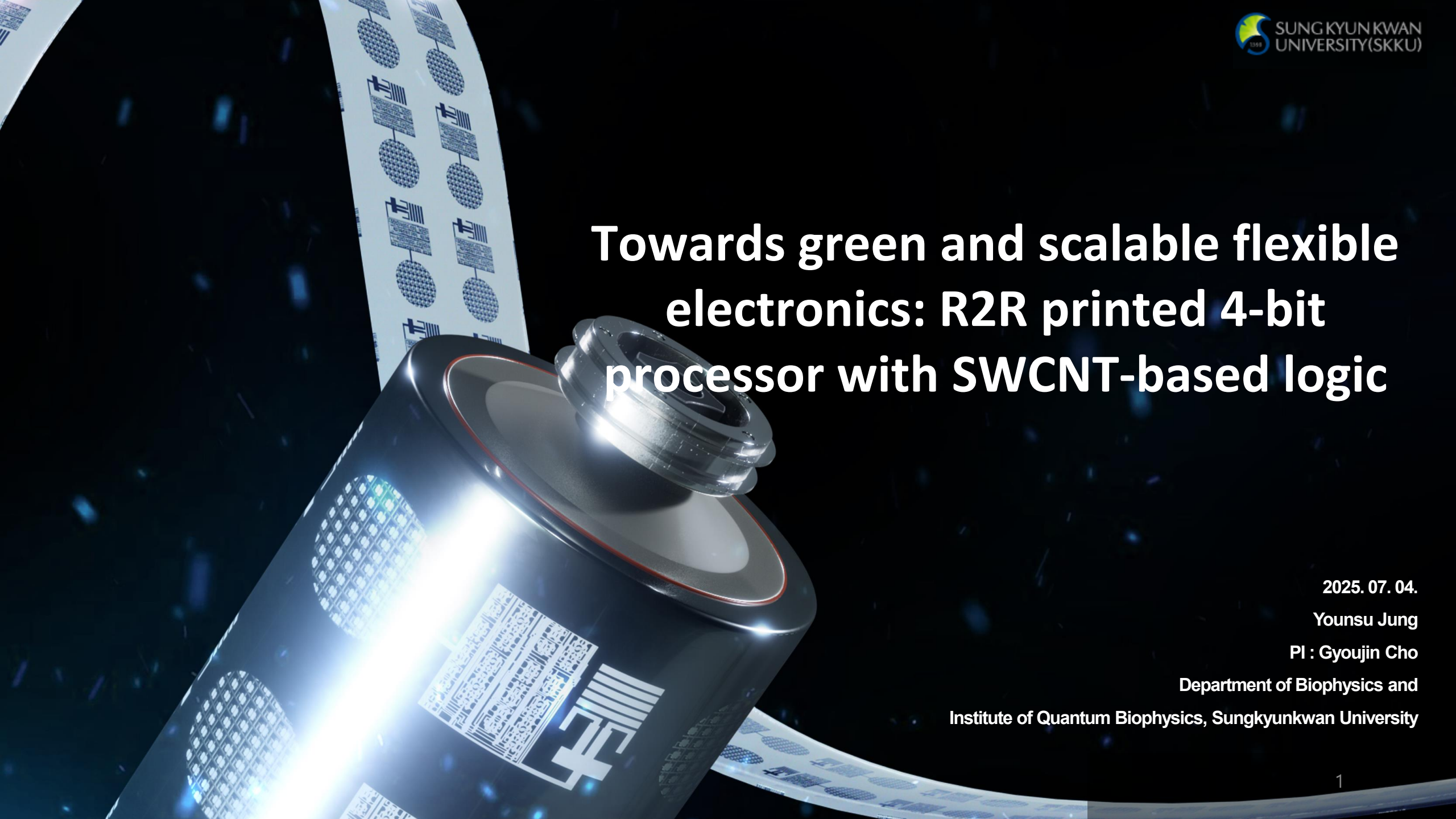


Towards green and scalable flexible electronics: R2R printed 4-bit processor with SWCNT-based logic

2025. 07. 04.

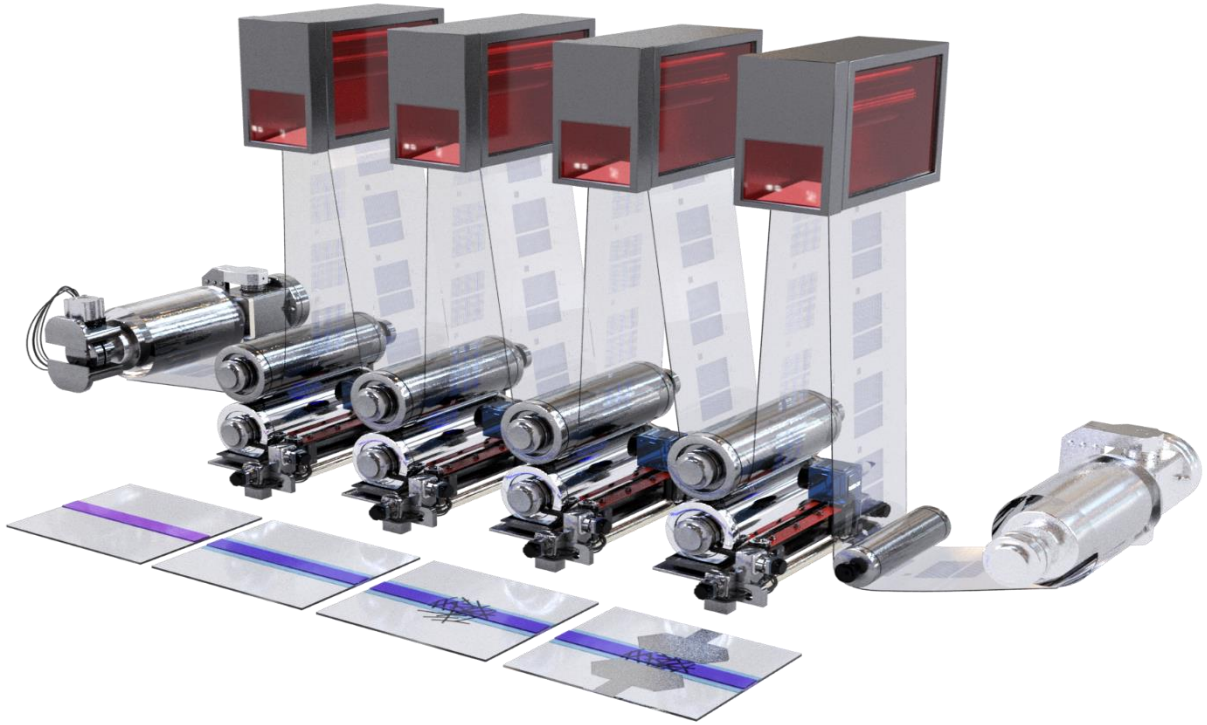
Younsu Jung

PI : Gyoujin Cho

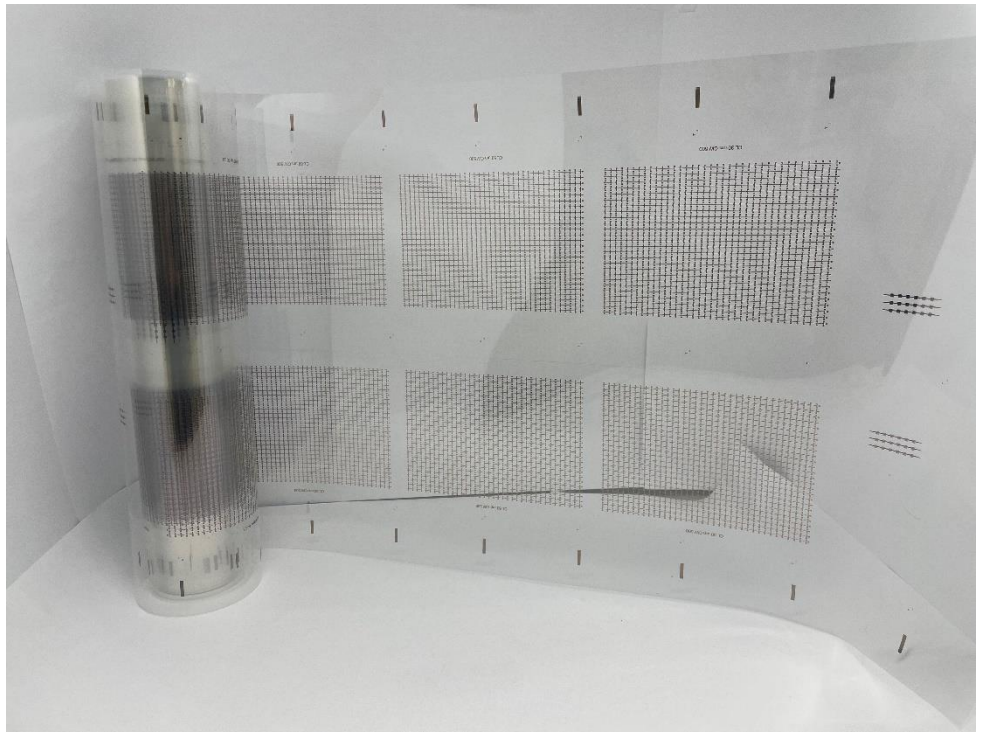
Department of Biophysics and

Institute of Quantum Biophysics, Sungkyunkwan University

1. R2R gravure printing process for 4-bit processor module

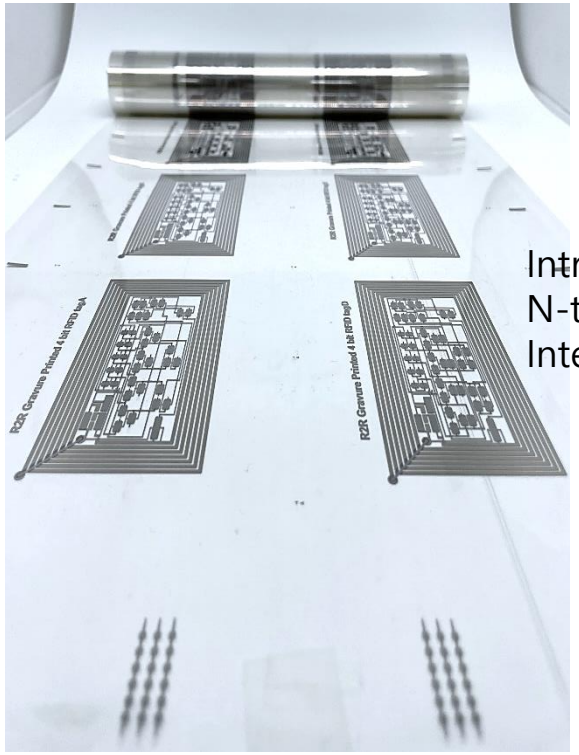


R2R in-line printing process for printing 4-bit processor via repeating rewinding and printing cycle 6 time to print active (3) to n-doping (8)



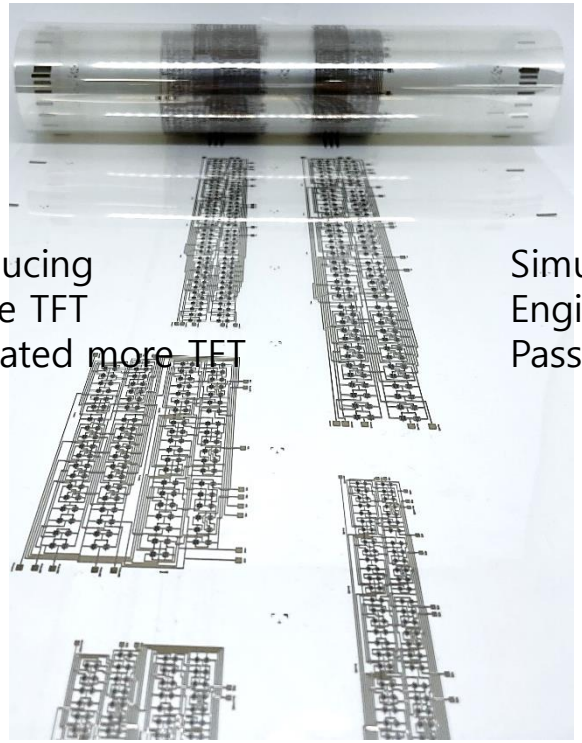
Roll images of R2R printed 4-bit processor including component, with optical image of TFT, SEM for SWCNT

2. Development of history of R2R printed transistor



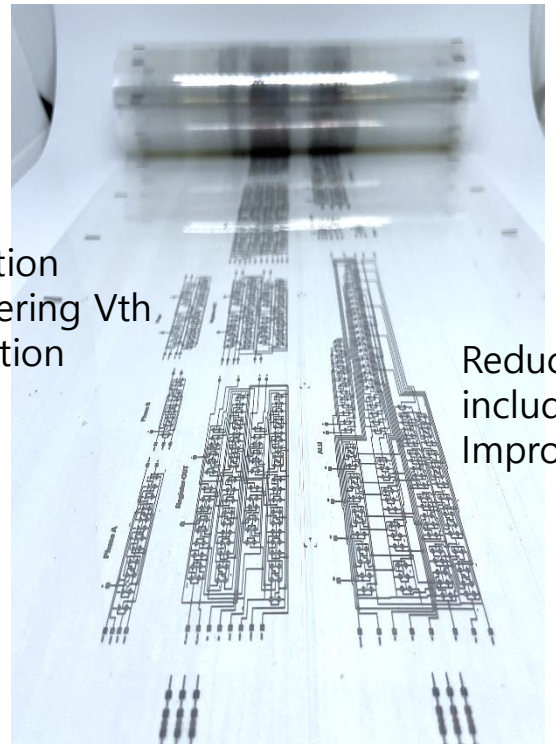
4-bit code generator device
with ~ 50 TFTs, p-type TFTs
Demonstration of this device
(-2019)

Introducing
N-type TFT
Integrated more TFT



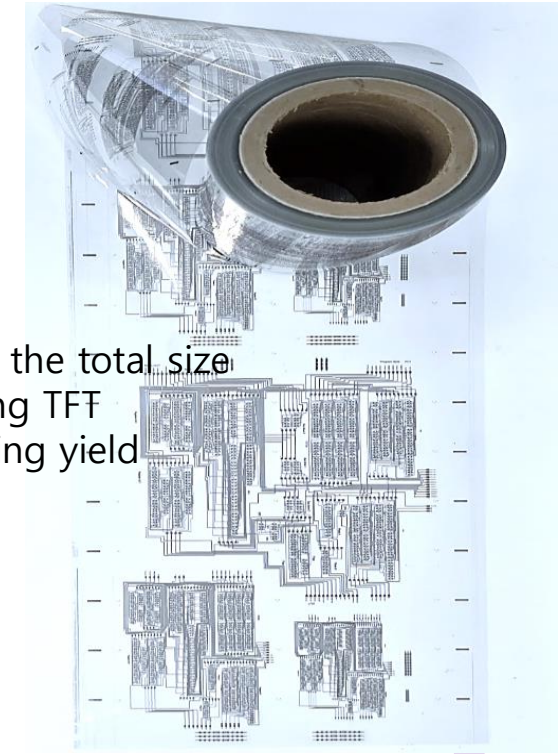
1-bit & 4-bit ALU device
with ~150 TFTs
Simple device function
Demonstration of this device
(2020-2022)

Simulation
Engineering Vth
Passivation



4-bit processor module
with ~ 1,200 TFTs
(2023-2024)

Reduce the total size
including TFT
Improving yield



4-bit one-chip processor with ~
1,200 TFTs (L, M. S)
(2025-)

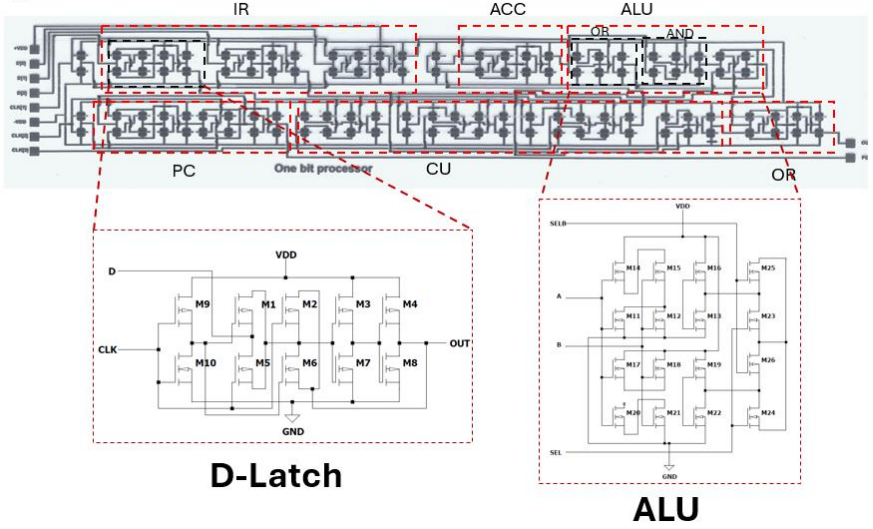
1. Integrating 1,200 TFTs
2. Various type of logic gate unit (ALU, PC, Register)
3. Major milestone on the path to demonstrating complex digital circuits
4. Simple processor towards full printed IoT, PoCT, Biosensor

Flex. Print. Electron, 6, 044005, 2021.
Adv. Electron. Mater, 200770, 2020.
npj. Flexible. Electronics, 8, 78, 2024

3. R2R gravure printed flexible 1-bit processor

Unpublished this result

a



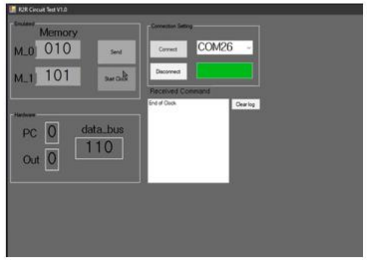
D-Latch

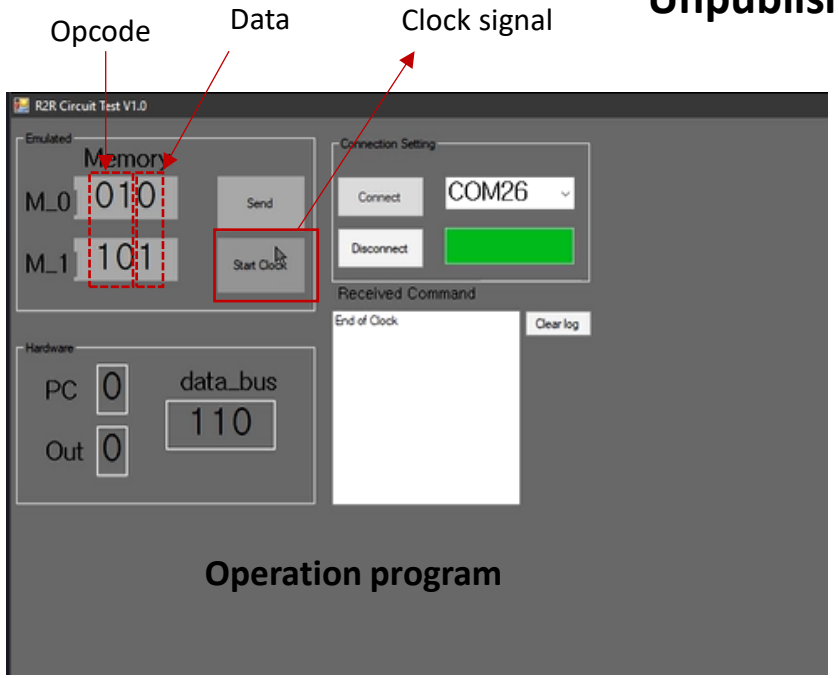
ALU

b

Opcode	Operation
00	NOP
01	Load
10	AND
11	OR

c





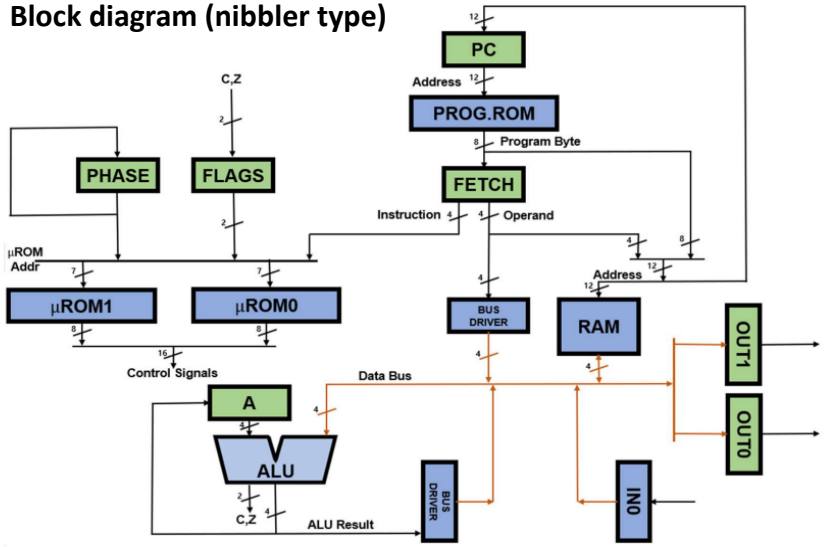
Operation program

Opcode	Operation
00	No operation
01	Load
10	AND
11	OR

4. Gravure roll pattern design for 4-bit processor module

SUNG KYUN KWAN UNIVERSITY(SKKU)

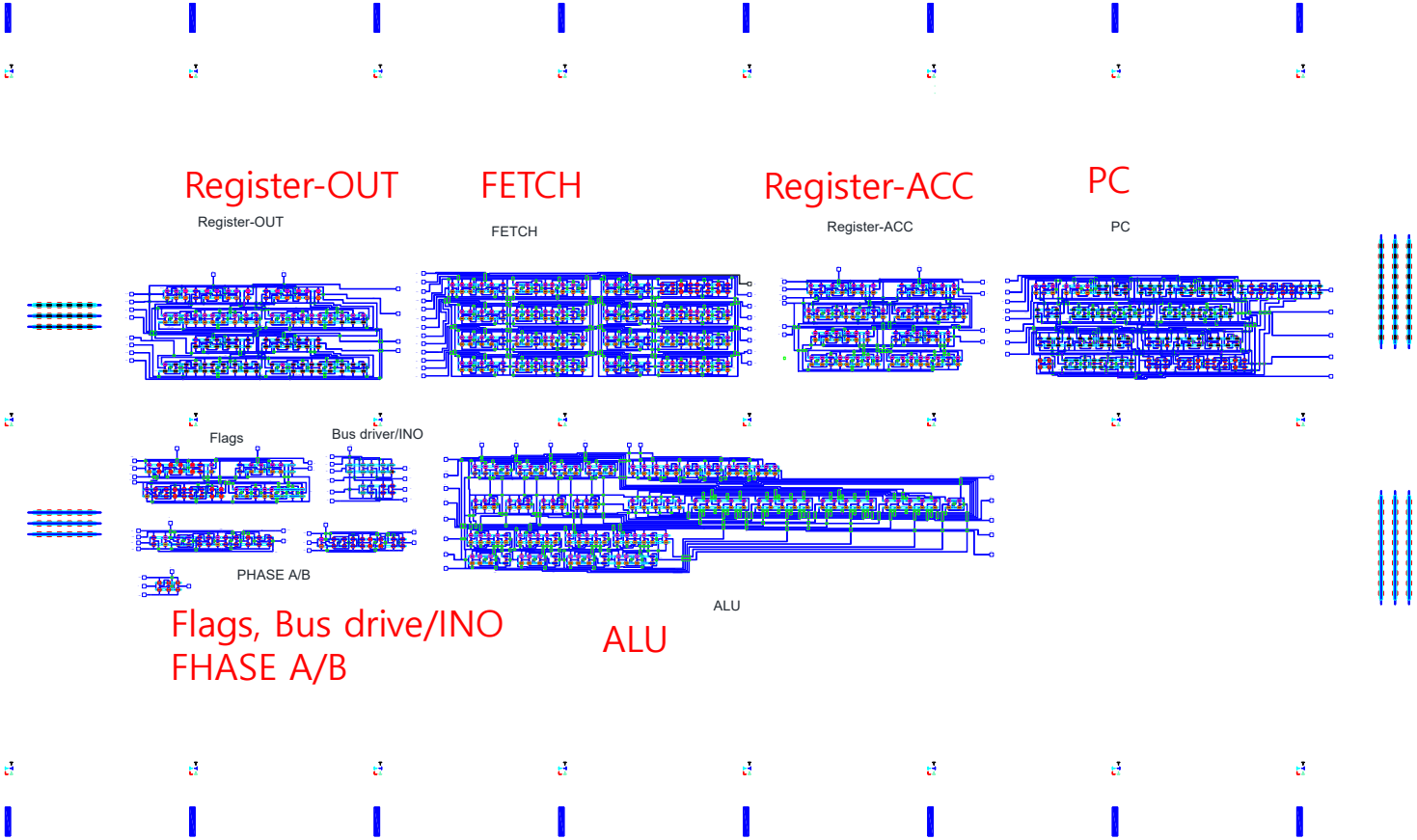
Block diagram (nibbler type)



Processor can be though of as the "brain"

1. Program counter (PC) : counts from 0000 to 1111. monitors the address of the active instruction
2. SRAM program memory : stores the program
3. Accumulator (ACC) A : stores the intermediate results computed by the processor
4. Accumulator (ACC) B : supply the number to be added or subtracted from accumulator A
5. Arithmetic unit (ALU) : performs the operation S=A+B (addition) or S=A+(not_B+1) (subtraction)
6. Input Register : outside world into the processor, keyboard
7. Output Register : transfer the contents to outside world, display
8. Phase Generator : counts phase "pulses" 1 clock pulse
9. Instruction Register (IR) : stores the currently addressed contents of the program memory
10. Micro-Controller : programmable logic memory

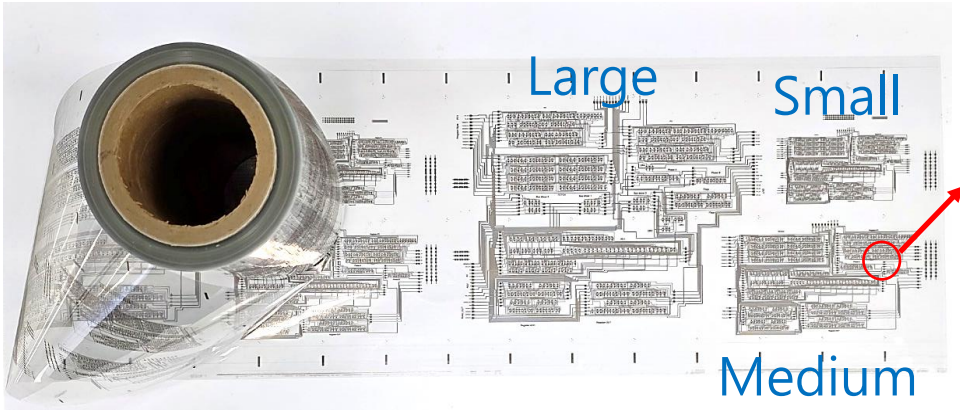
Schematic CAD for Gravure Roll

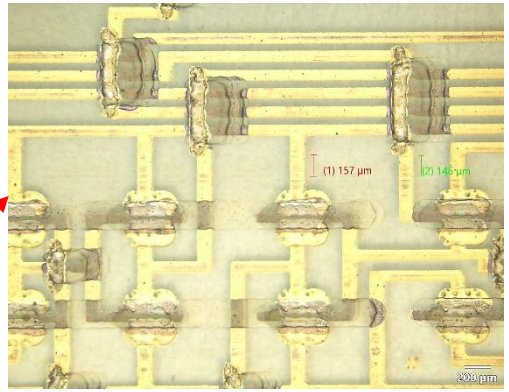


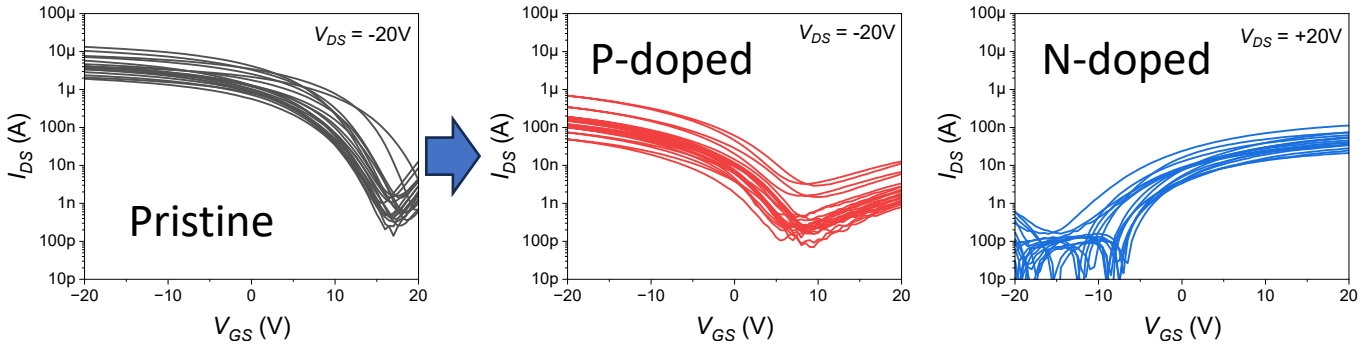
Confirmed by ANN based PDK model

SUNG KYUN KWAN UNIVERSITY(SKKU)

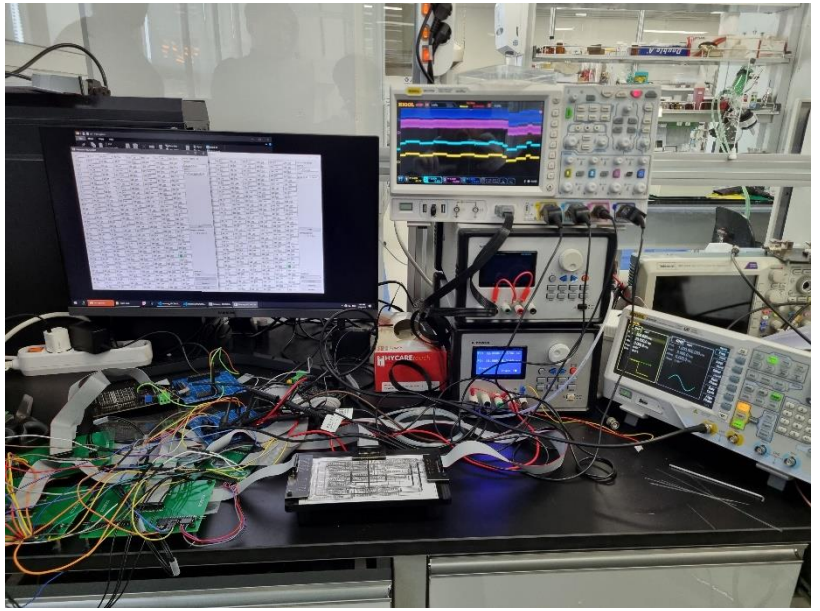
One-chip type of 4-bit processor
Size reduction through high OPRA, improve device yield

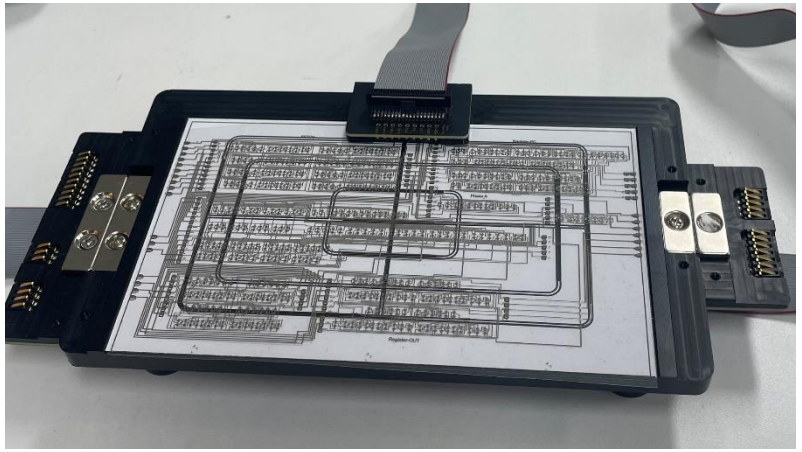




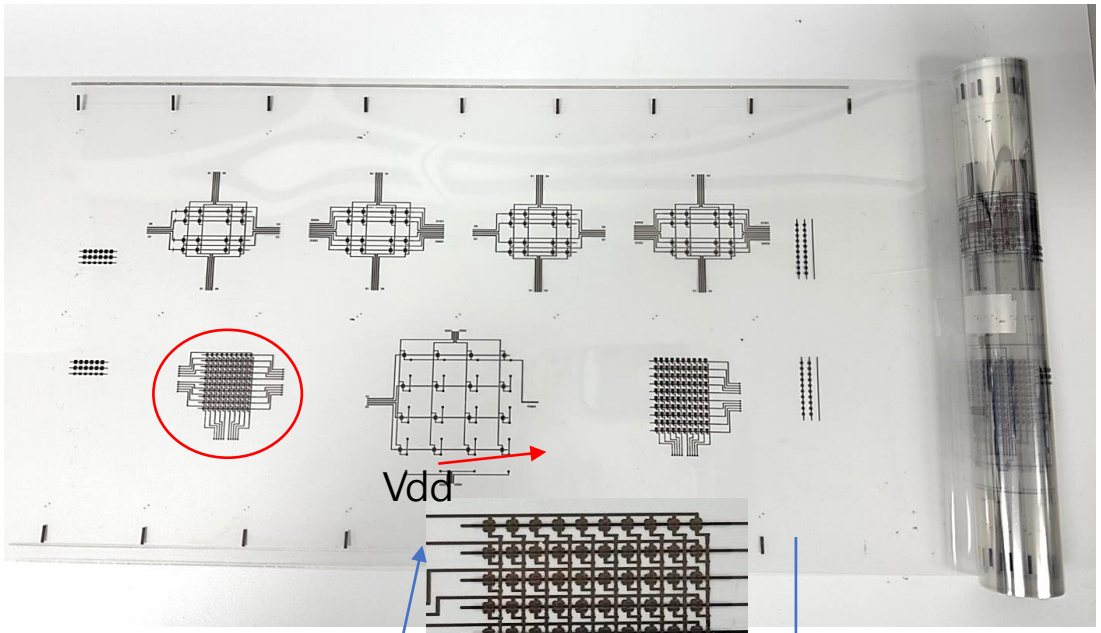


Unpublished this result



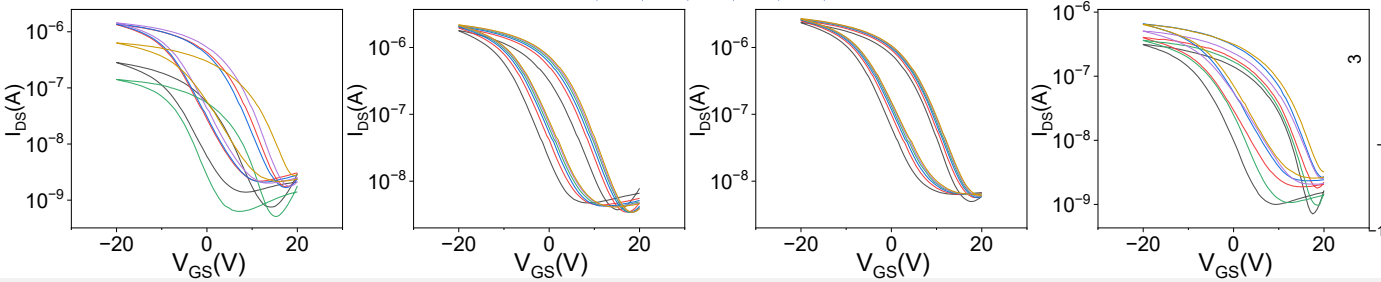


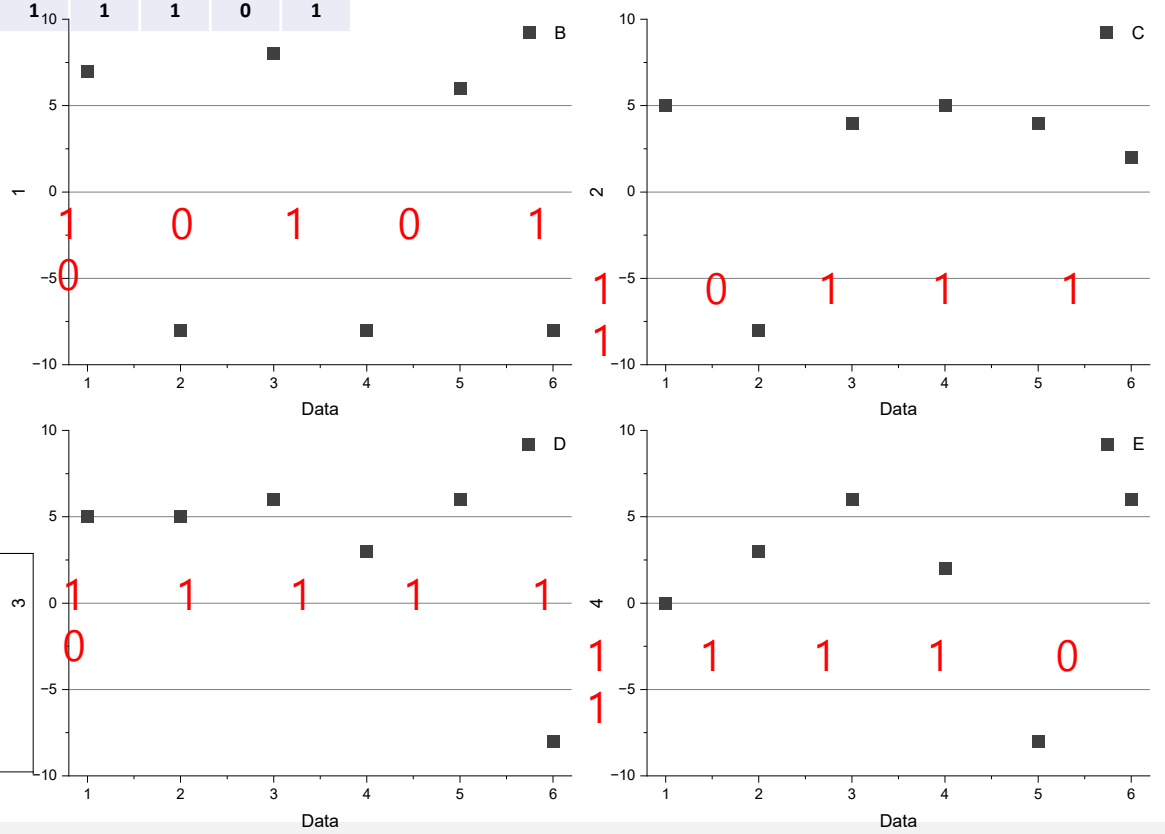
7. R2R stop&go printed flexible ROM for computer application



	1	2	3	4	5	6
1	1	0	1	0	1	0
2	1	0	1	1	1	1
3	1	1	1	1	1	0
4	0	1	1	1	0	1

Inputted data





- **Through years of research on R2R gravure printing, this study has progressed from the initial development of 4-bit code generation to the recent demonstration of a 4-bit one-chip processor as noble technology.**
- **By proposing three key rules (prediction model, ink formulating, ANN) in R2R gravure printing, we successfully demonstrated a world first fully printed 4-bit processor.**
- **For commercialization, we demonstrated the printed ROM based on TFTs using an R2R process.**

Acknowledgement

This research was supported by the Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIT) (No. 2018-0-00389, R2R printed NFC active QR code-label for checking the history of agro-fishery products to prevent forged records using a smartphone), the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2020R2A5A1019649), and Technology Innovation Program (20018357, Development of design for user biological and environmental information reactive printed electronic chameleon sheet) funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea).

Thank you.

Q&A