#16.2

Cut-and-Paste Organic FET Customized ICs for Application to Artificial Skin

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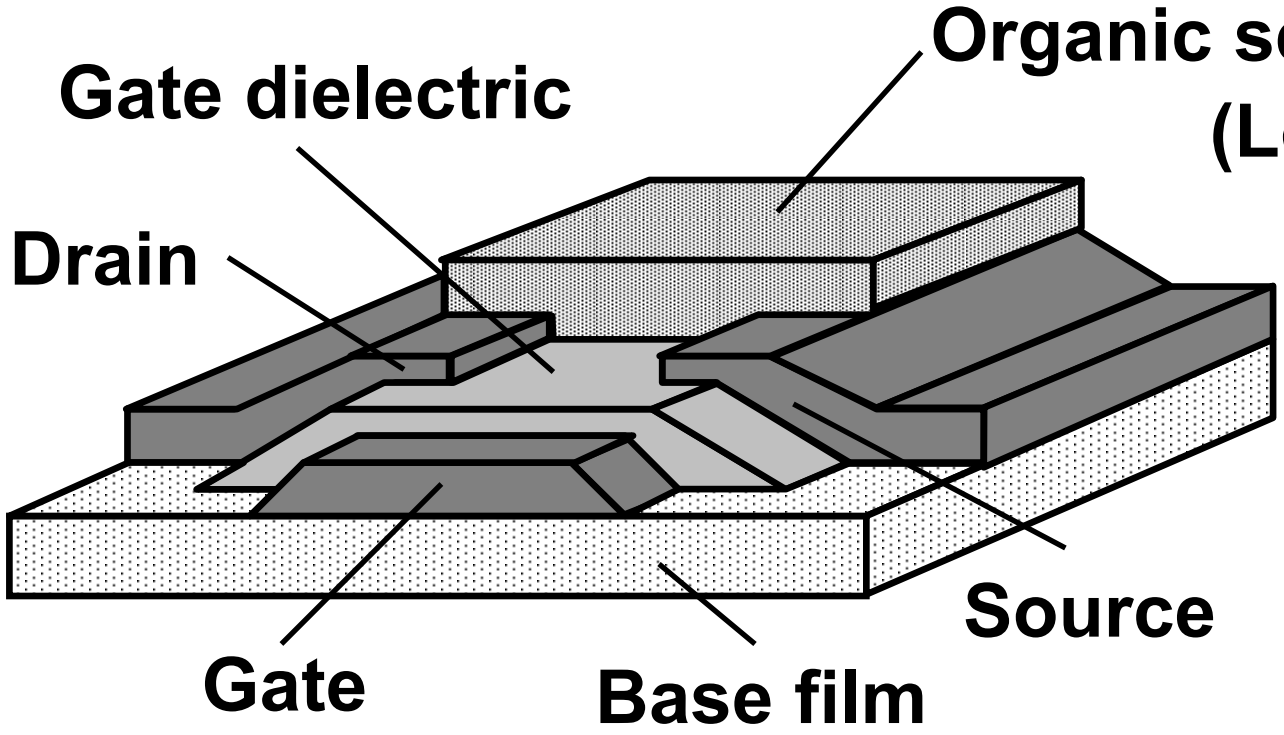
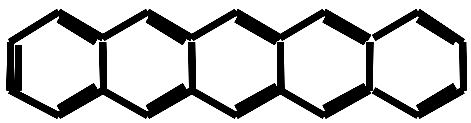
Outline

- Introduction & motivation
- Manufacturing process
- Circuit design
- Results & discussion
- Summary

Introduction

- Attributes of organic transistors
  - –Mechanically flexible
  - –Large area manufacturability
  - –Potentially low cost manufacturing

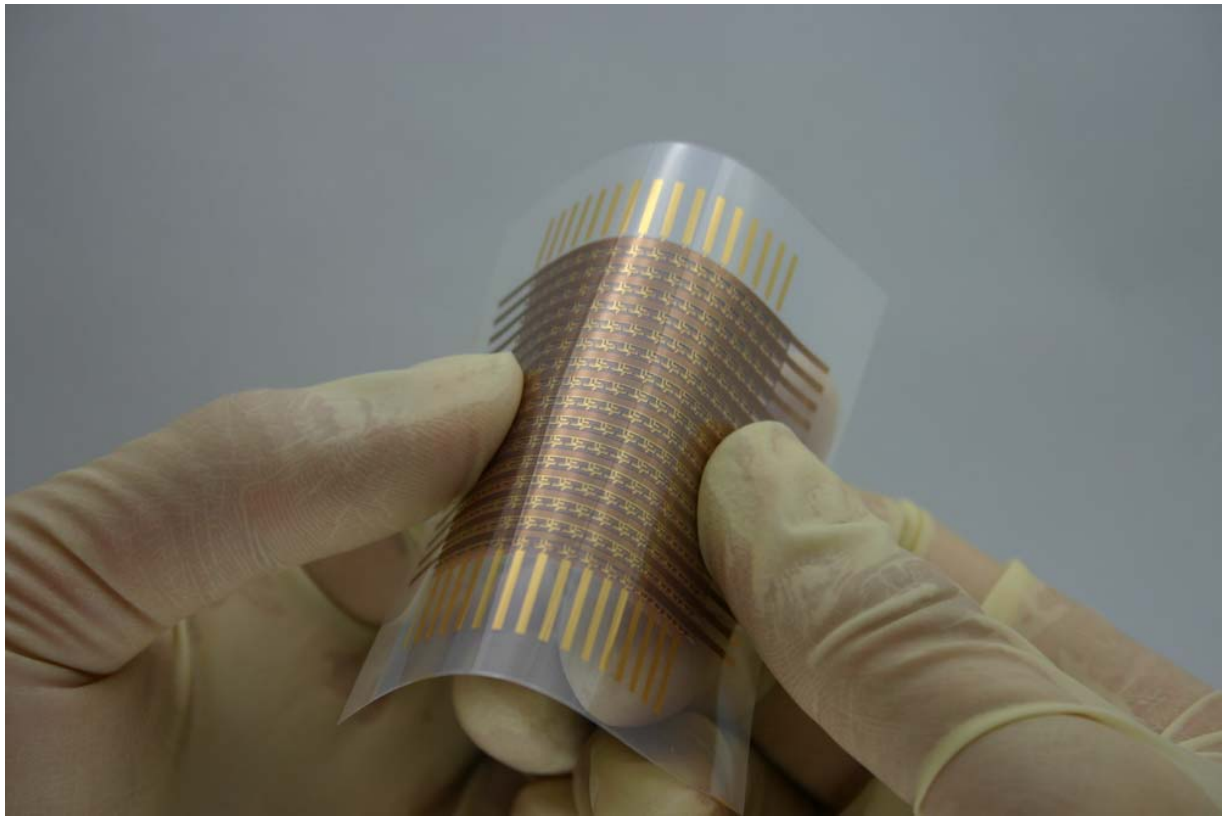




Pentacene
> 1 cm^2/Vs

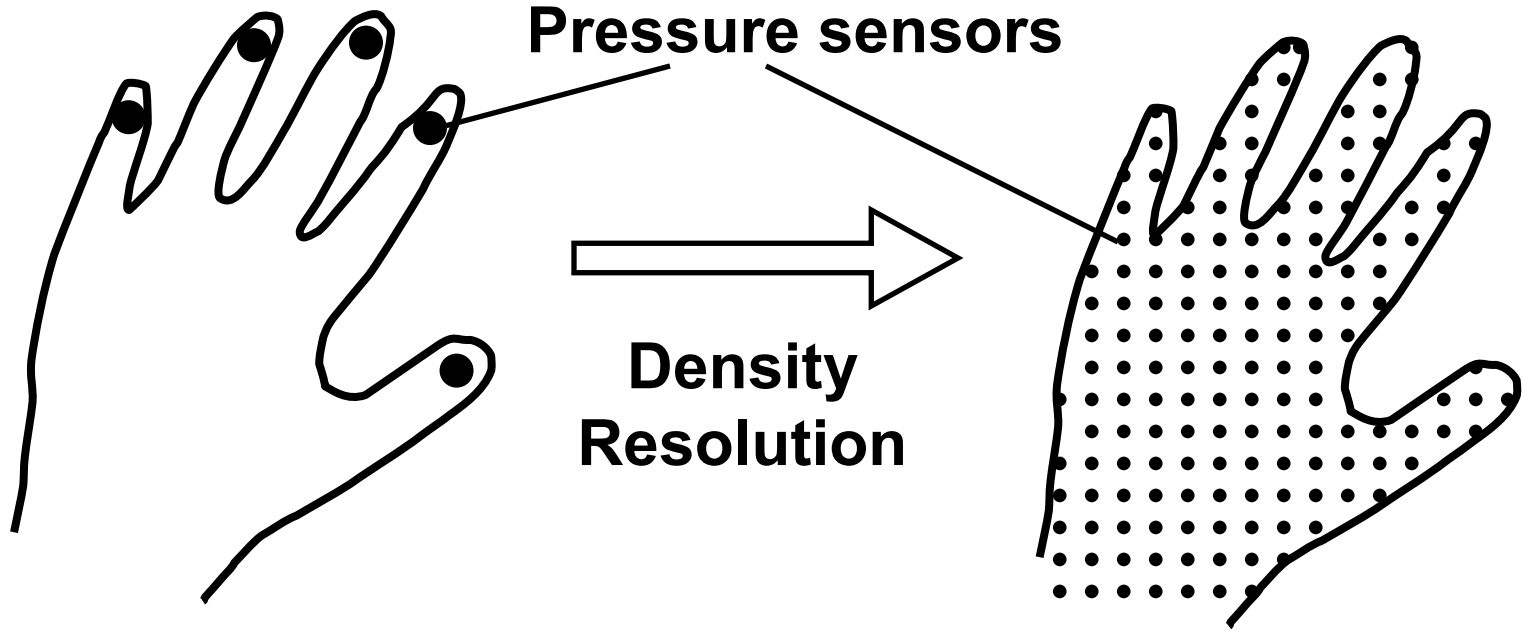
Motivation

- Two driving applications of organic FETs
  - RF ID tags and displays
- Our proposal: flexible, large-area sensors
  - Organic FET + pressure sensor = artificial skin



Tactile sensors for robots

- A sensitive skin with 1,000~1M pressure sensors requires flexible, large-area switches.



Static drivers (Existing devices)

Active matrix drivers (Present study)

Manufacturing process

- Introduction & motivation
- **Manufacturing process**
- Circuit design
- Results & discussion
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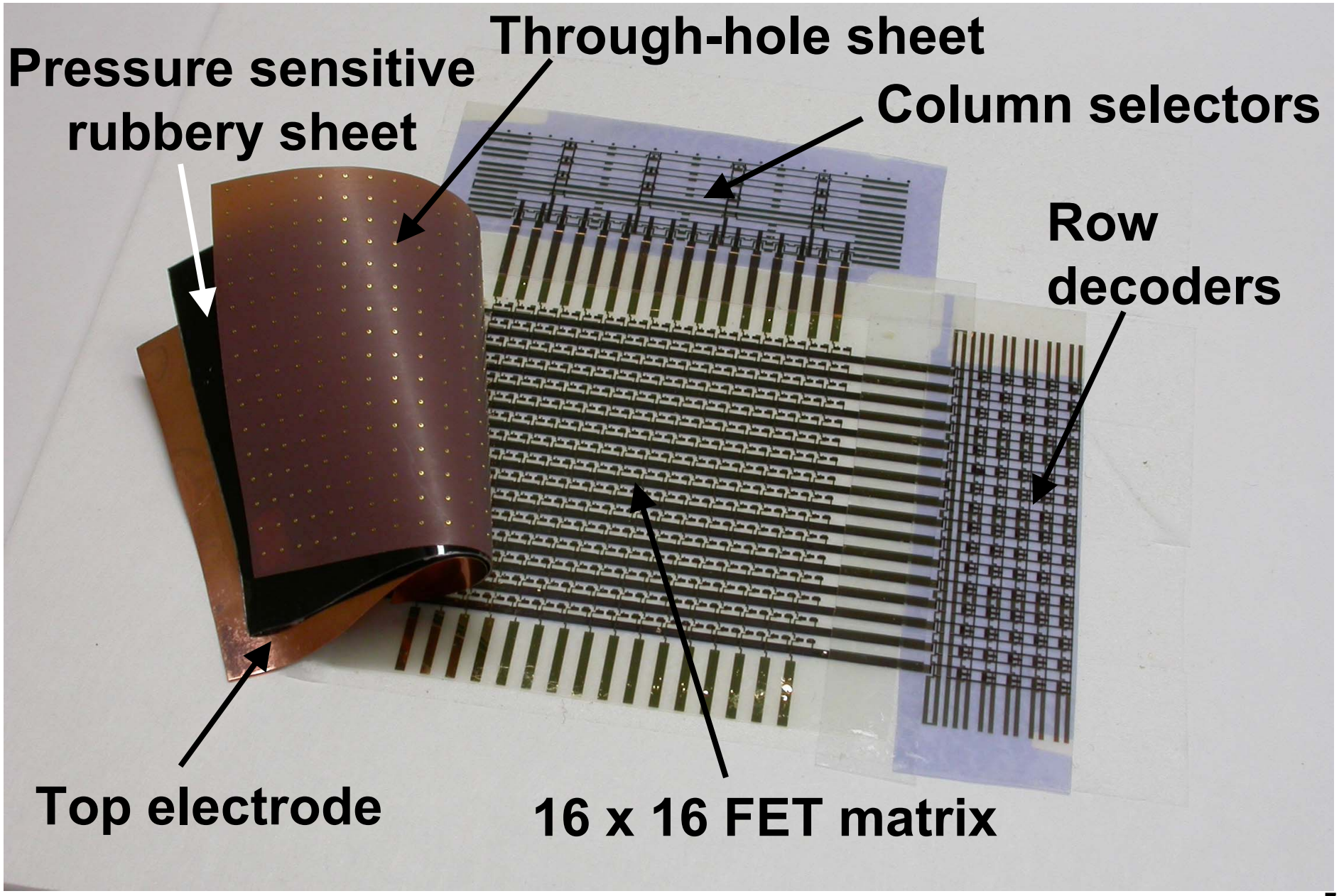
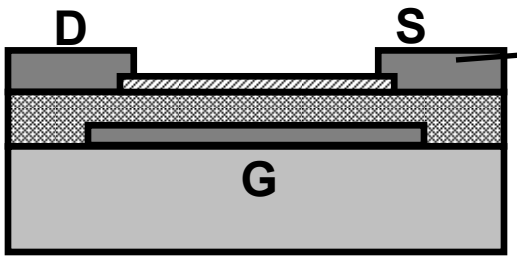
Picture of artificial skin



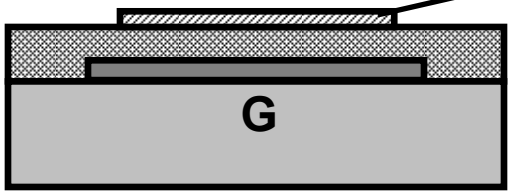
Manufacturing process (I)

4.



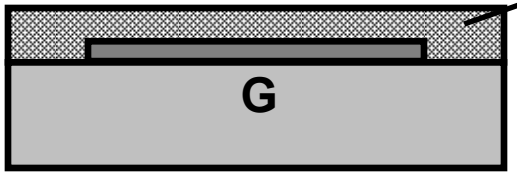
Source & Drain
60 nm Au

3.



Semiconductor
50 nm pentacene

2.



Gate insulator
500 nm polyimide
Spin coating

1.

Gate
5nm Cr/ 100 nm Au

Manufacturing process (II)

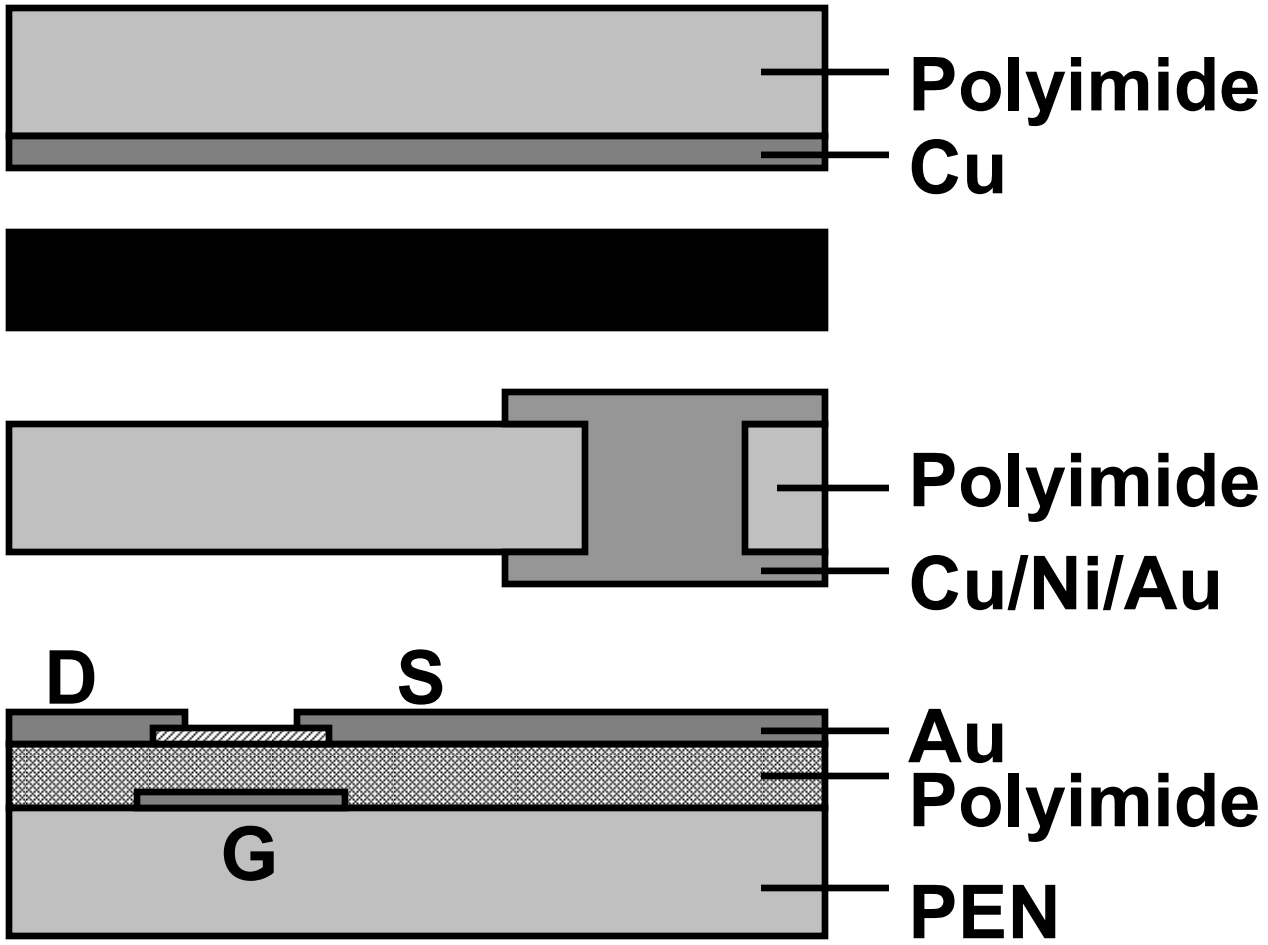
The device is manufactured with laminating four different sheets.

7. Top electrode

6. Rubber sheet

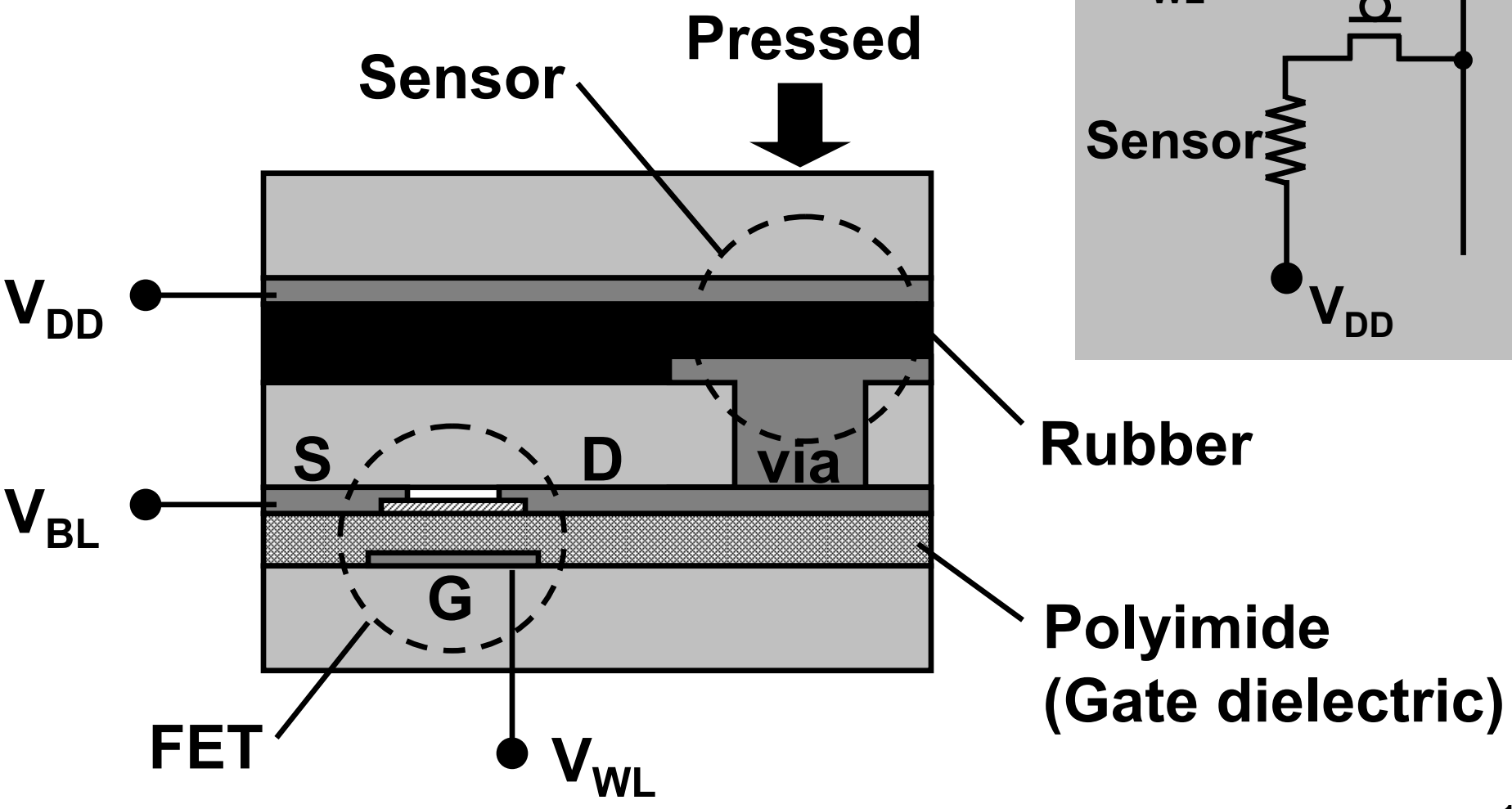
5. Through holes

4. FET sheet



One sensor cell (Sencel)

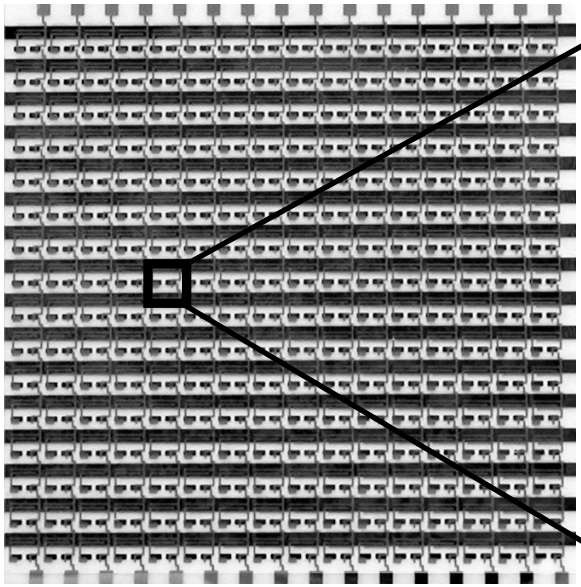
FET + Sensor = Sencel

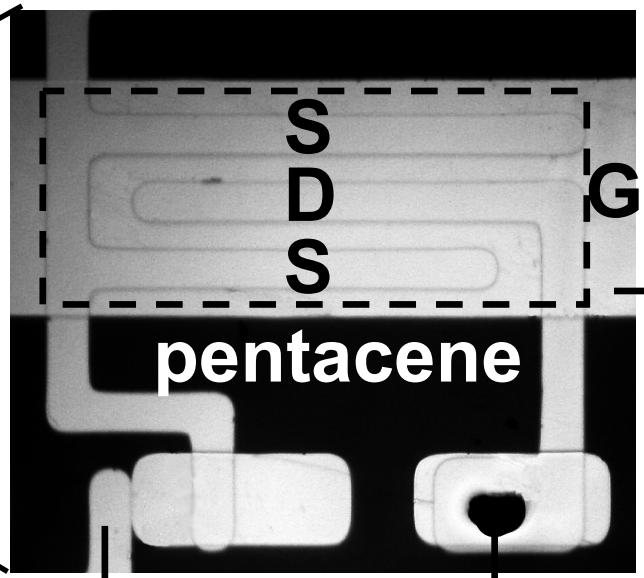


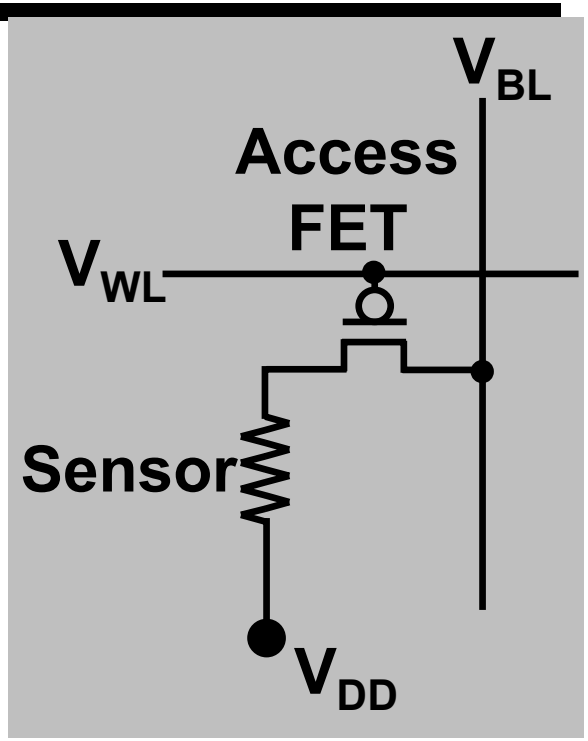
Sensor cell (Sencel)

16 x 16
FET matrix
4 x 4 cm^2

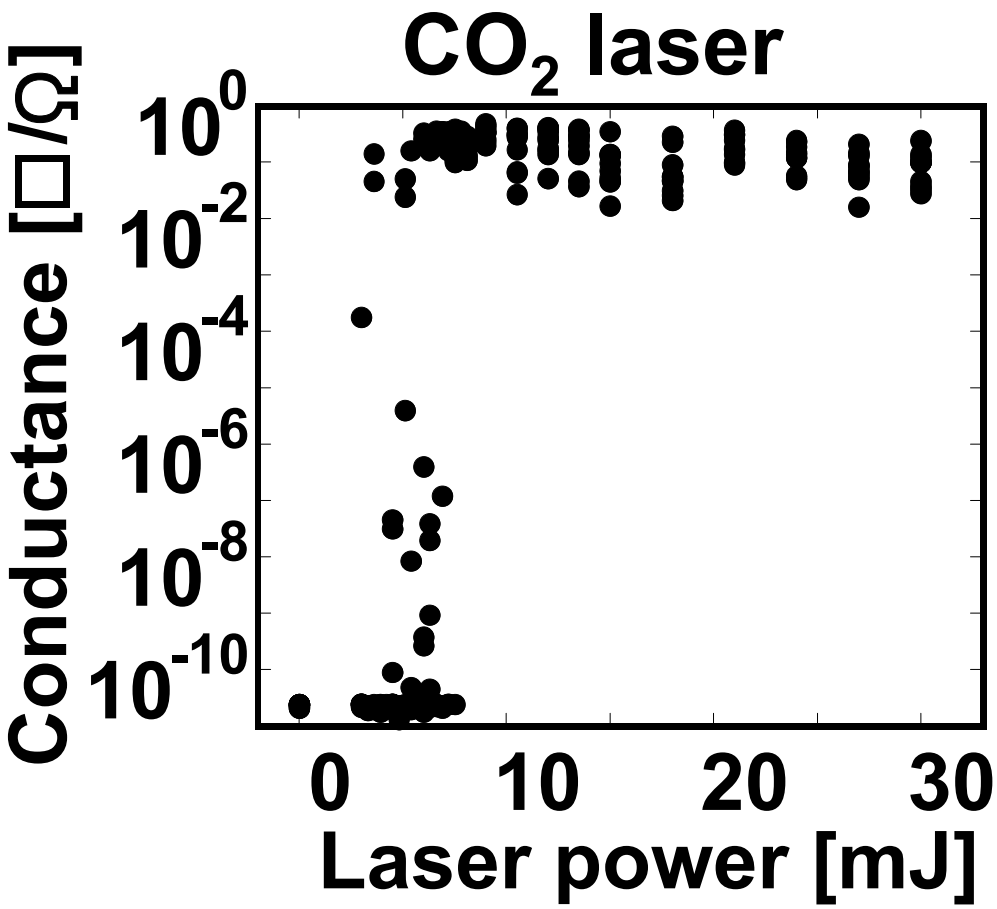
One sencel
2.54 x 2.54 mm^2

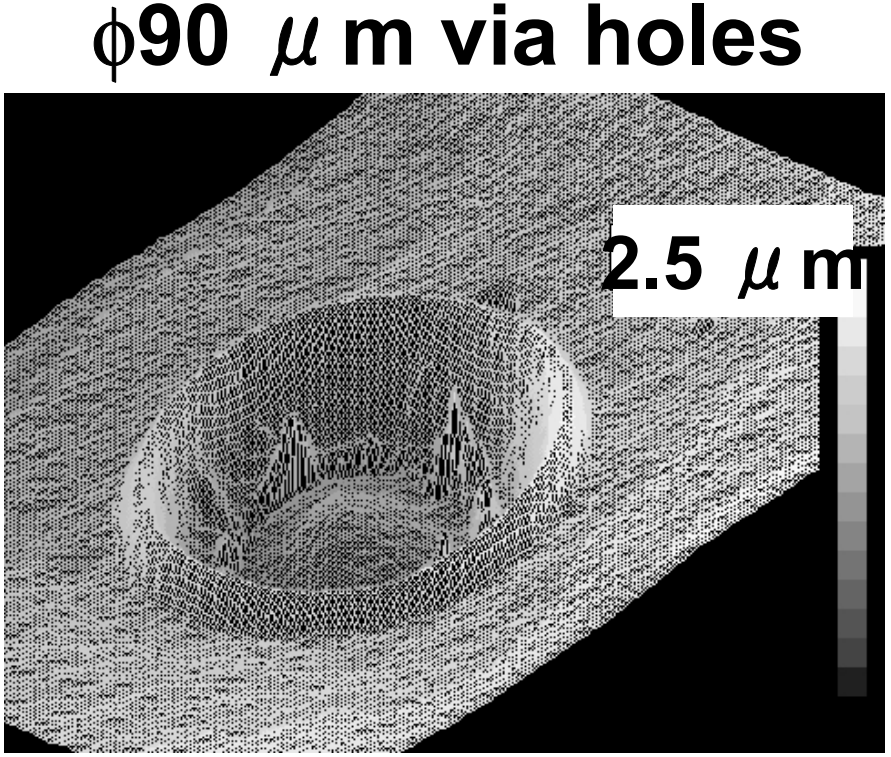




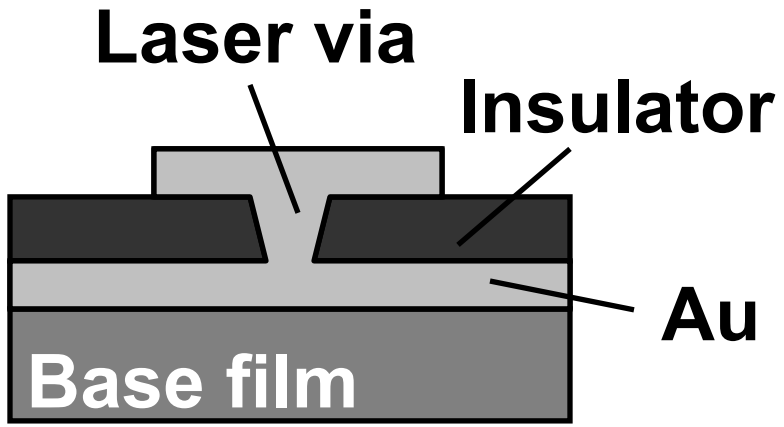


Via holes by laser drilling machine





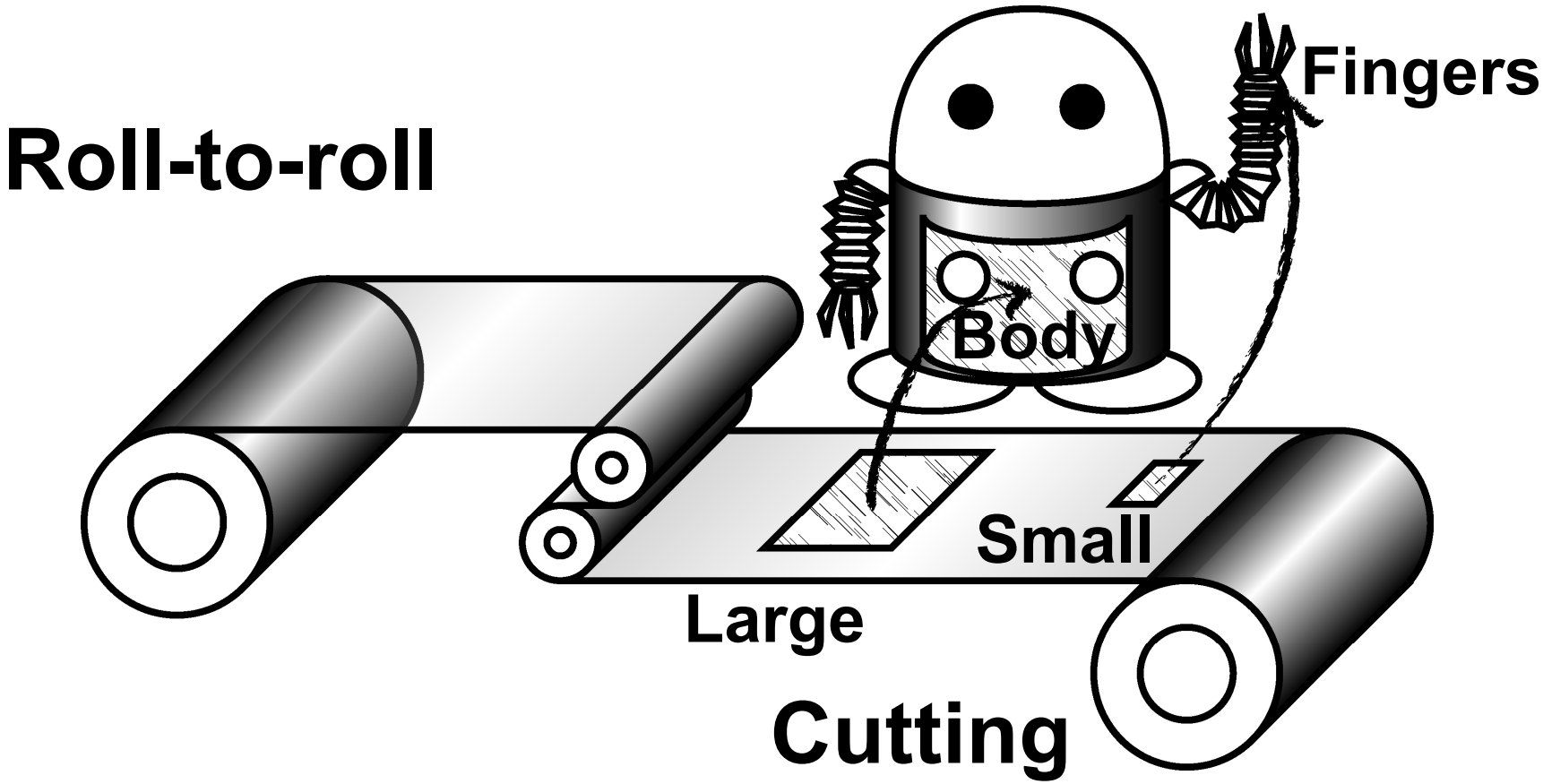
Yield > 99% /pulse
(R < 10Ω)



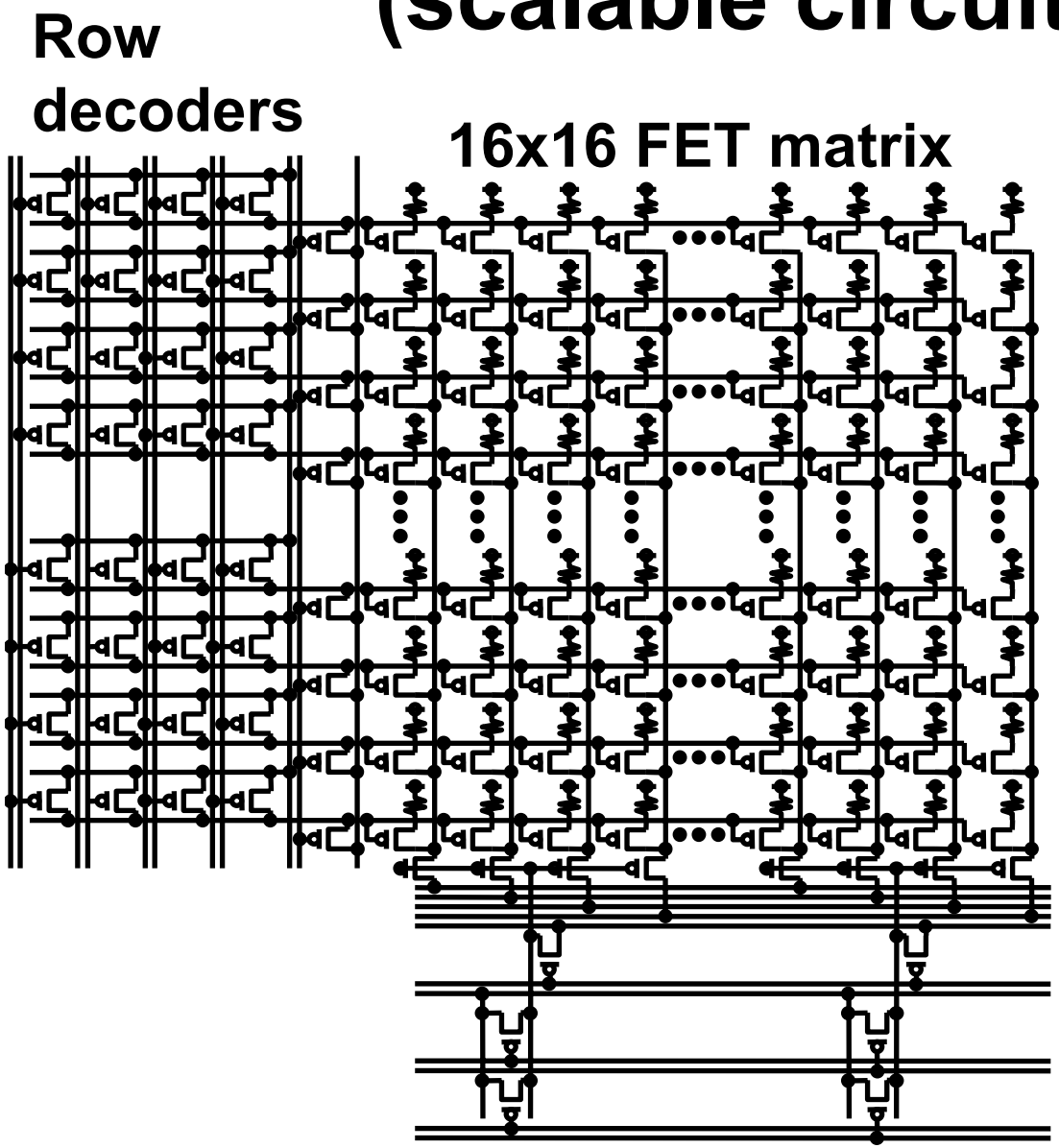
Circuit design

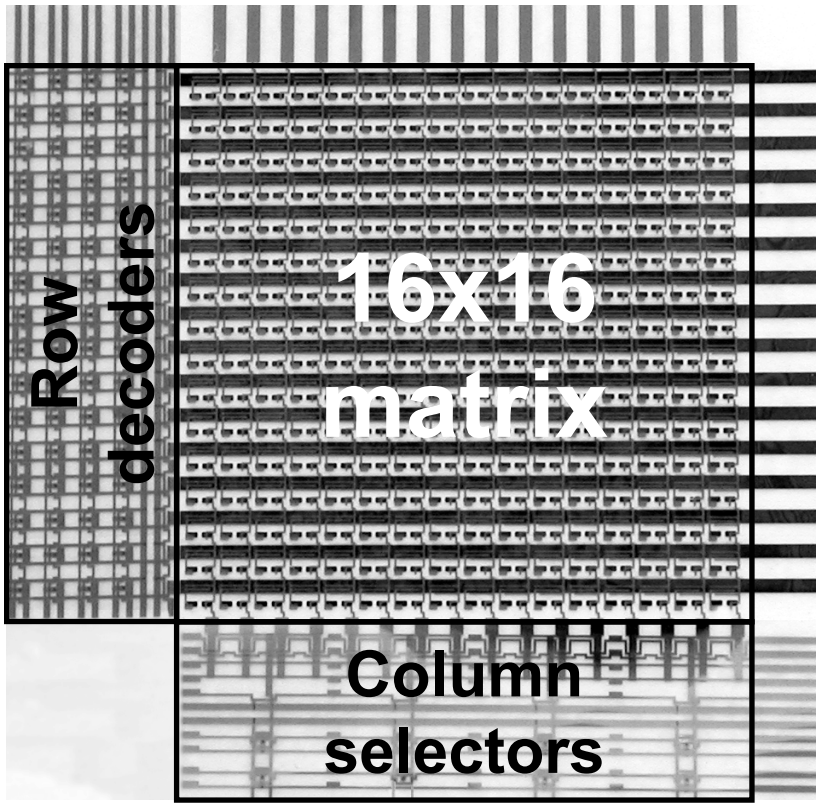
- Introduction & motivation
- Manufacturing process
- **Circuit design**
- Results & discussion
- Summary

Concept

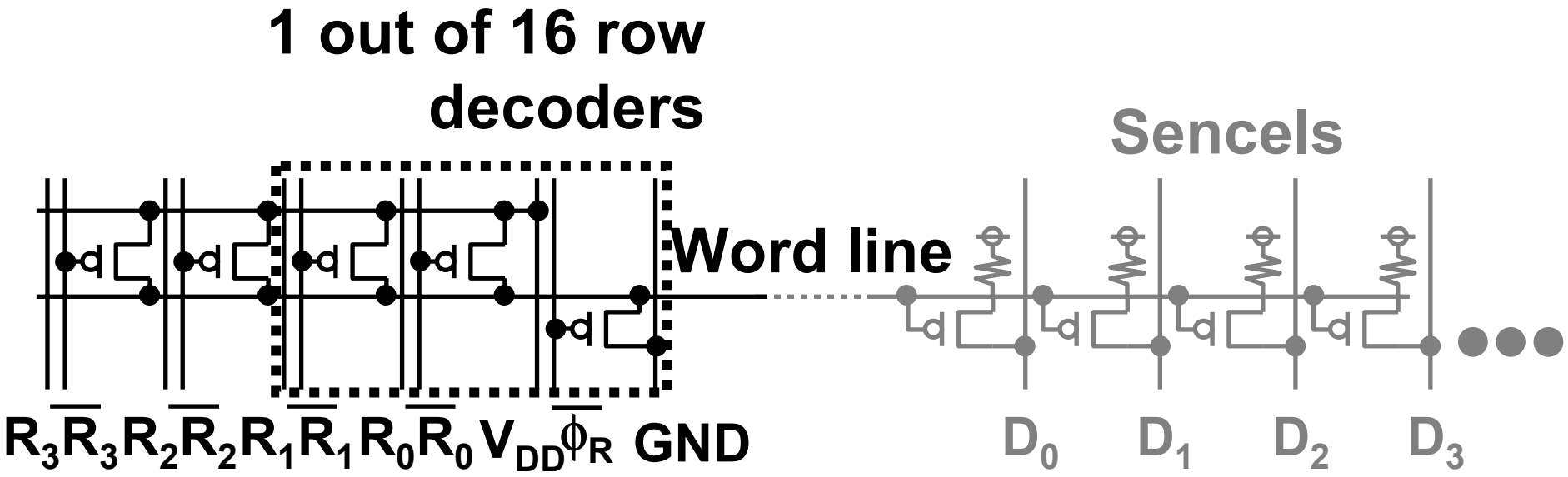


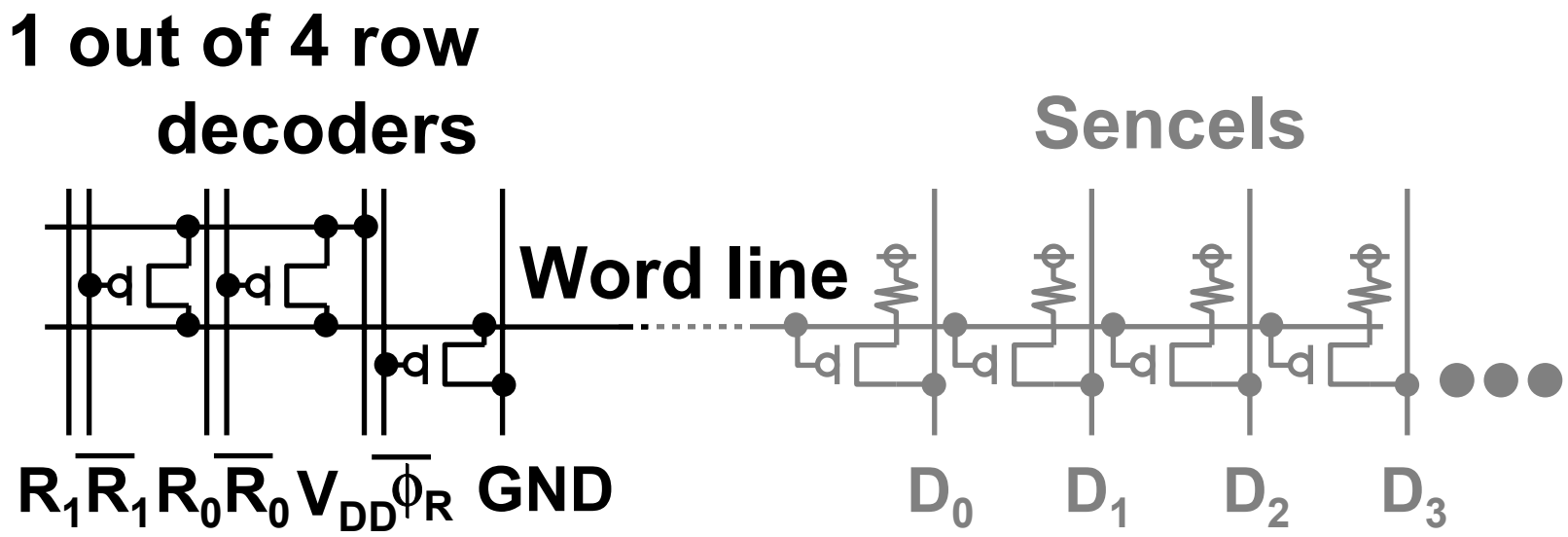
Cut-and-paste feature (scalable circuit concept)



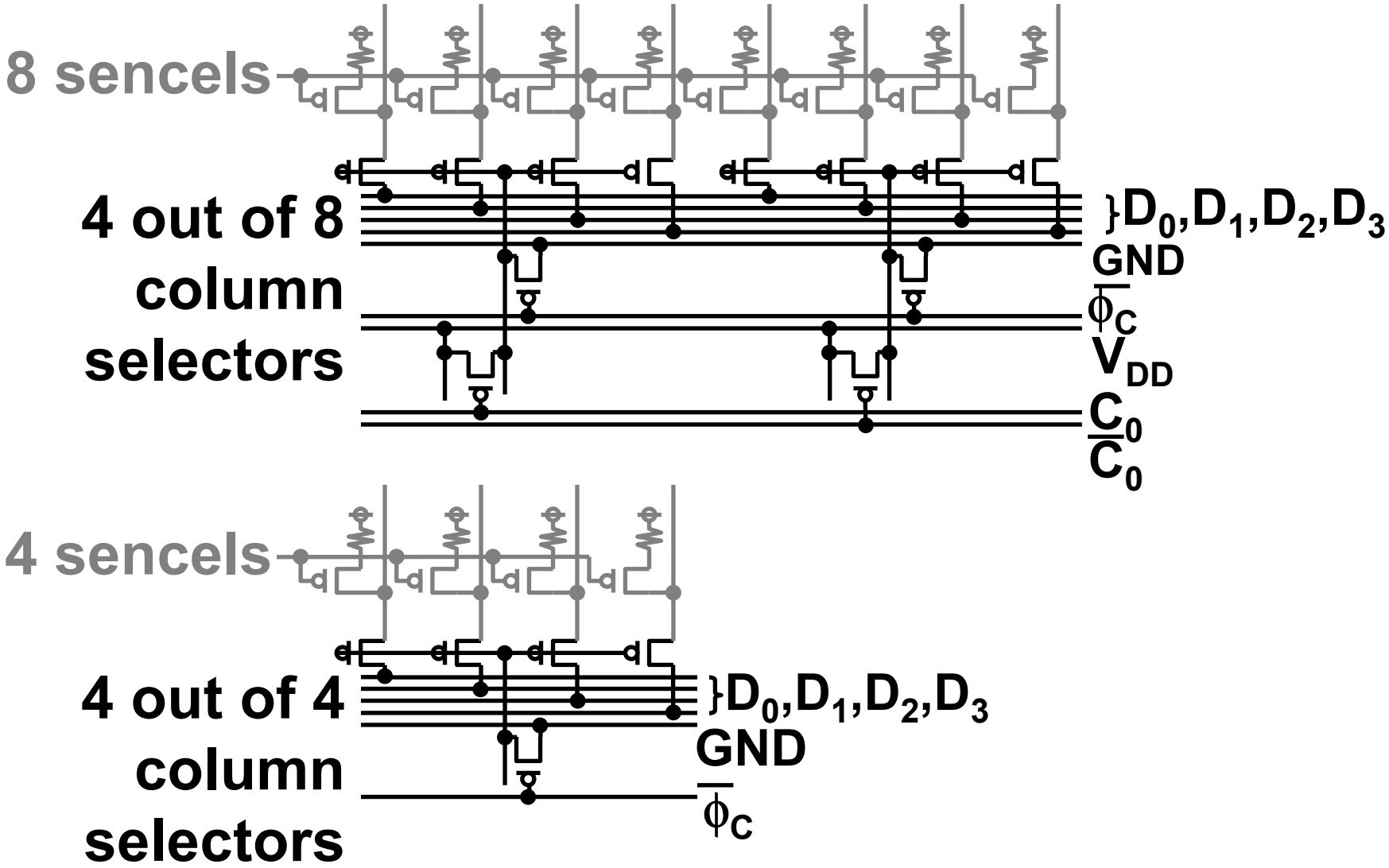


Circuit scalability (row decoder)

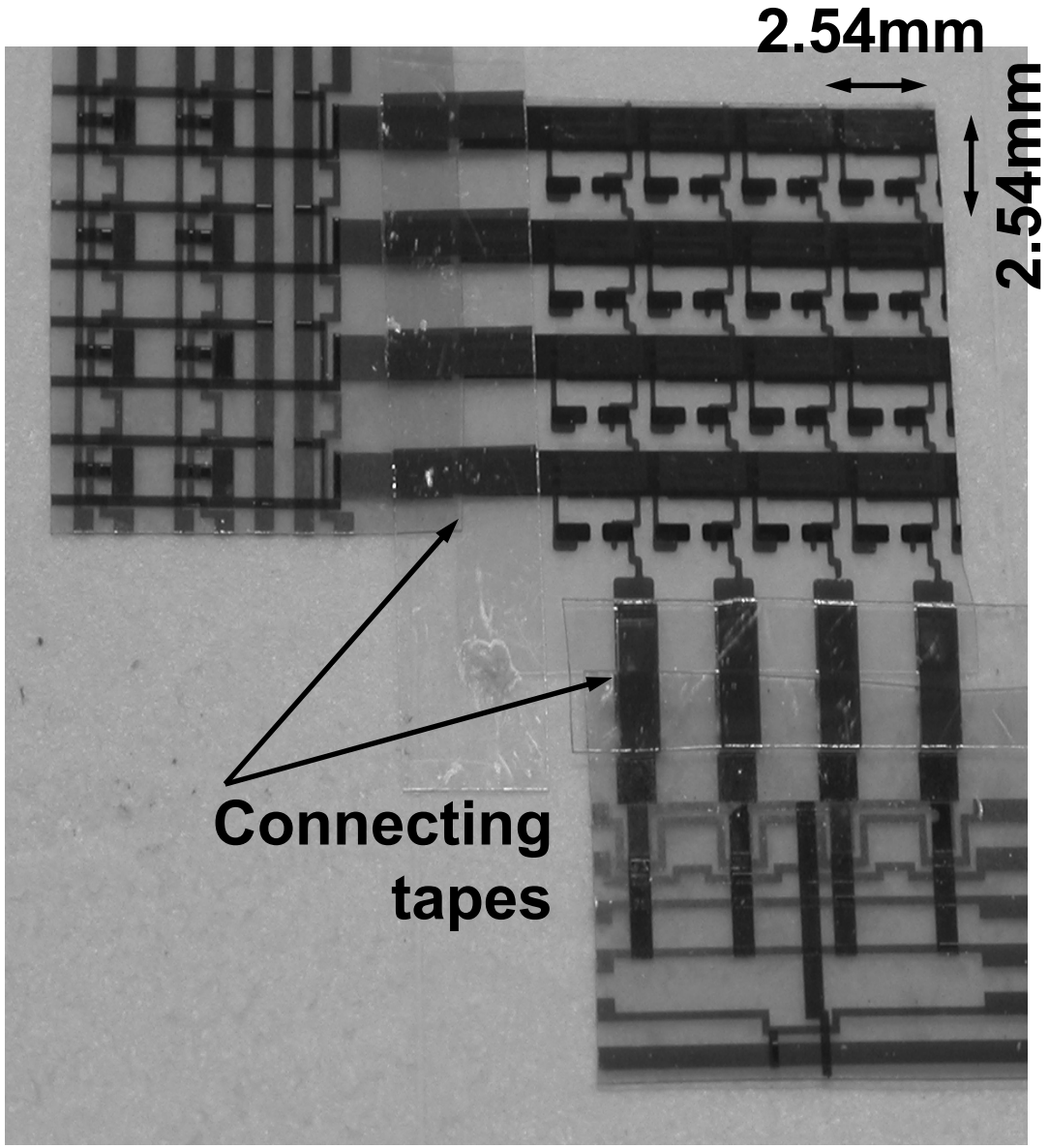




Circuit scalability (column selector)

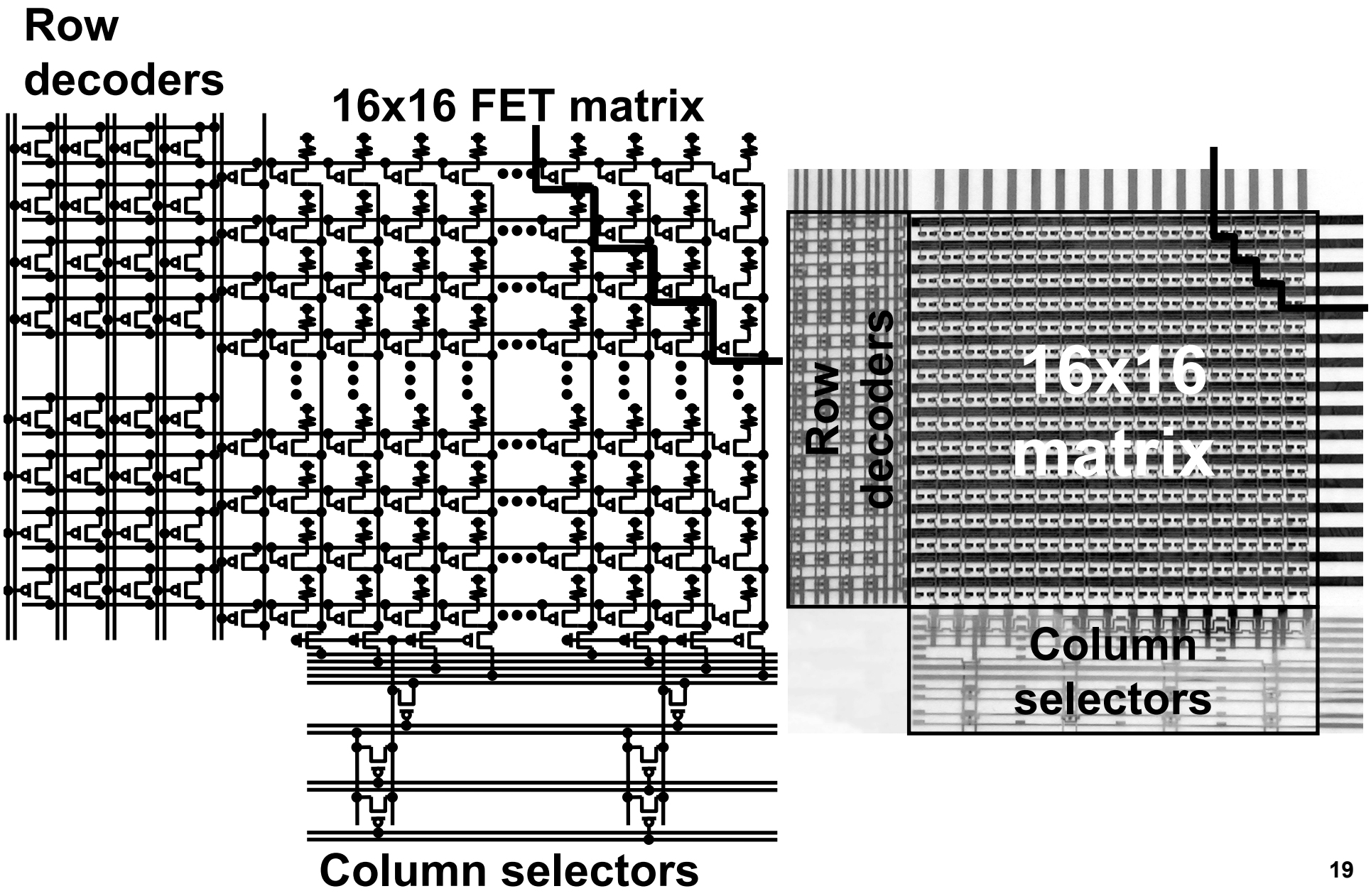


Connecting tape to paste

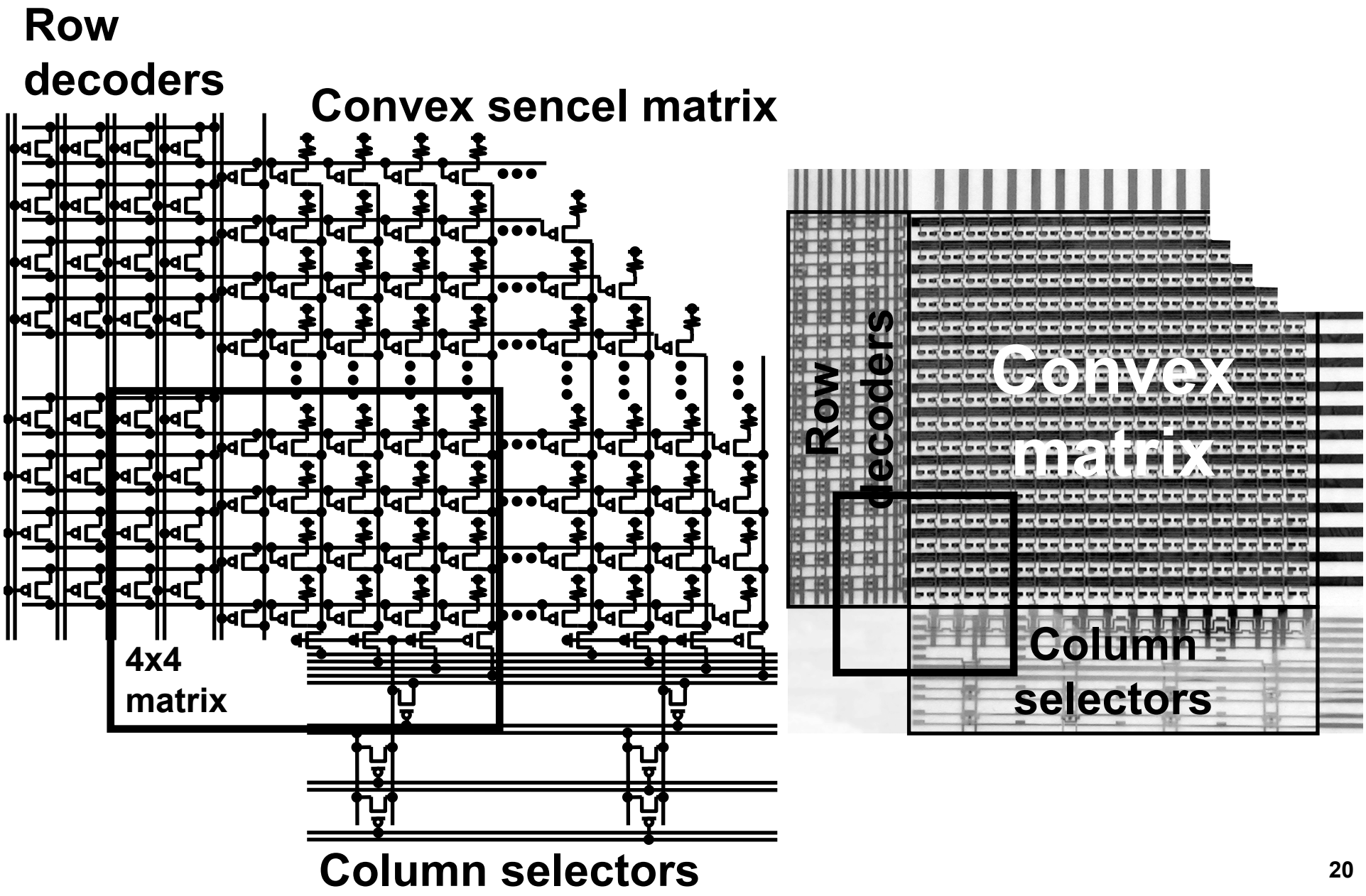


- Connects sheet to sheet
- PET film with 0.1-inch pitch Au lines
- Silver paste

Cut-and-paste feature (16x16 sencels)



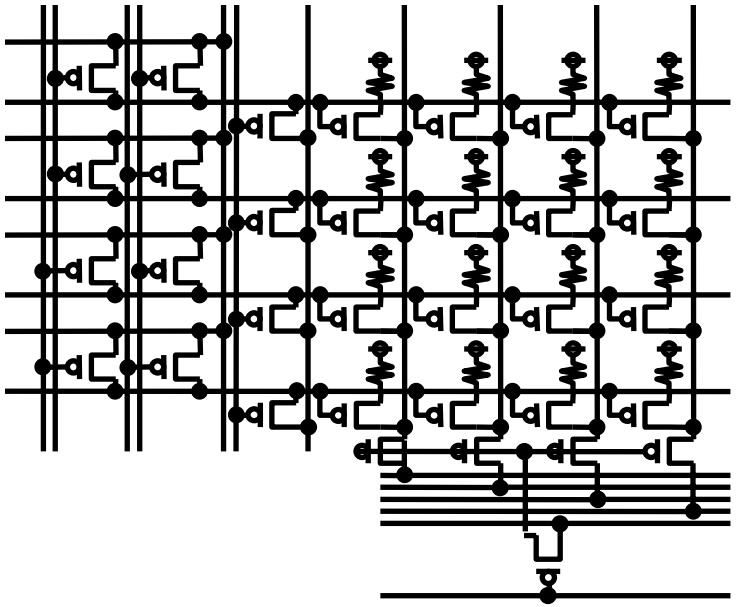
Cut-and-paste feature (convex shape)



Cut-and-paste feature (4x4 sencels)

Row decoders

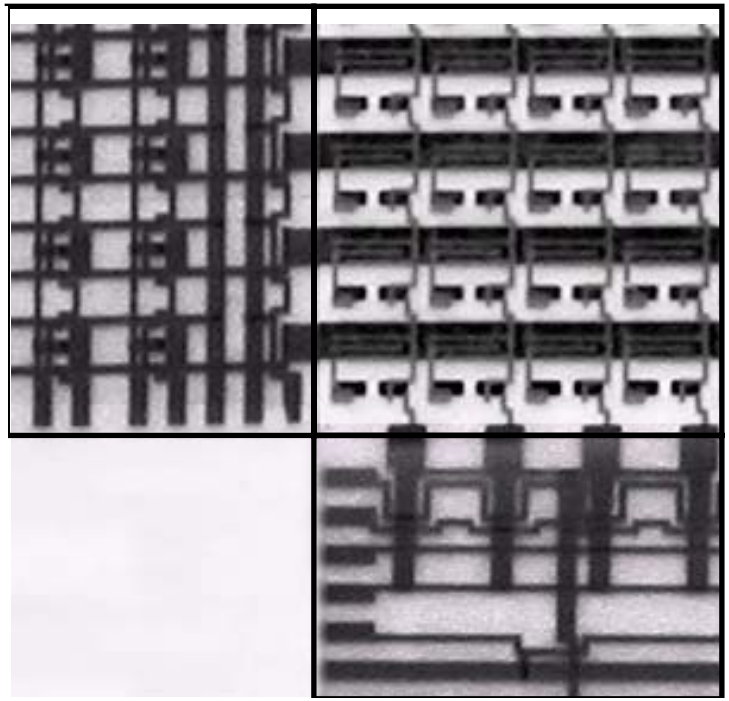
4x4 sencels



Column selectors

Row decoders

4x4 FET matrix



Results & discussion

- Introduction & motivation
- Manufacturing process
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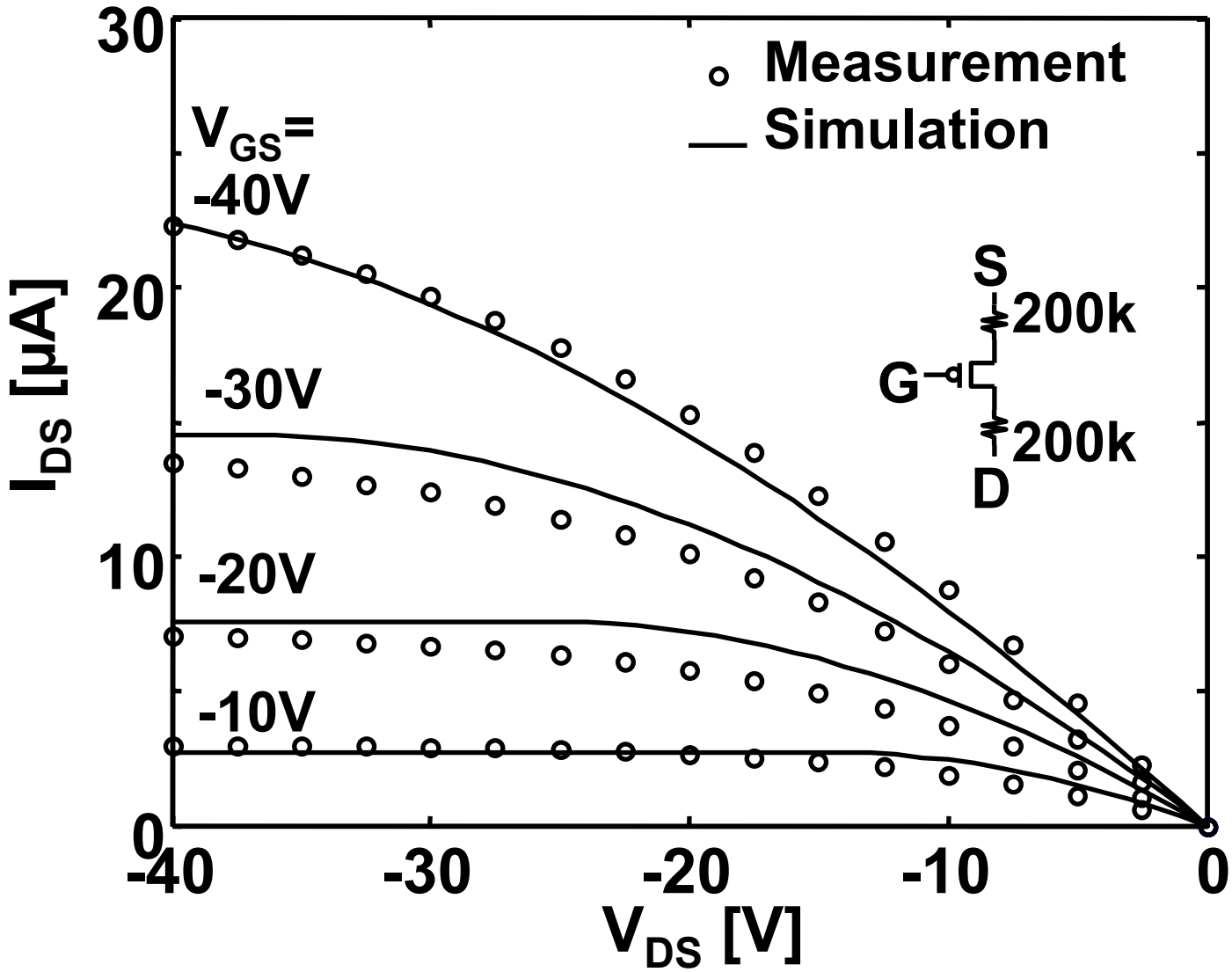
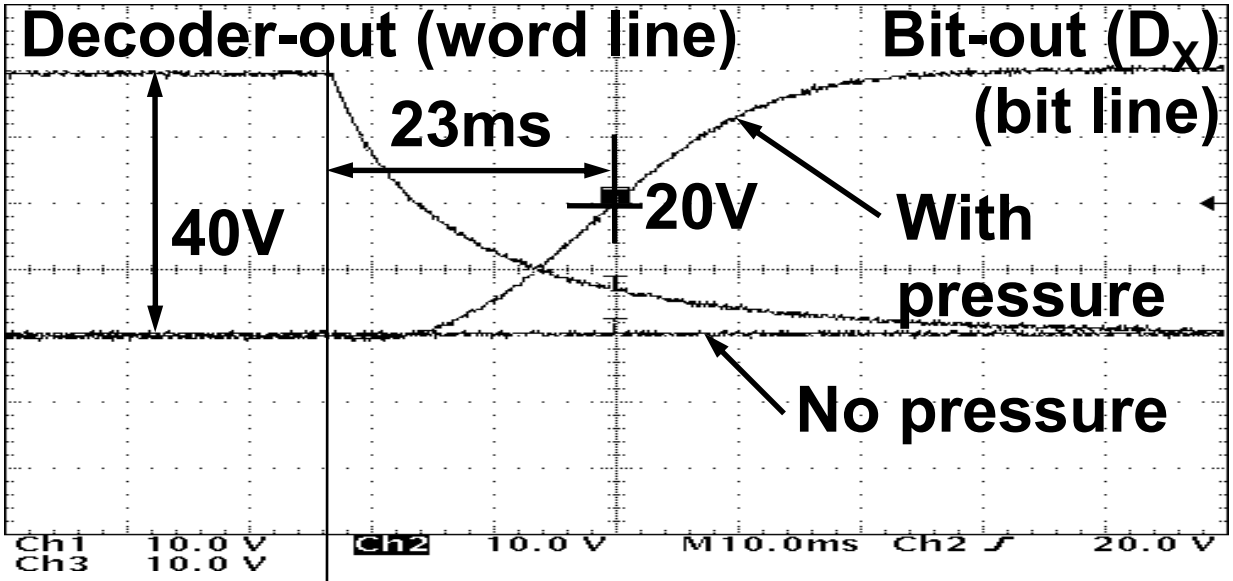
V_{DS}-I_{DS} characteristics

- Match level 1 SPICE MOS model with 200kΩ

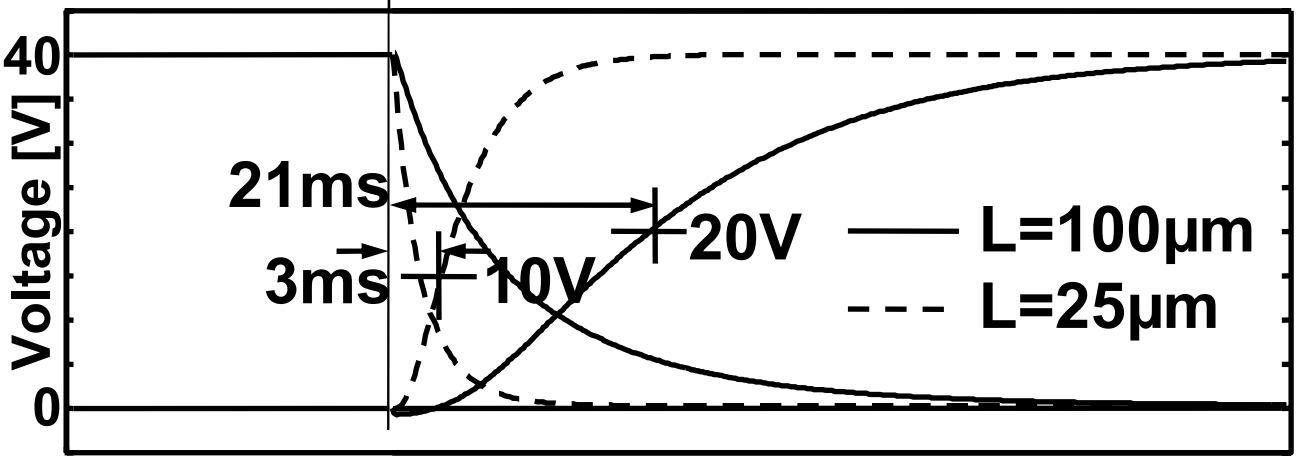


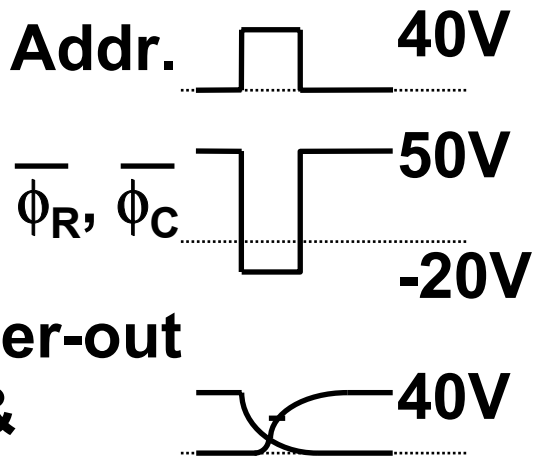
L=100μm
W=2mm

Measured & simulated waveforms



- Access time: 23ms
- Cycle time: 30ms





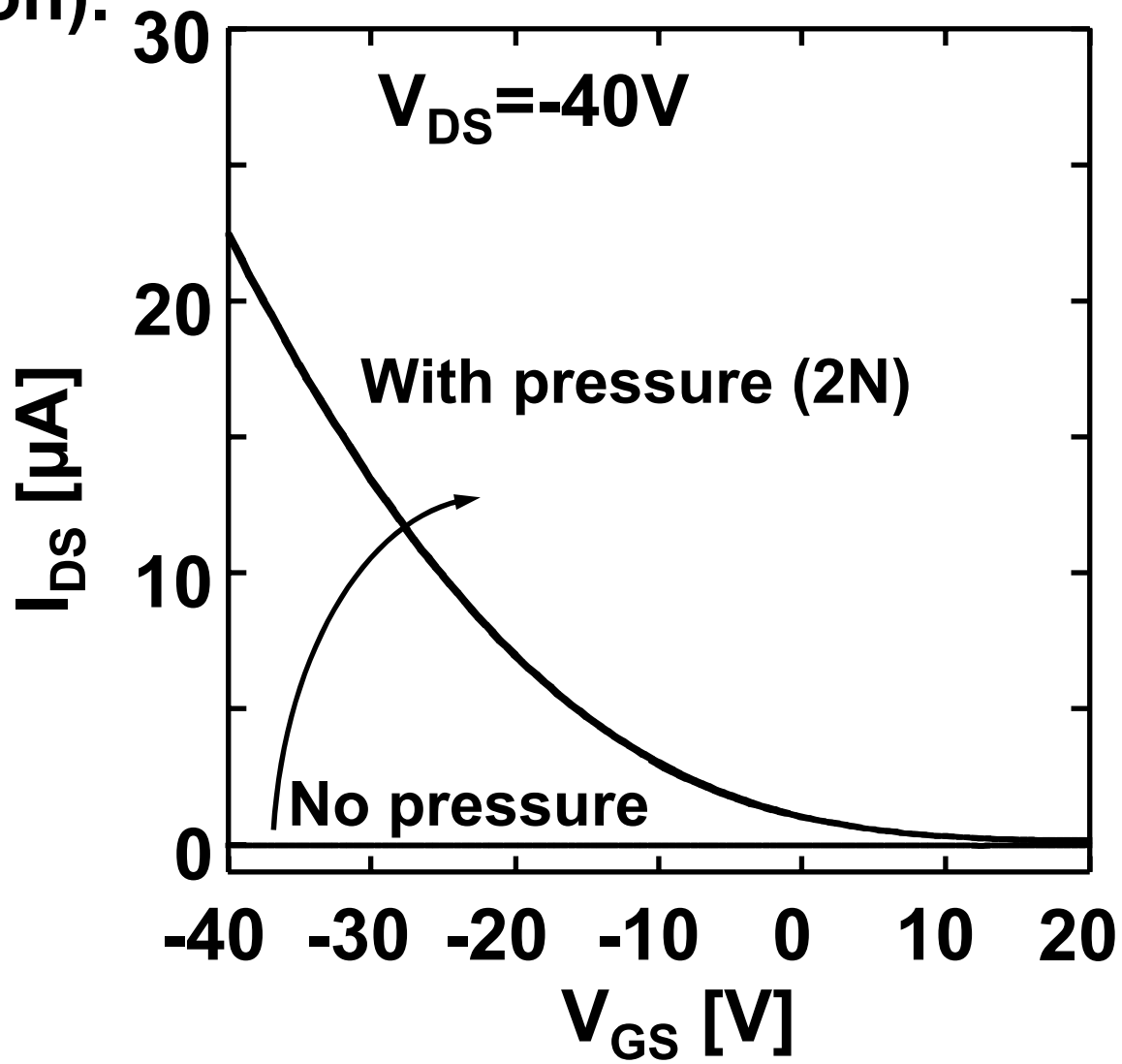
Sheet scan:

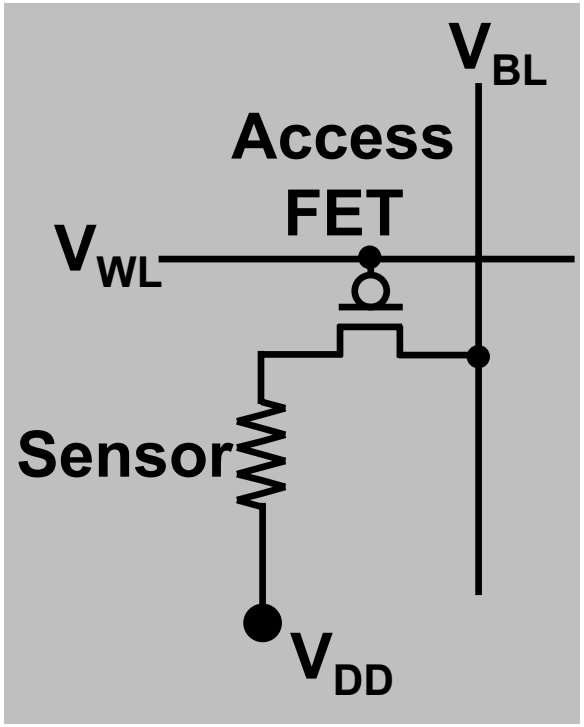
30ms x 16 x 4 = 2s @L=100µm

4ms x 16 x 4 = 0.25s @L=25µm

I_{DS} dependence on pressure

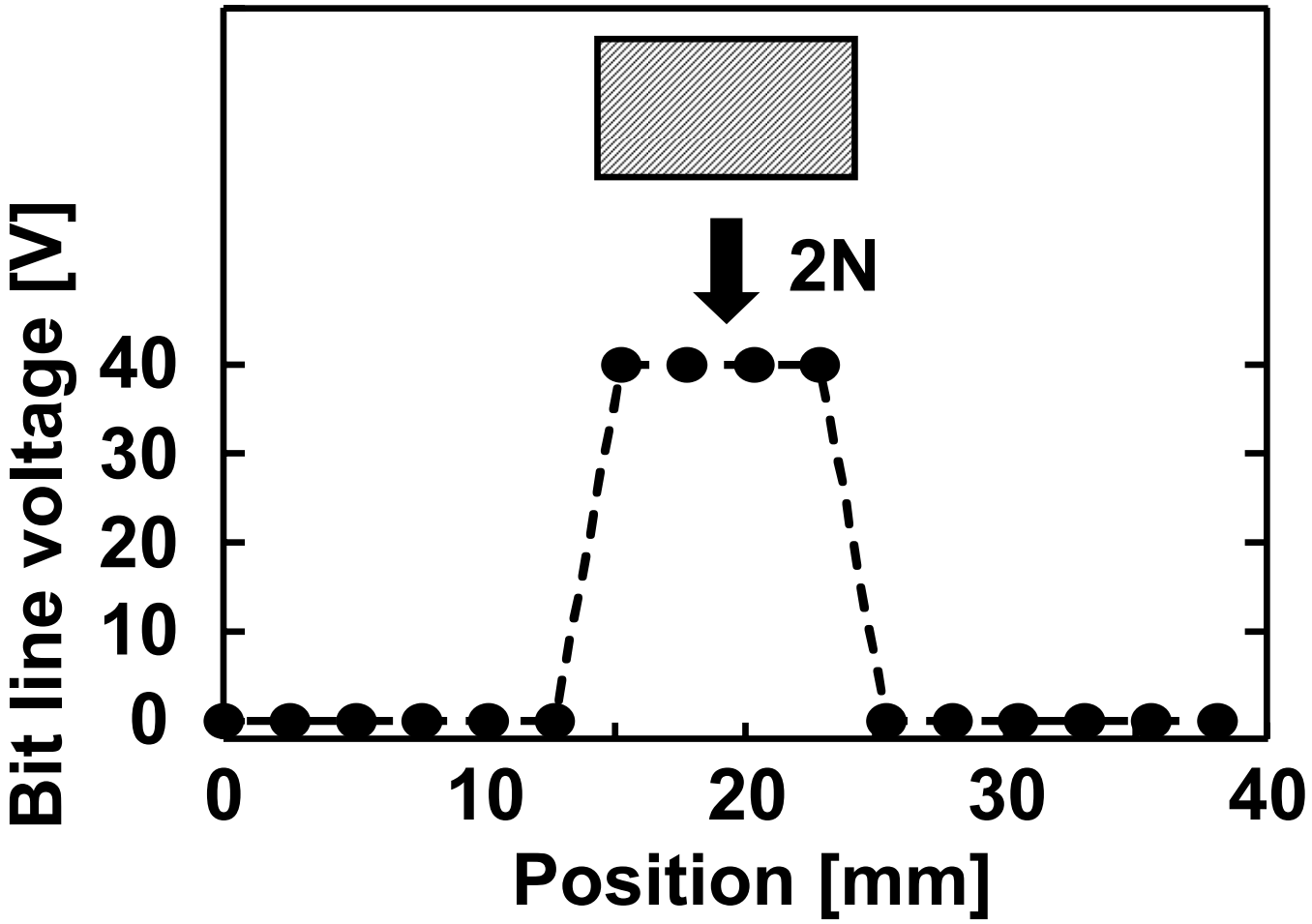
- Resistance changes between 10MΩ (off) & 1kΩ (on).





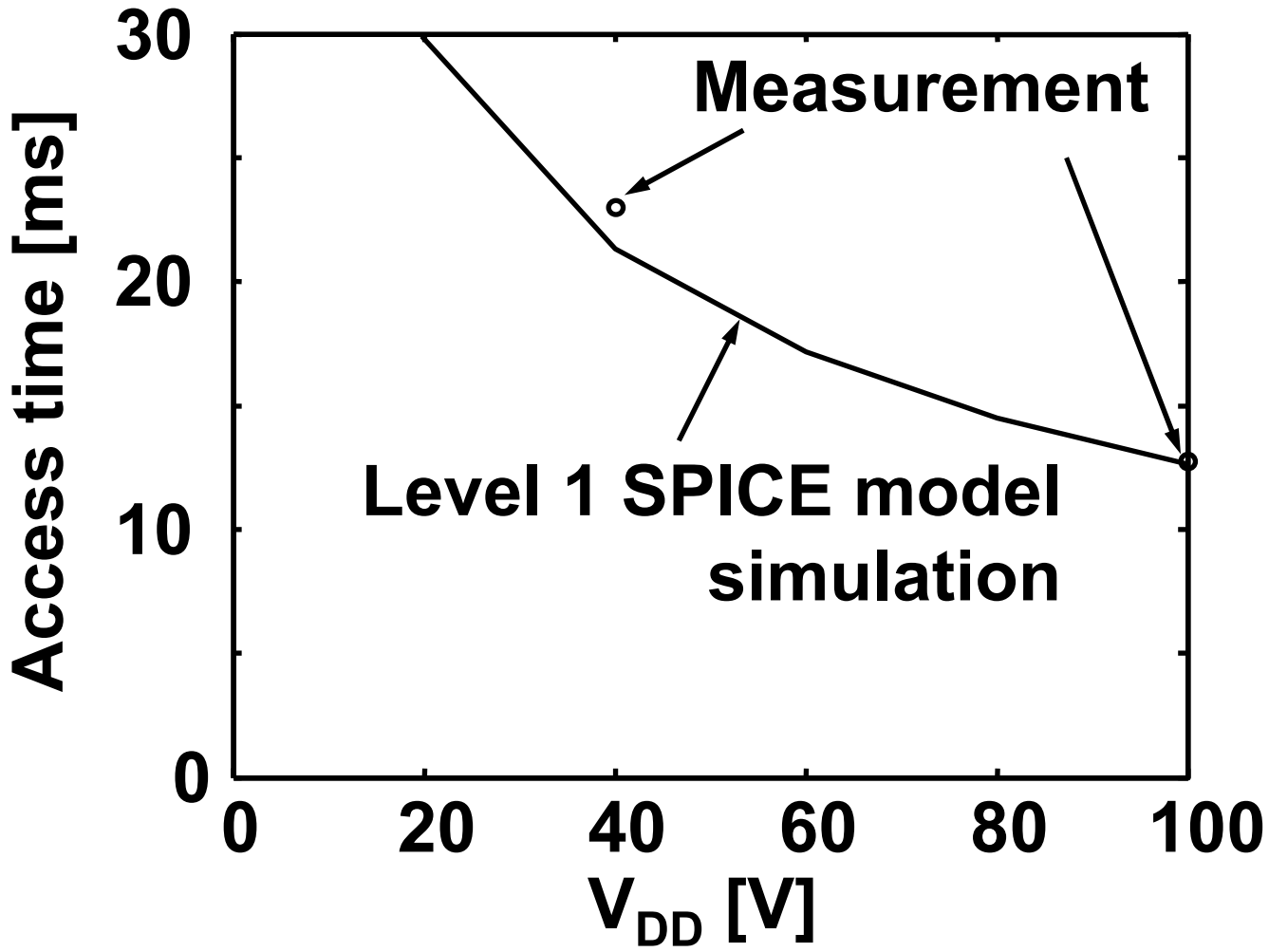
Bit-out when pressed

- Pressed sencel pulls bit line up to V_{DD}.



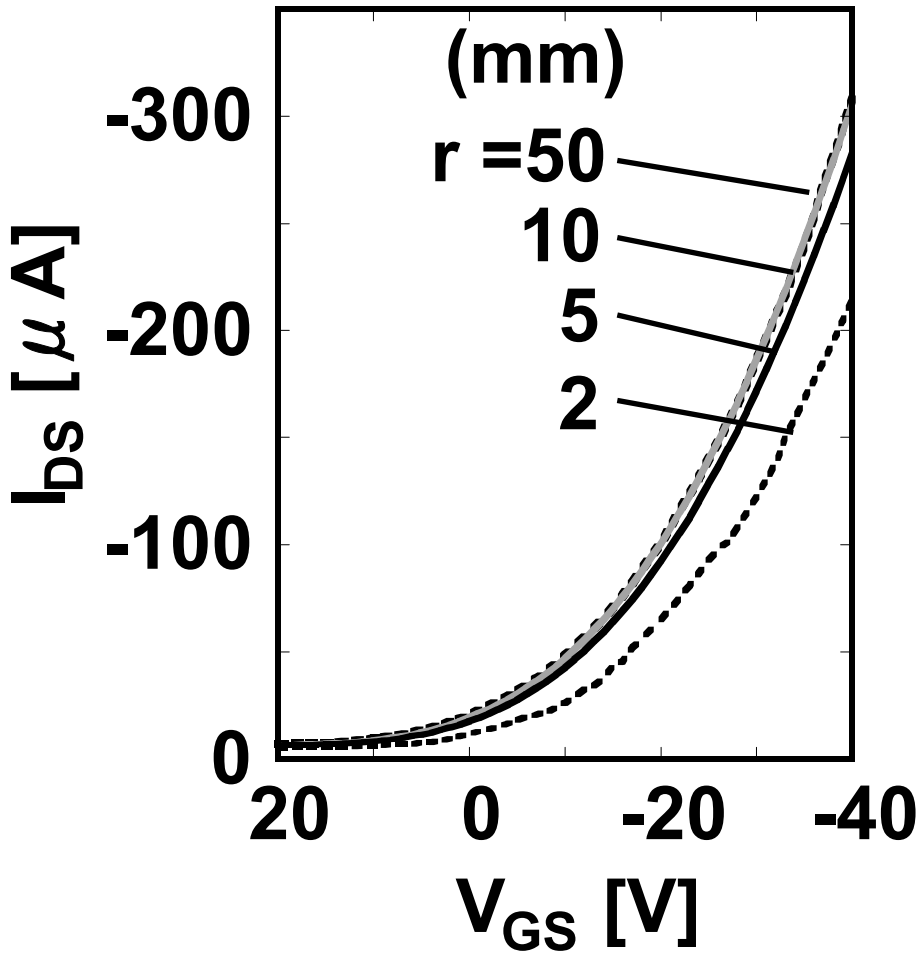
Access time dependence on V_{DD}

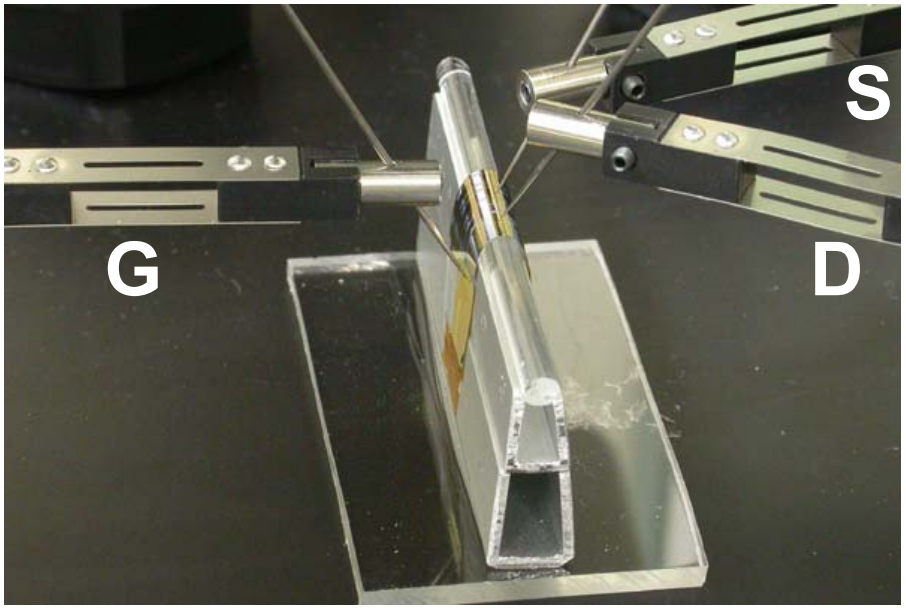
- Access time reduces to half @100V V_{DD}.
- Simulation agrees with measurement.

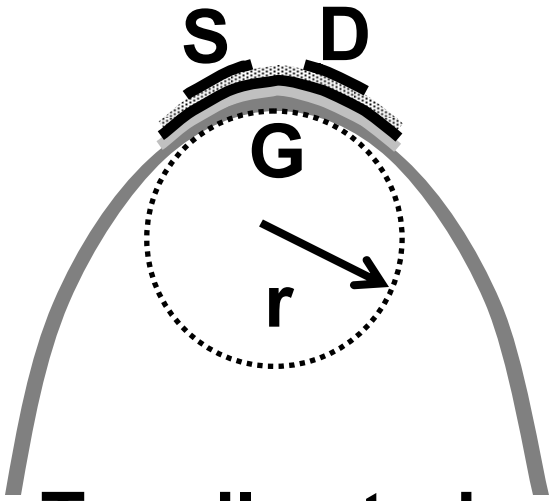


Bending test

L=50 μ m, W=16mm
V_{DS}= - 40V







Tensile strain

Remaining issues

- **Enhancing reliability and stability**
  - **Current lifetime: days → months, years**

    Encapsulation
  - **Initial transistor yield > 99% for $t_{insulator}$=500 nm**

- **Lowering operation voltage**
  - **Currently 40V → <10V**

    Shorter L

    Thinner insulator

    High-k

Summary

- An electronic artificial skin system
  - A large-area pressure sensor matrix
  - Column selectors and row decoders
  - Laser via process for circuit implementation
- Cut-and-paste customization
- Mechanical flexibility down to r=5 mm
- 23 ms delay for read-out