Organic-Transistor Based Systems and Platforms

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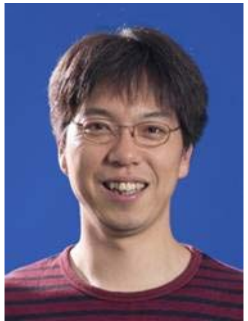
Outline

- **Organic transistor based systems**
  - **Large-area electronics applications**
  - **Bio-compatible applications**
- **Other nano-electronics devices**
- **What is lacking : platform for systems**

Acknowledgement (organic FET part)

Circuits and systems design

T. Sakurai



H. Kawaguchi

M. Takamiya

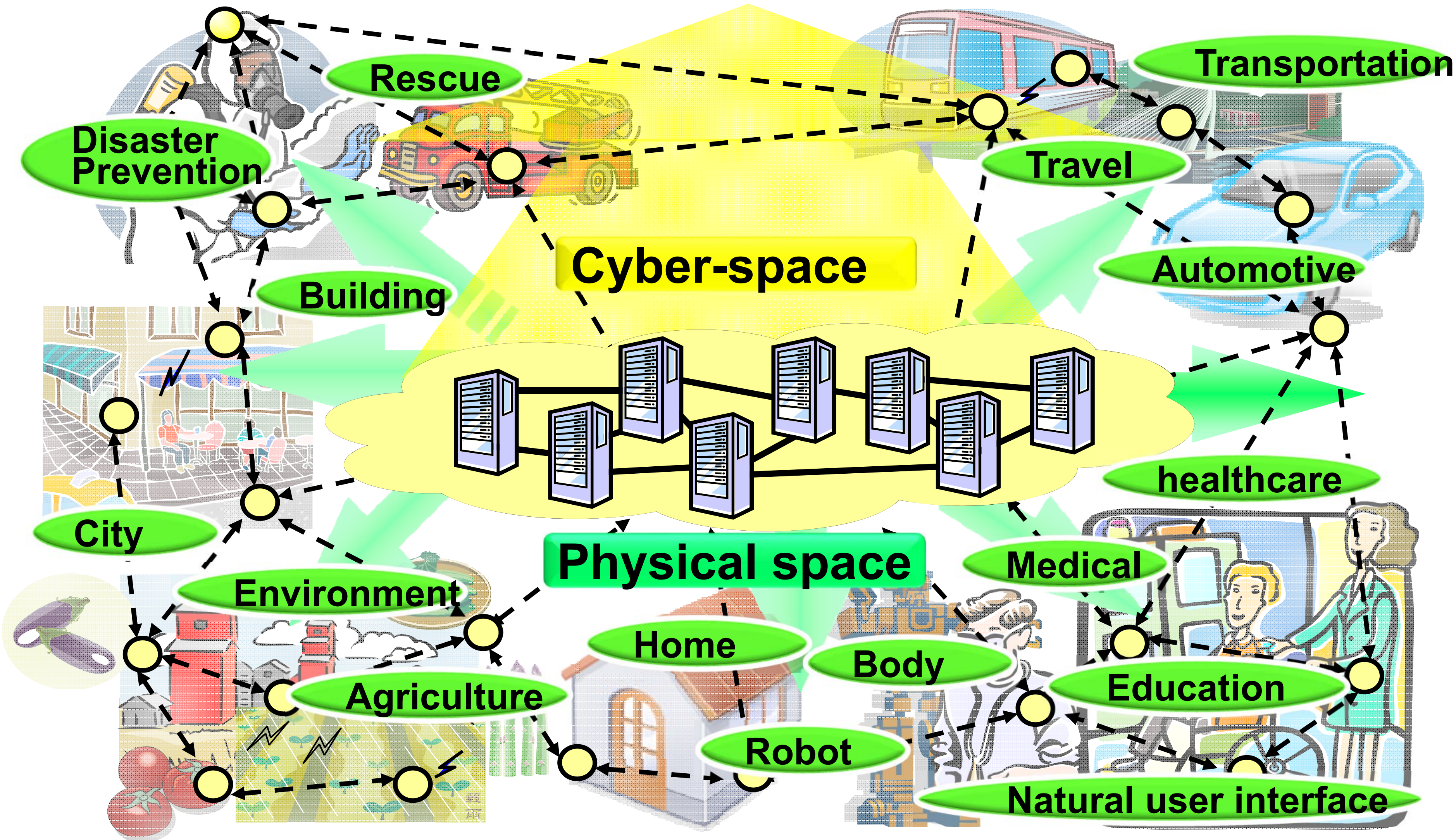
K. Ishida

H. Fuketa

Process and device technologies (team Someya)

Electronics to support people's life

Organic electronics: more physical-space apps



IoT, IoE, CPS, M2M, Ambient, Swarm, whatever you name it

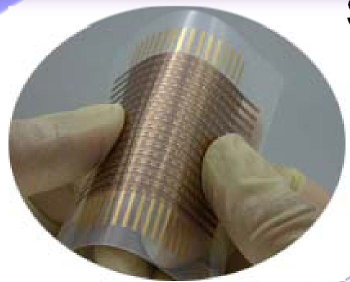
T.Sakurai

Flexible organic electronics

Samsung

Sony

Gyricon



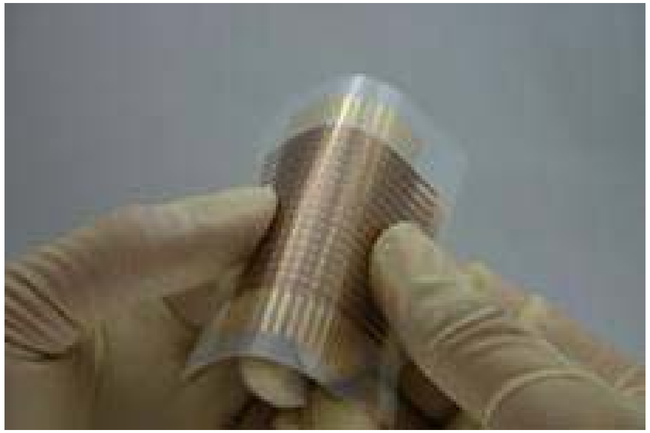
OSRAM

University of Tokyo

Pioneer

T.Sakurai

Organic transistor

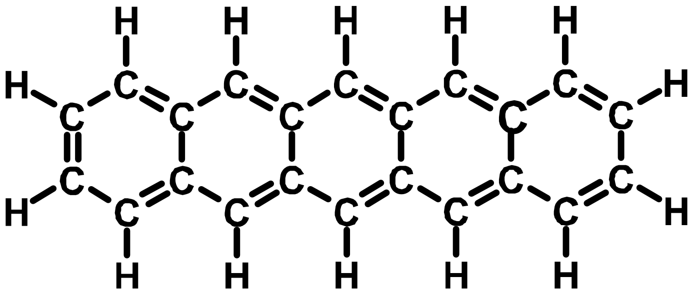


- **Advantages**
  - Low-cost manufacturing for large area
    - (Cost per transistor > 10^4 of Si)
  - Mechanical flexibility

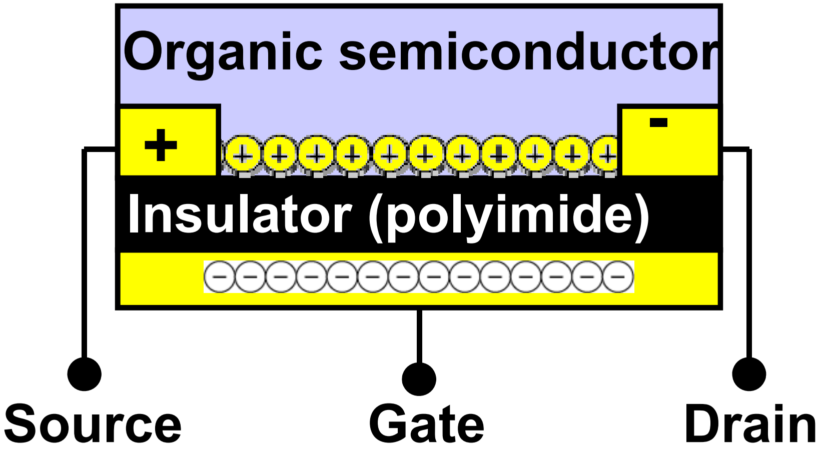
- **Disadvantages**
  - Low density (<10^{-4} of Si: 10nm vs 10μm)
  - Low speed (<10^{-4} of Si: 100GHz vs kHz)

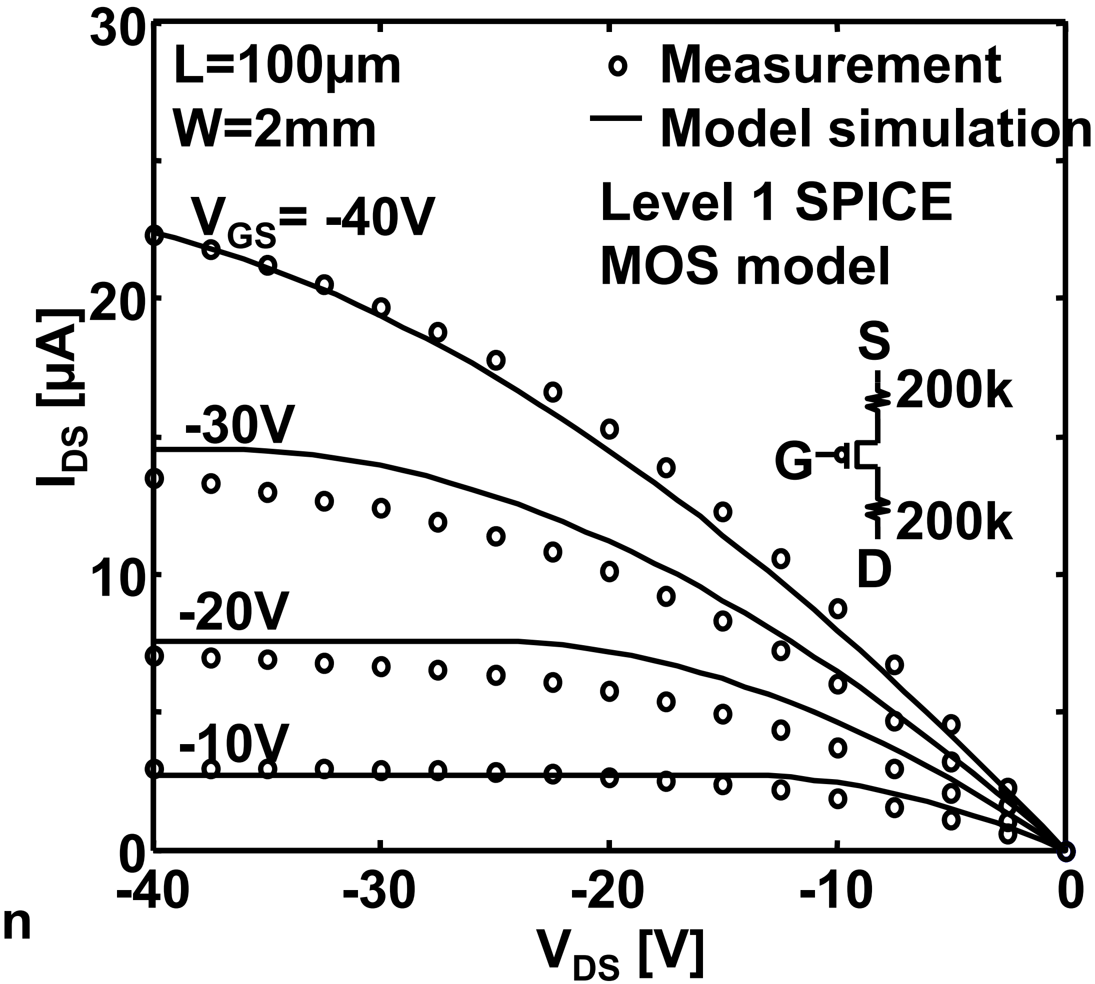
V_{DS}-I_{DS} characteristics

Modeled by level 1 SPICE MOS model with 200kΩ



Pentacene (PMOS)

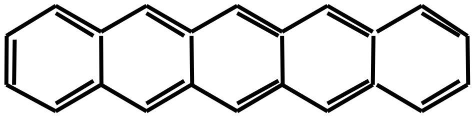




Cadence layout tools

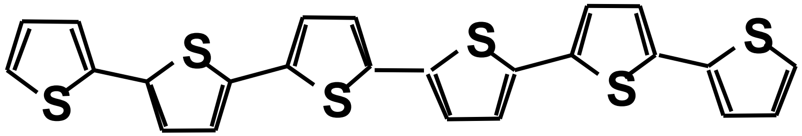
Organic semiconductors

P-type: low molecular weight

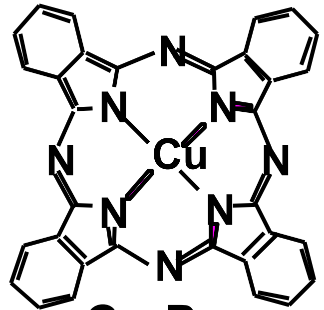


Pentacene
(stable and high mobility)

1 cm²/Vs

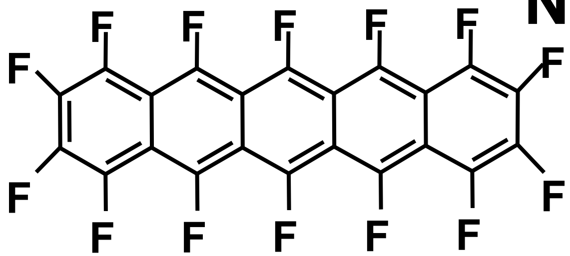


α -6T



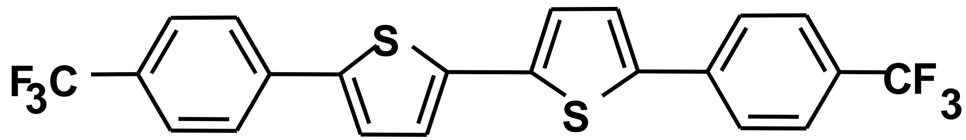
Cu-Pc

N-type: low molecular weight



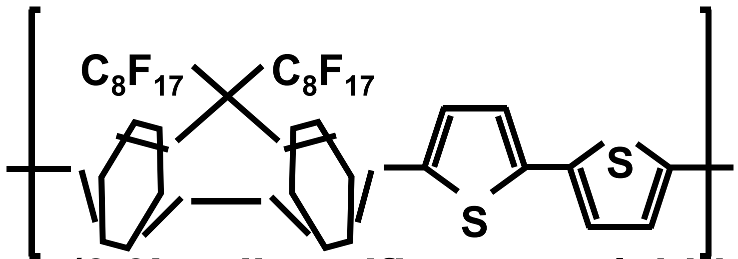
0.7cm²/Vs

perfluoropentacene



trifluoromethylphenyl groups

Polymer: soluble



0.02 cm²/Vs

poly(9,9'-*n*-dioctylfluorene-*alt*-bithiophene) (F8T2)

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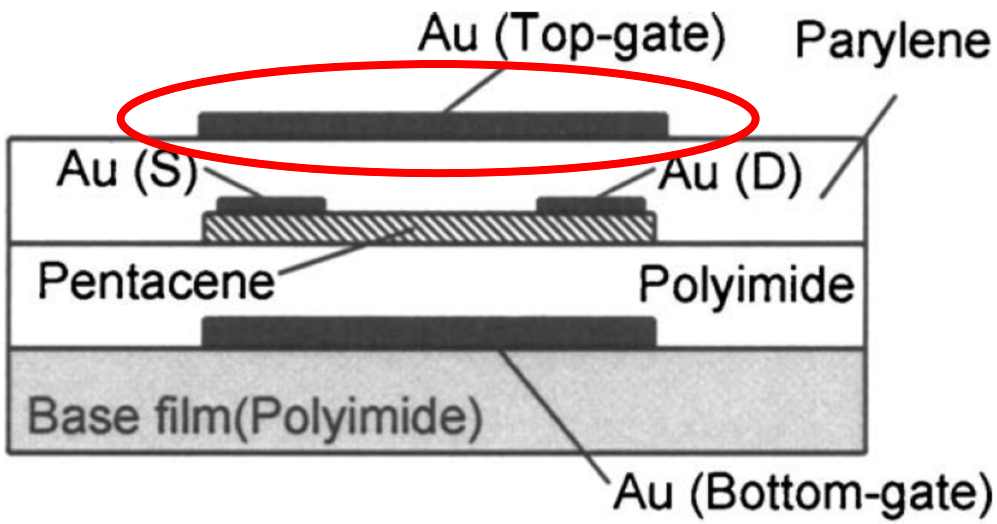
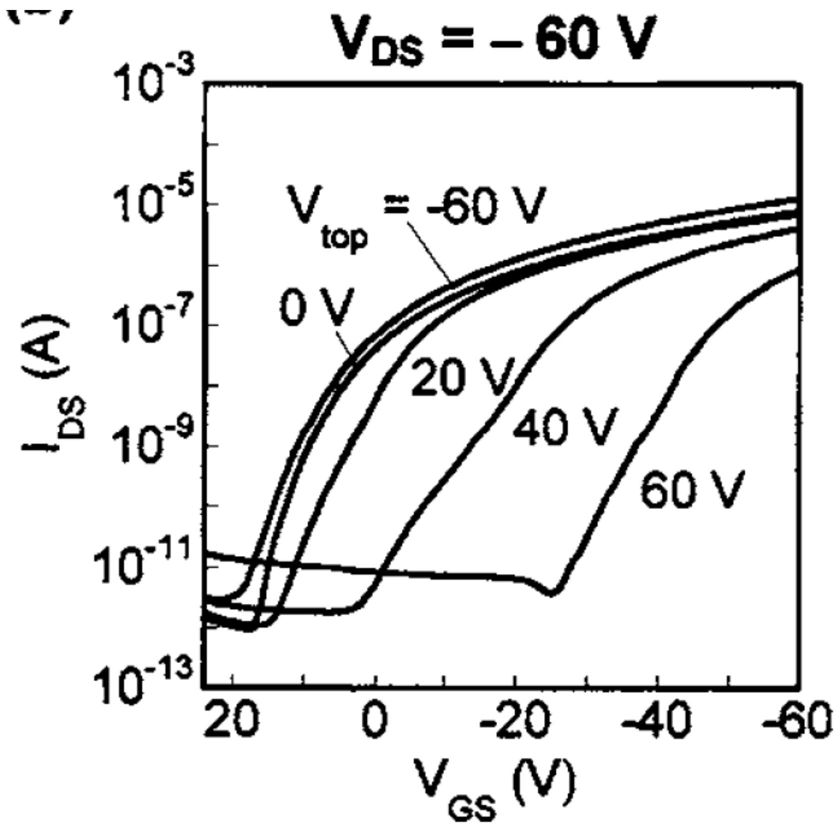
Double-gate OFET and control of V_{TH}

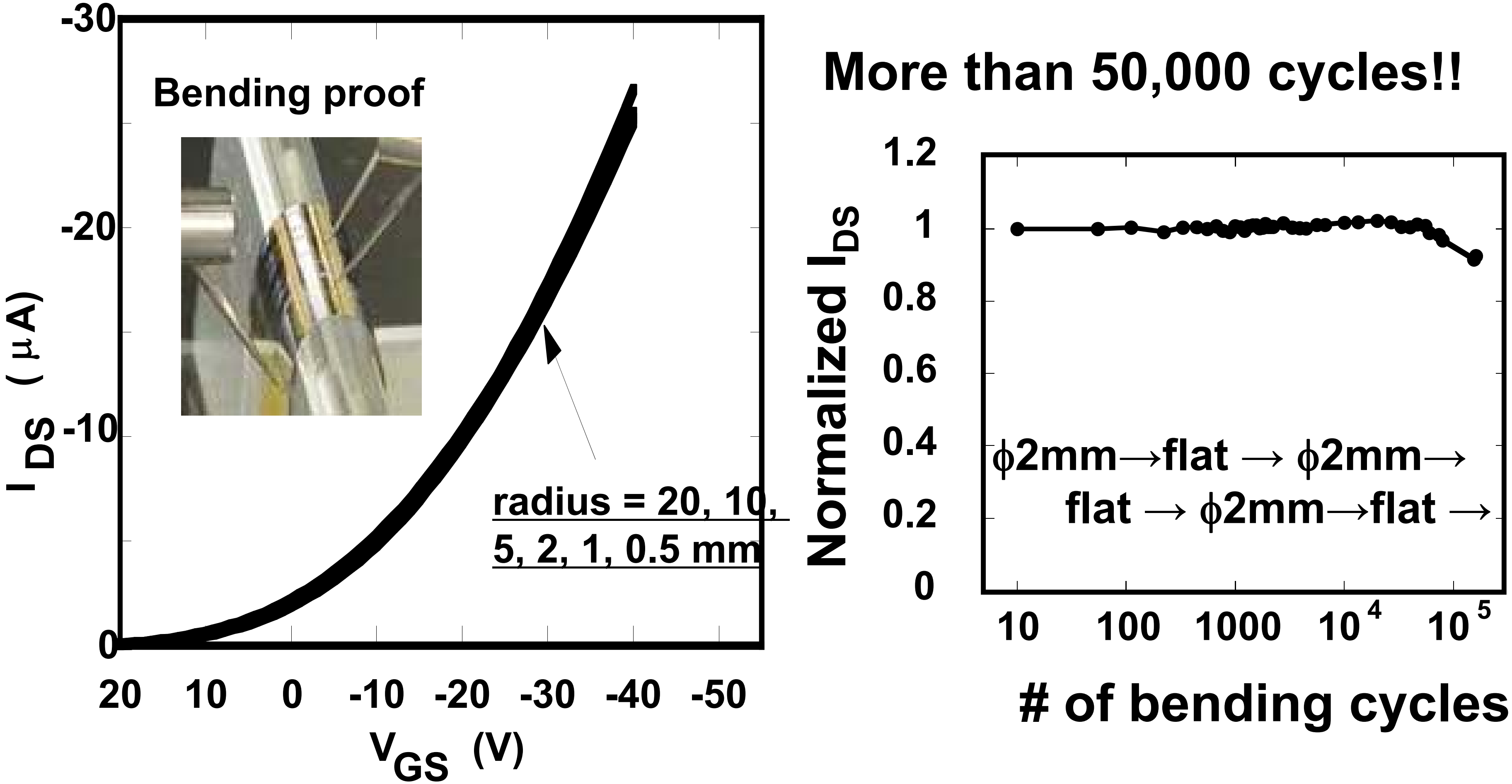




By adding one more gate, V_{TH} can be controlled.

S.Iba,T.Sekitani,Y.Kato,T.Someya, S.Takagi, H.Kawaguchi, M.Takamiya, T.Sakurai, "Control of threshold voltage of organic field-effect transistors with double-gate structures," Applied Physics Letters 87,023509, 2005.

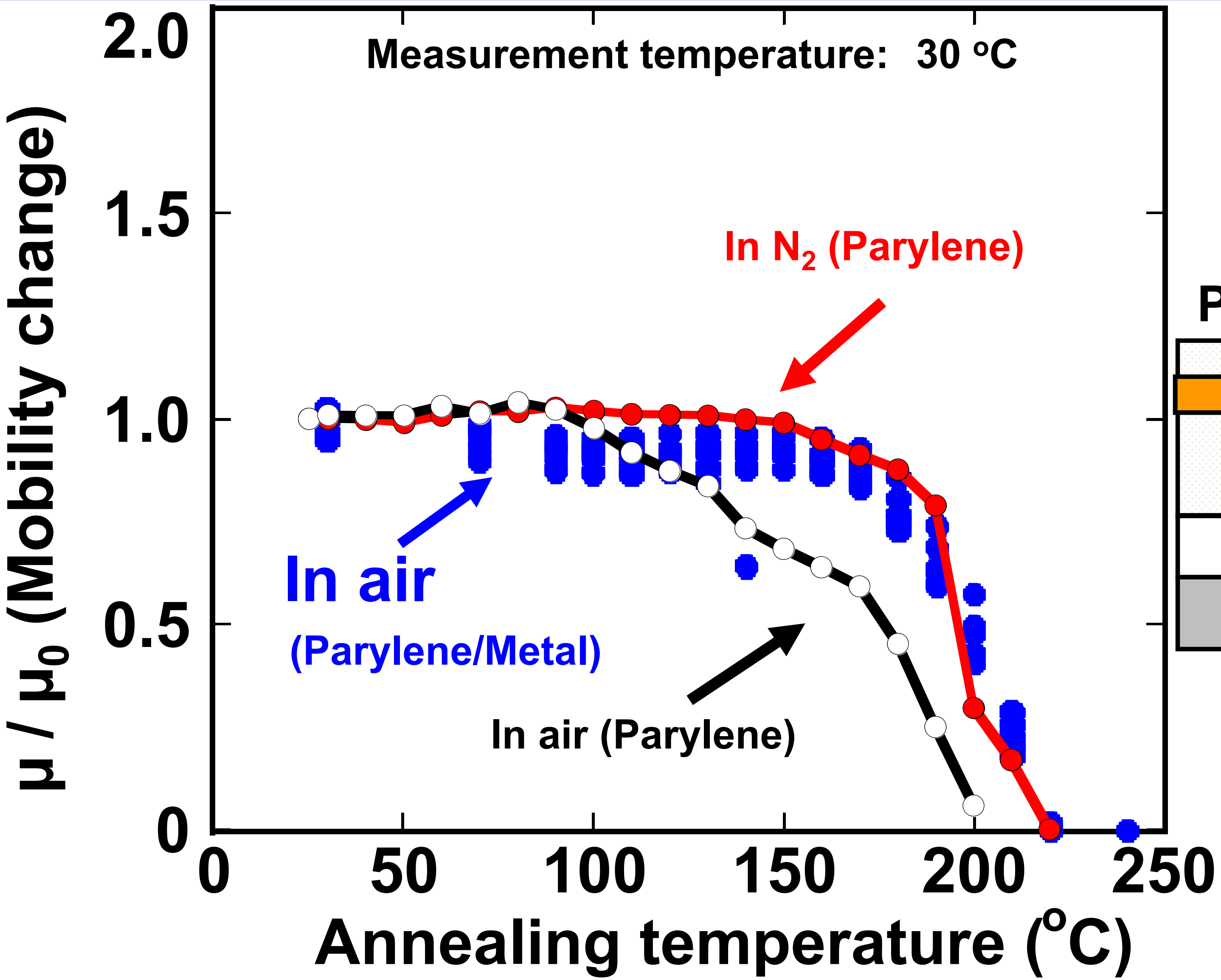
Bending proof

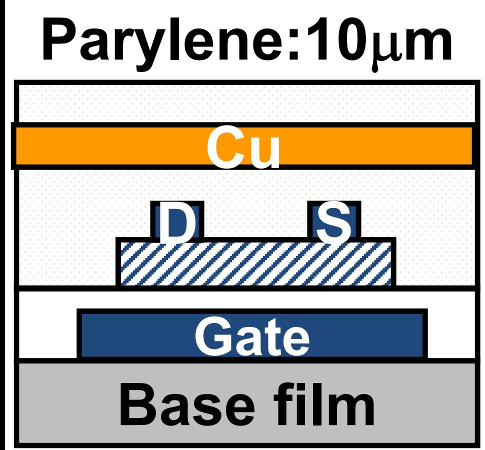


Less than 3% of I_{DS} change for bending over 0.5mm radius

No I_{DS} change for 50k cycles of bending & flattening

Heat cycles





Up to 150°C with good encapsulation

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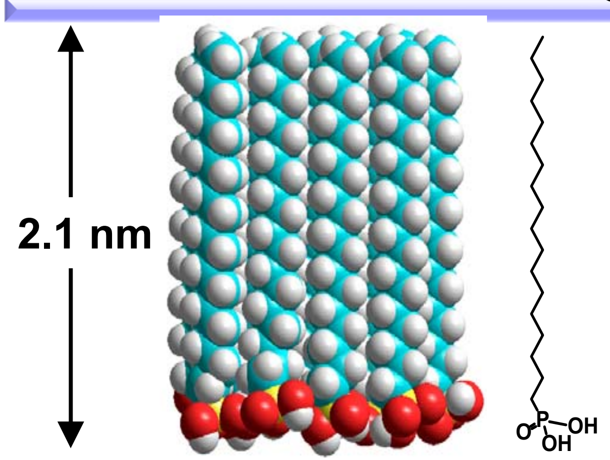
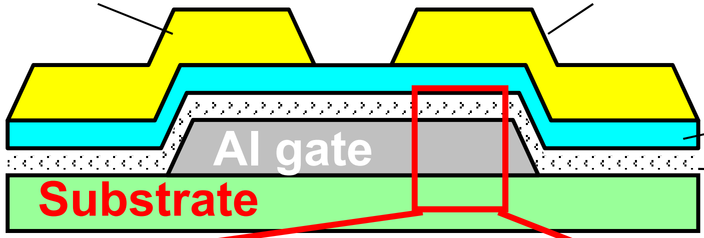
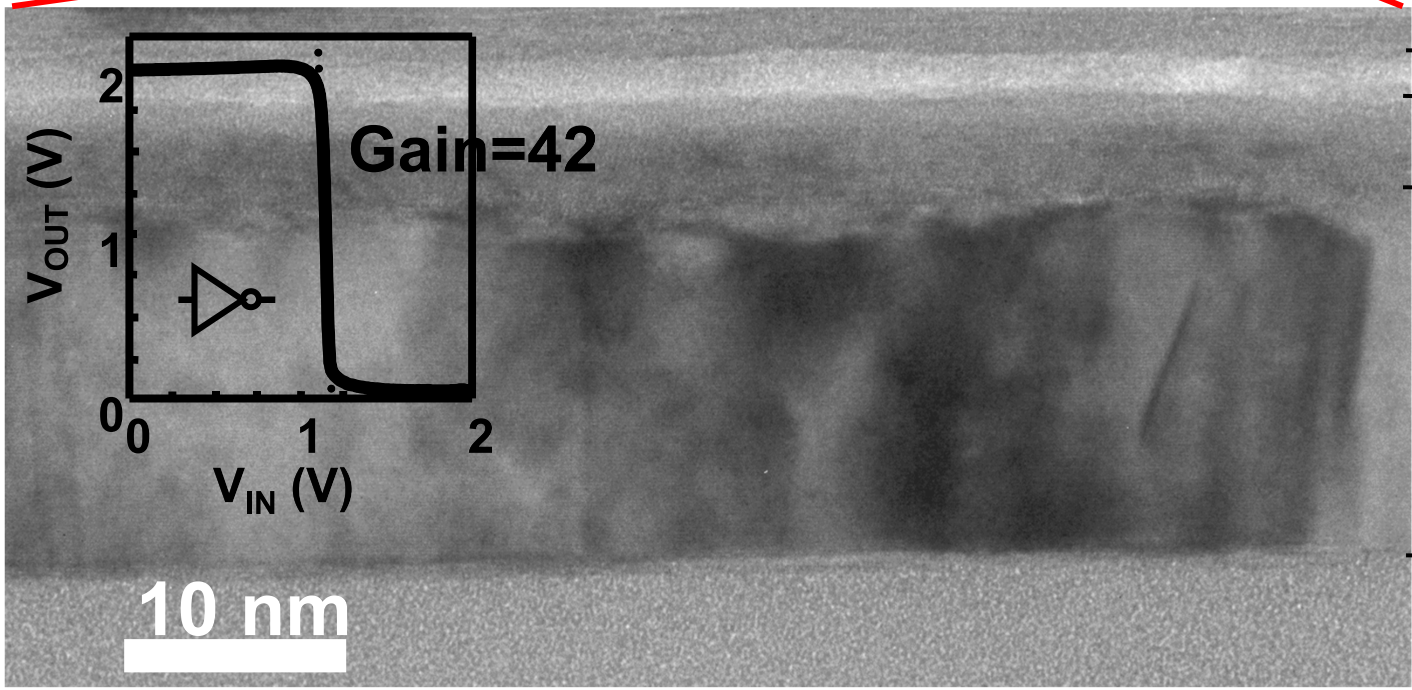
Organic TFTs with SAM





T.Someya with Hitach Hitech Ltd.

Pentacene (pMOS)
$F_{16}CuPc$ (nMOS)
SAM (2 nm)



Pentacene
SAM (2 nm)
AlO_x (4 nm)
Al (18 nm)
Substrate

* SAM: Phosphonic acid-based self-assembled monolayers T.Sakurai

Technical advances in organic circuits

Year ISSCC	Target	FET	VDD	New technology	New circuits
2004	e-Skin	PMOS	40V	FET on plastic	Active matrix
2005	Scanner Sheet	PMOS	40V	Photo-diode	Logic Double WL/BL
2006	Braille Sheet	PMOS	40V	Double gate Arti. mussle	SRAM Adaptive VTH
2007	Wireless Power	PMOS	40V	Plastic MEMS	Diff. amp. Level shifter
2008	Comm. Sheet	PMOS	30V	NVRAM	Organic +Si LSI
2009	EMI Furoshiki	CMOS	2V	SAM Stretch wire	OTFT+Si MOS Direct connect
2010	FPGA paper	CMOS	2V	Printing wire	FPGA arch.

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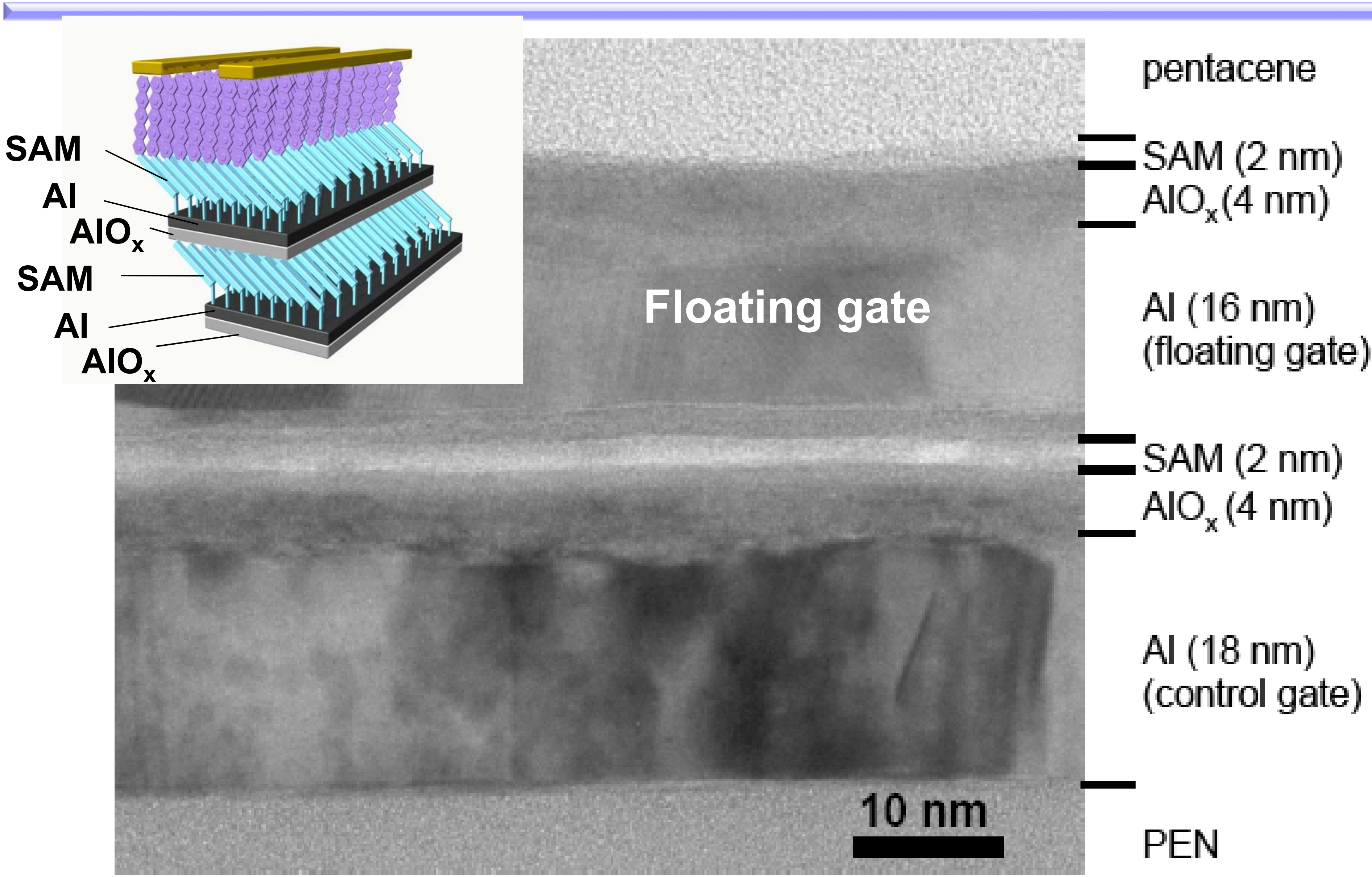
Non-volatile memory using double SAM gates



T.Someya: IEDM'09

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Organic FETs (OFETs) vs. Silicon

	Organic FETs	Si MOSFETs
Minimum gate length	20 μm	45 nm
Mechanical flexibility	Flexible, thin & stretchable	Very limited
Normalized ON current	3 nA / μm @ 3 V	1 mA / μm @ 1 V
Gate delay	0.1 s @ 3 V	10 ps @ 1 V
Cost / area	Low	High
Cost / transistor	High	Low
Lifetime	Months	Years

- Large-area electronics
- Bio-compatible applications

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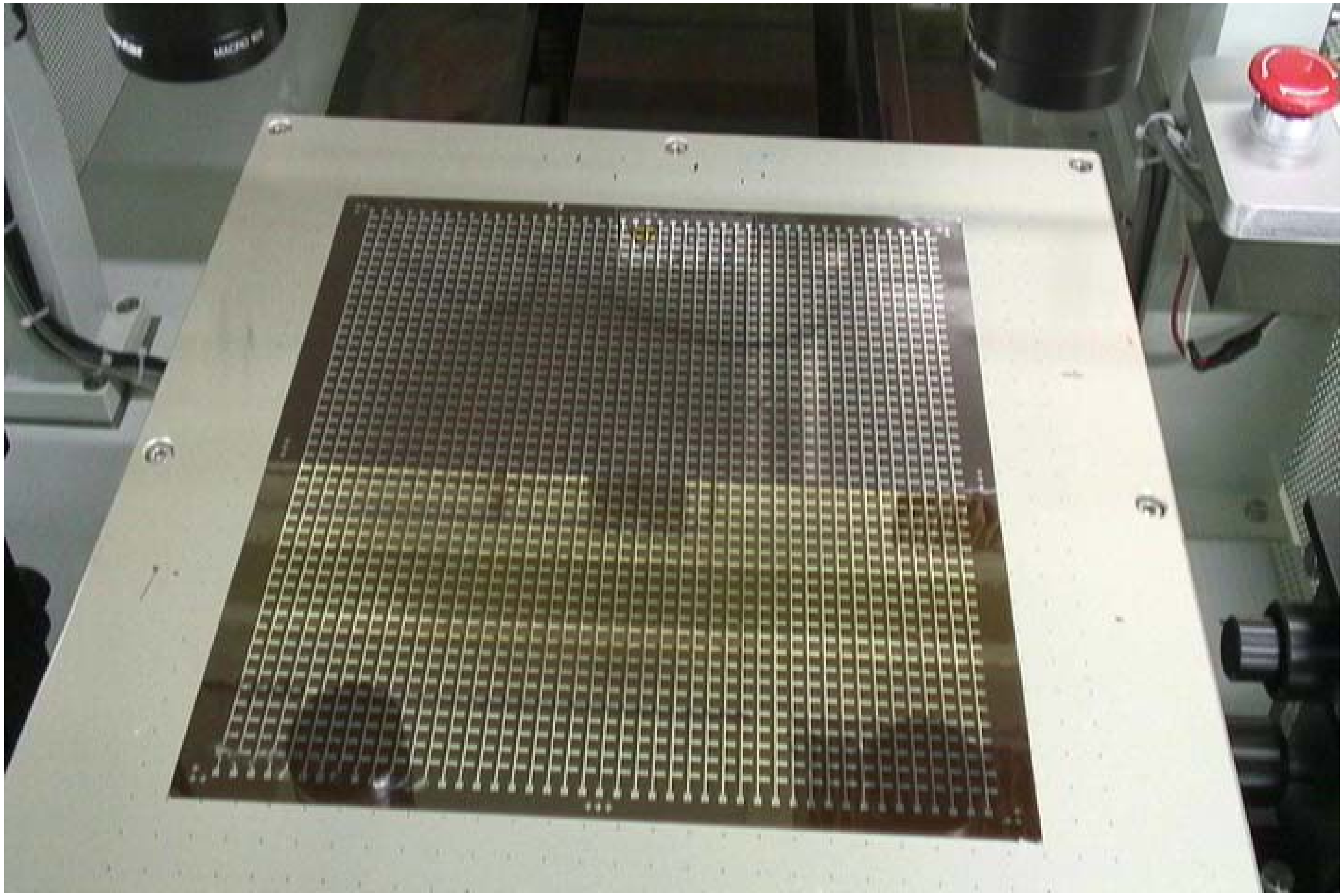
Unique manufacturing process: Printing large-area organic transistor array

Manufacturing process

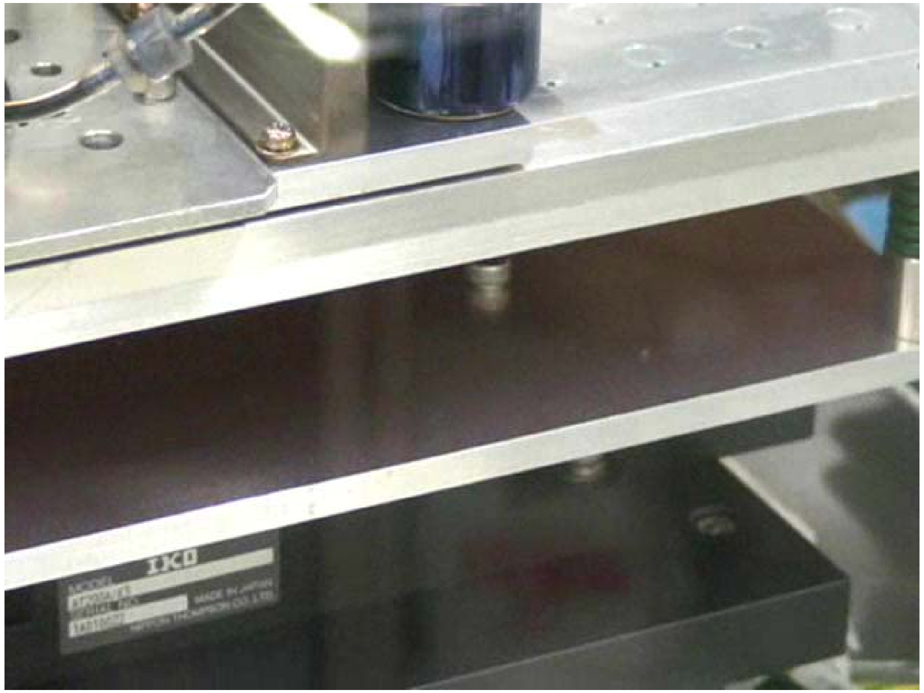
Printable electronics

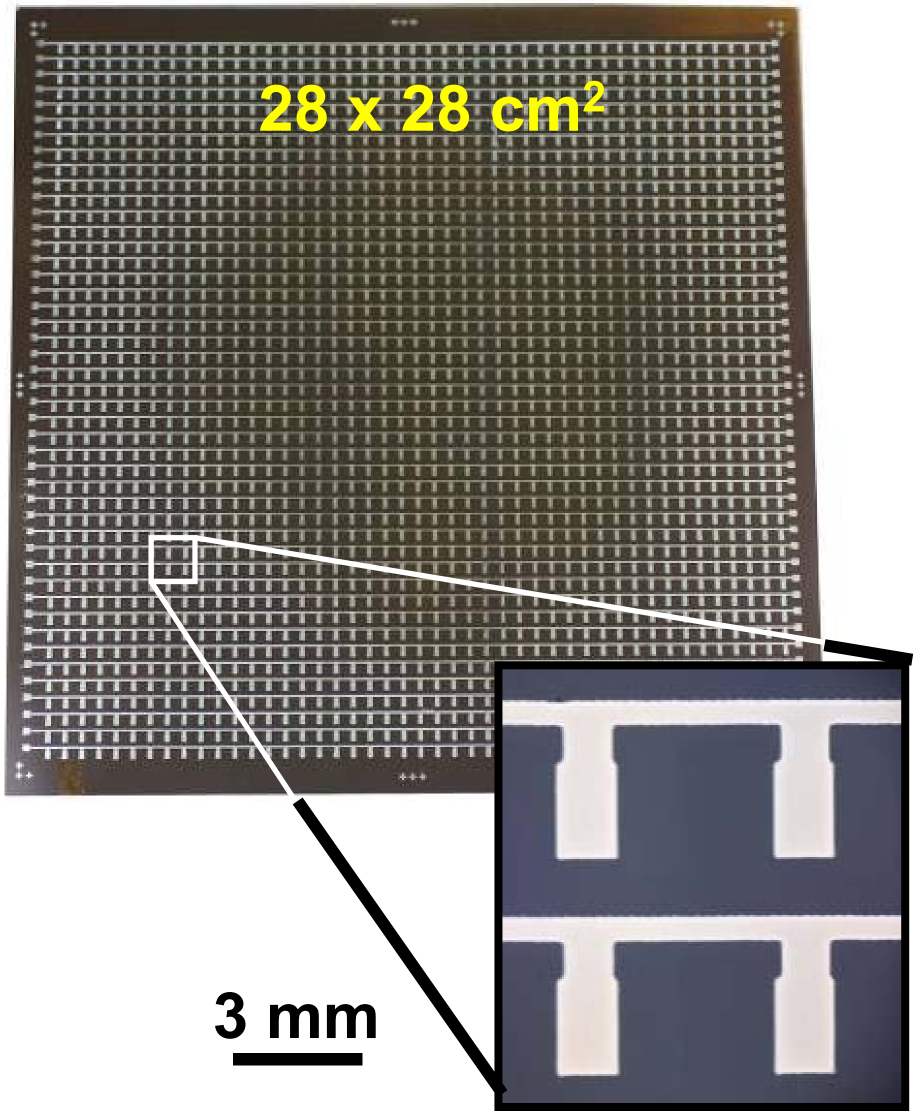
Screen printing



Inkjet printing

Gate electrodes & Word line





Gate electrodes : 45 x 45
Word line : 45 lines

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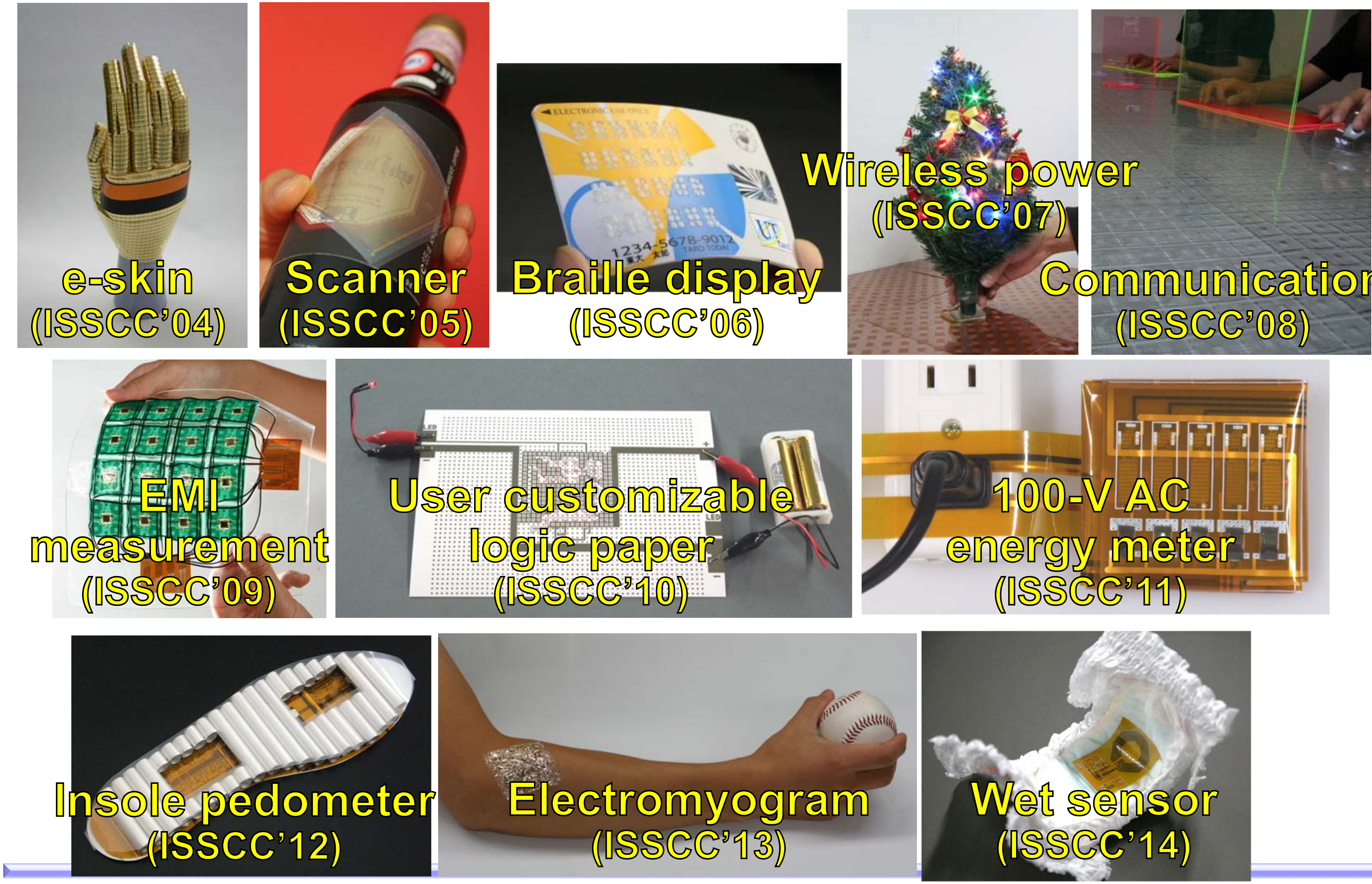
Examples of organic circuits & systems

Large-Area OFET Applications



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Large-area electronics

Human-scale interfaces

E-skin — IEDM'03 / ISSCC'04 — Pressure sensors + OFETs

Sheet scanner — IEDM'04 / ISSCC'05 — Photodetectors + OFETs

Braille display — IEDM'05 / ISSCC'06 — Actuators + OFETs

Power sheet — IEDM'06 / ISSCC'07 — Coils + MEMS + OFETs

Comm sheet — IEDM'07 / ISSCC'08 — Organics + Si co-design

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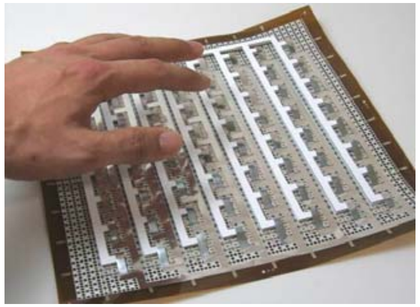
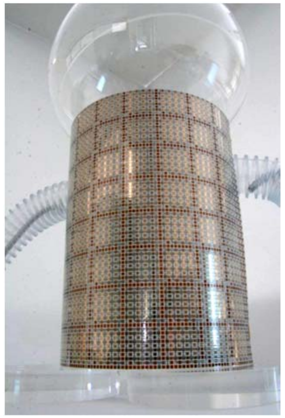
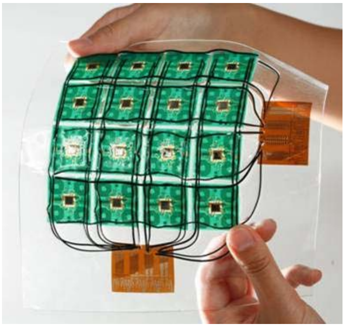
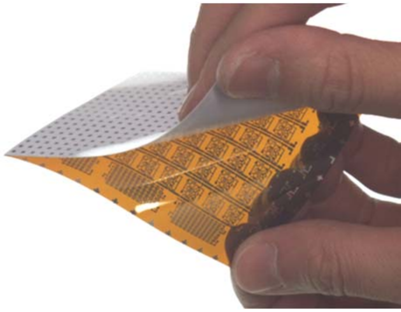
Large-area electronics

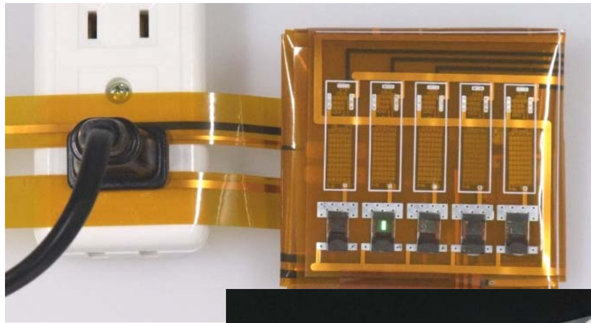
Human-scale interfaces

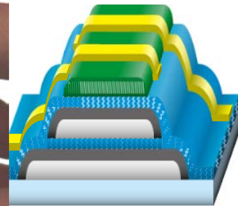












Hyper-skin — IEDM'08
Sheet-type ultrasonic sensing without touch

EMI Furoshiki — ISSCC'09
Org CMOS + Si CMOS direct communication

Organic FPGA — ISSCC'10
Manufacturing IC at home with printer

Power meter — ISSCC'11
System on a film

Energy Harvester — ISSCC'12
Energy harvesting

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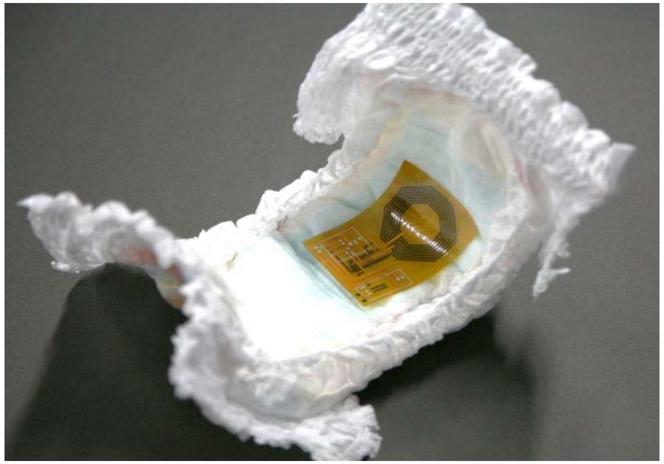
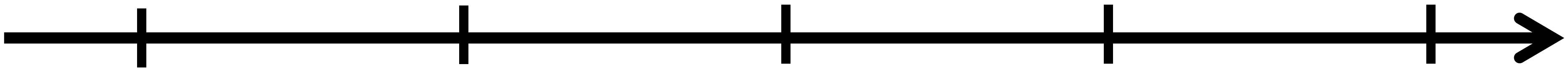
Large-area electronics



Electromyogram

Flexible bio-sensor



Solution for totally wireless System: energy, data, Sensor & ESD protection

Human vital data measurement

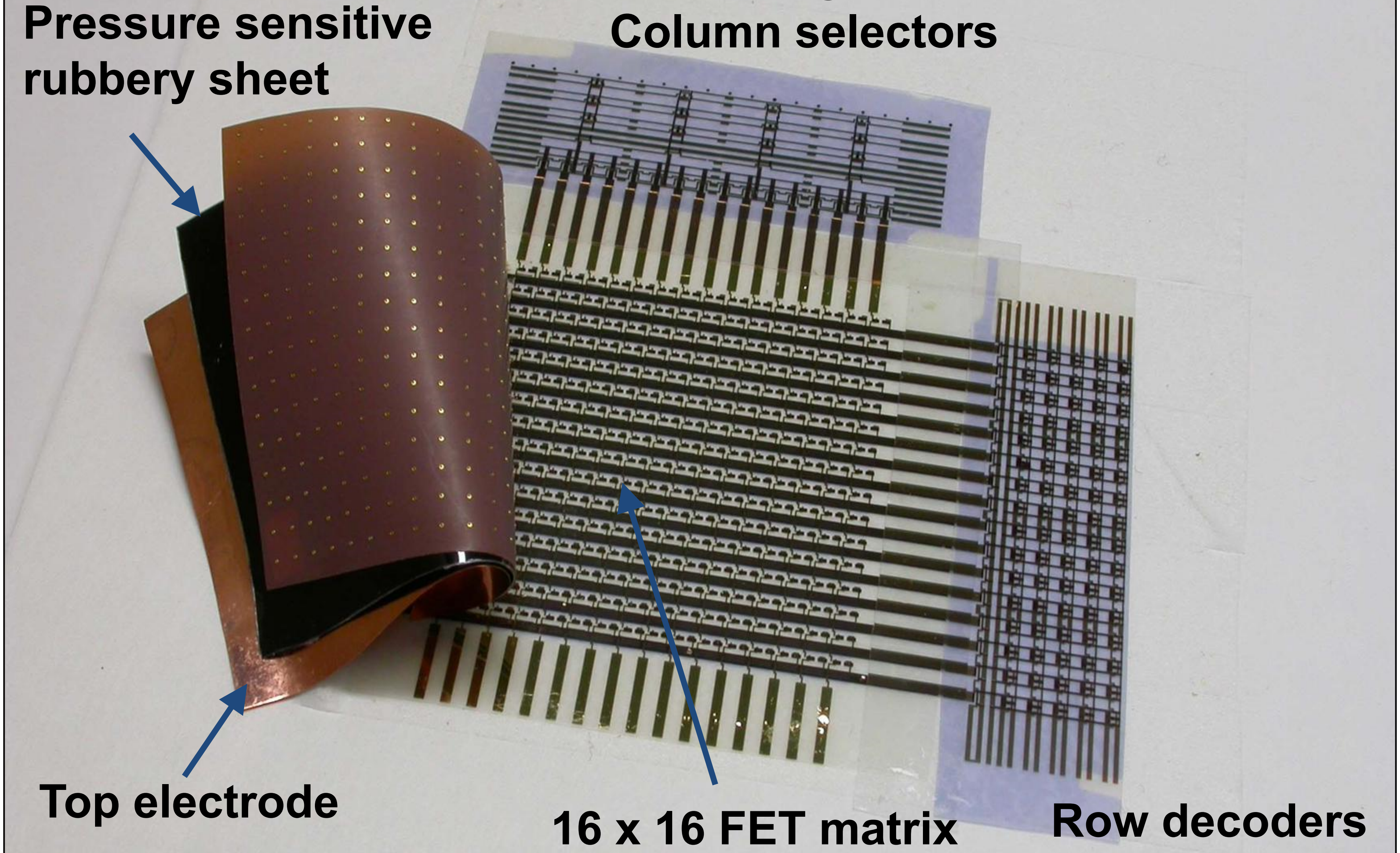
T.Sakurai

E-skin: large-area pressure sensor

T.Someya, H.Kawaguchi, T.Sakurai, "Integration of Organic Filed-Effect Transistors and Rubbery Pressure Sensor for Artificial Skin Applications," IEDM, 8.4.1-8.4.4, Sept. 2003.

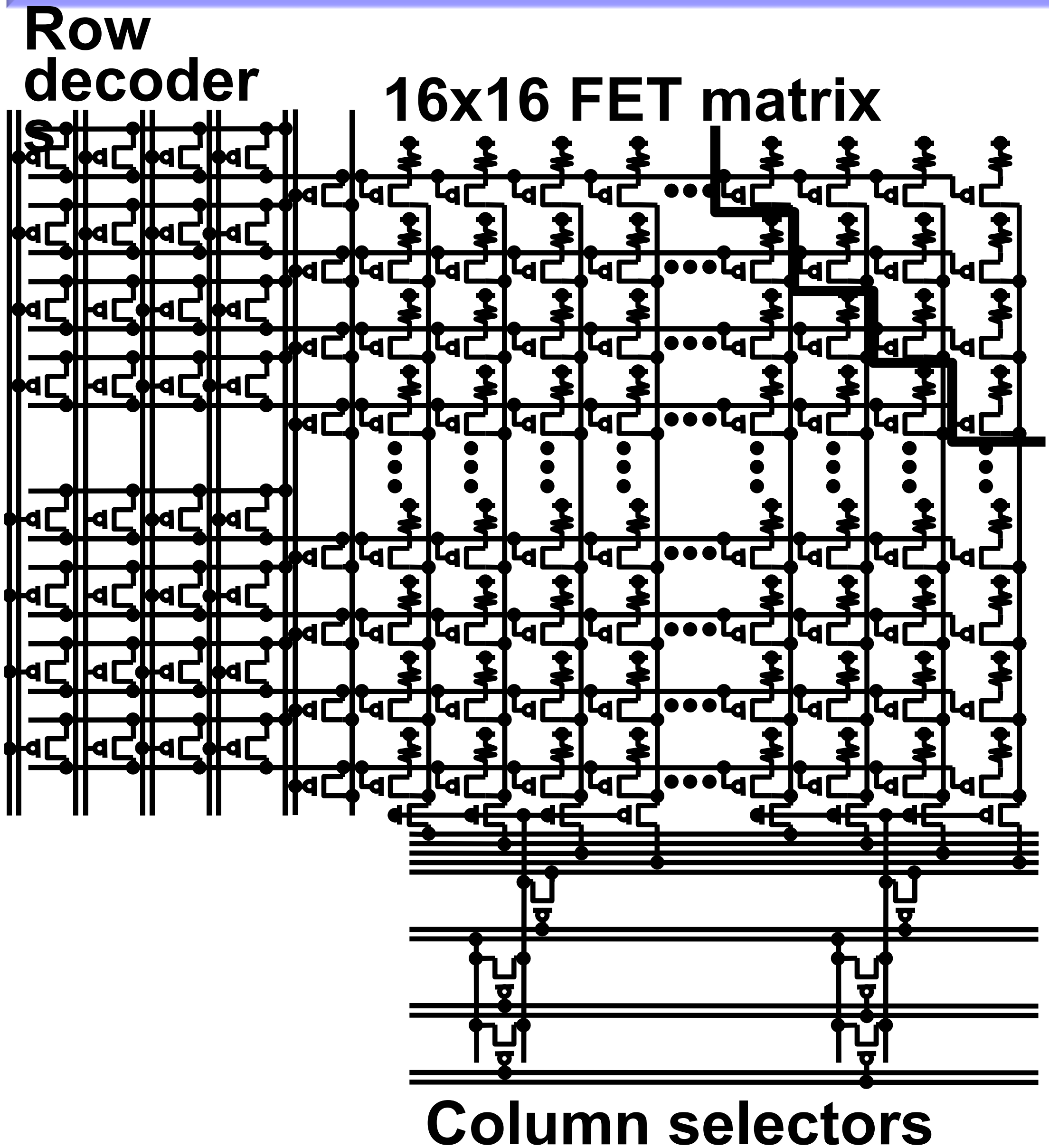
T.Someya, H.Kawaguchi, T.Sakurai, "Cut-and-Paste Organic FET Customized ICs for Application to Artificial Skin," ISSCC'05, paper#16.2, Feb. 2004.

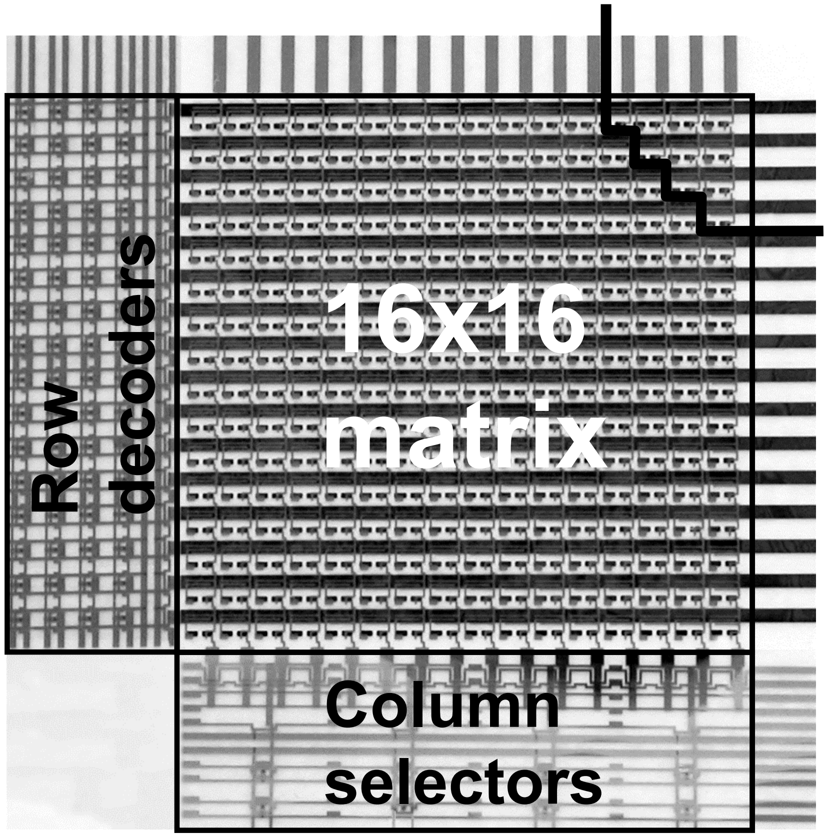
Artificial Skin Systems



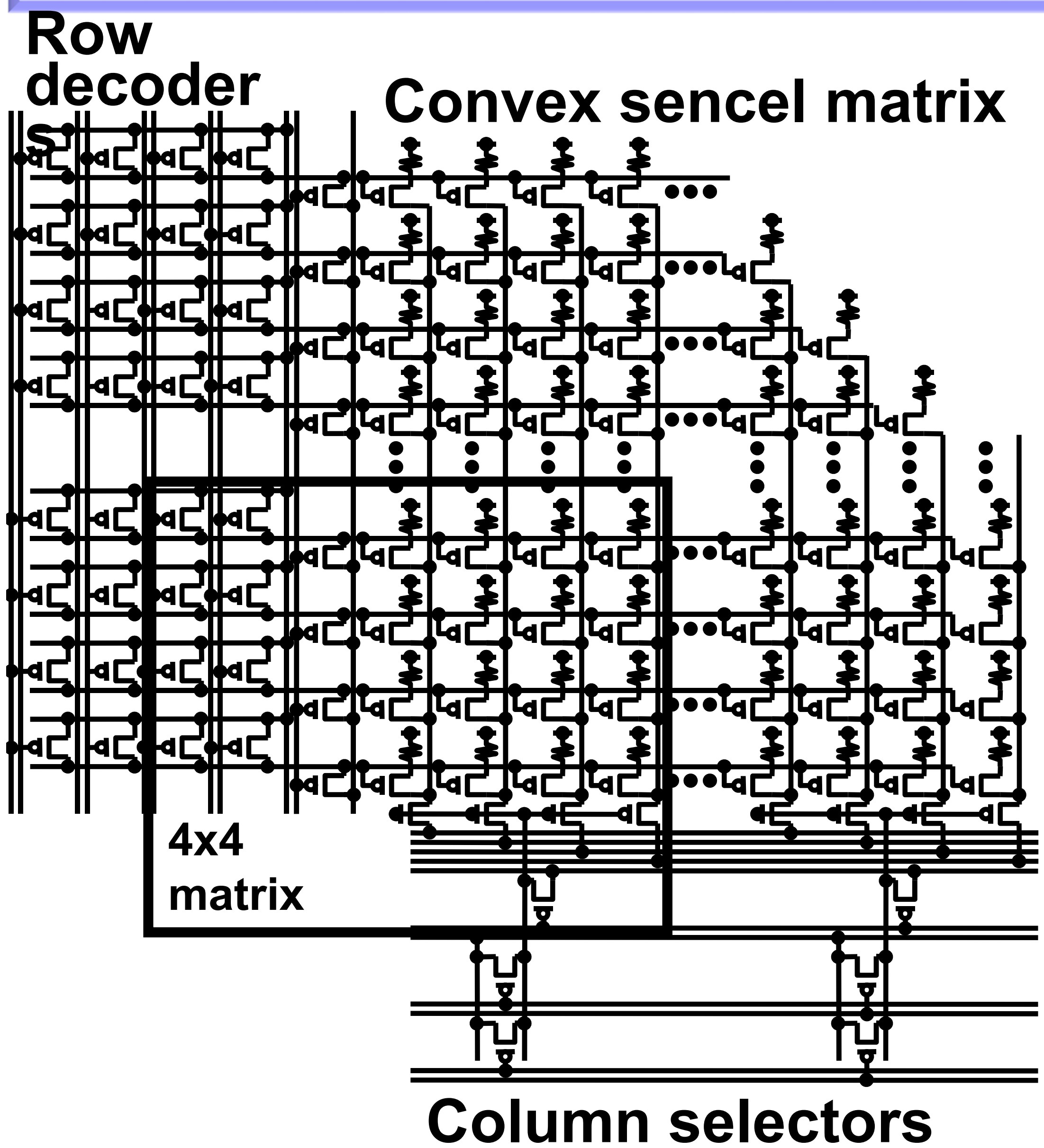
T.Someya, H.Kawaguchi, T.Sakurai, "Cut-and-Paste Organic FET Customized ICs for Application to Artificial Skin," ISSCC'05, paper#16.2, Feb. 2004.

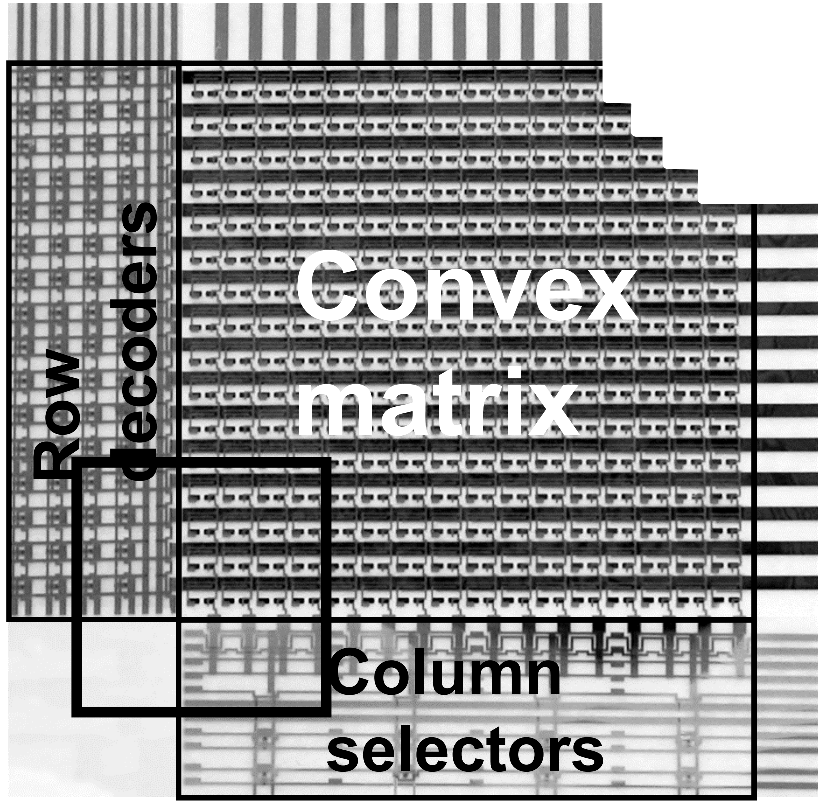
Cut-and-paste feature (16x16 sencels)



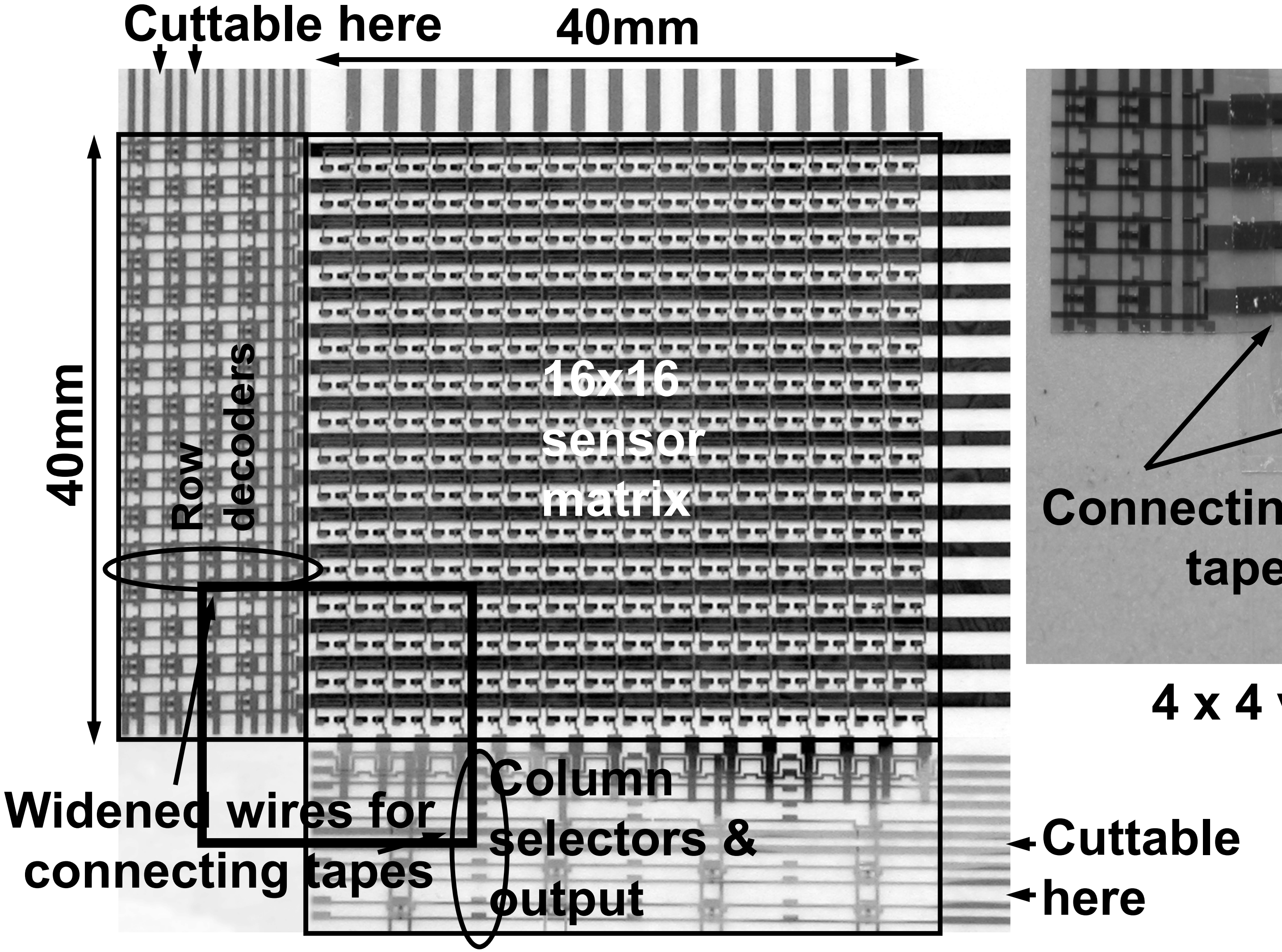


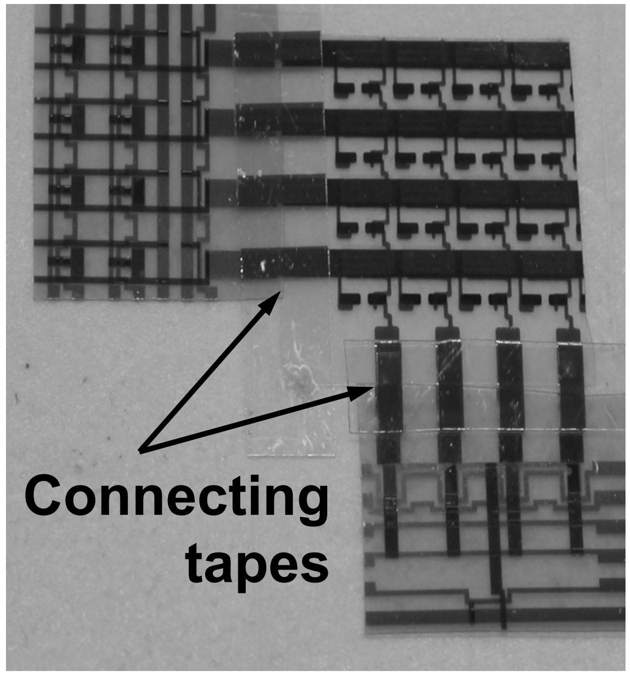
Cut-and-paste feature (convex shape)





Photograph of artificial skin system

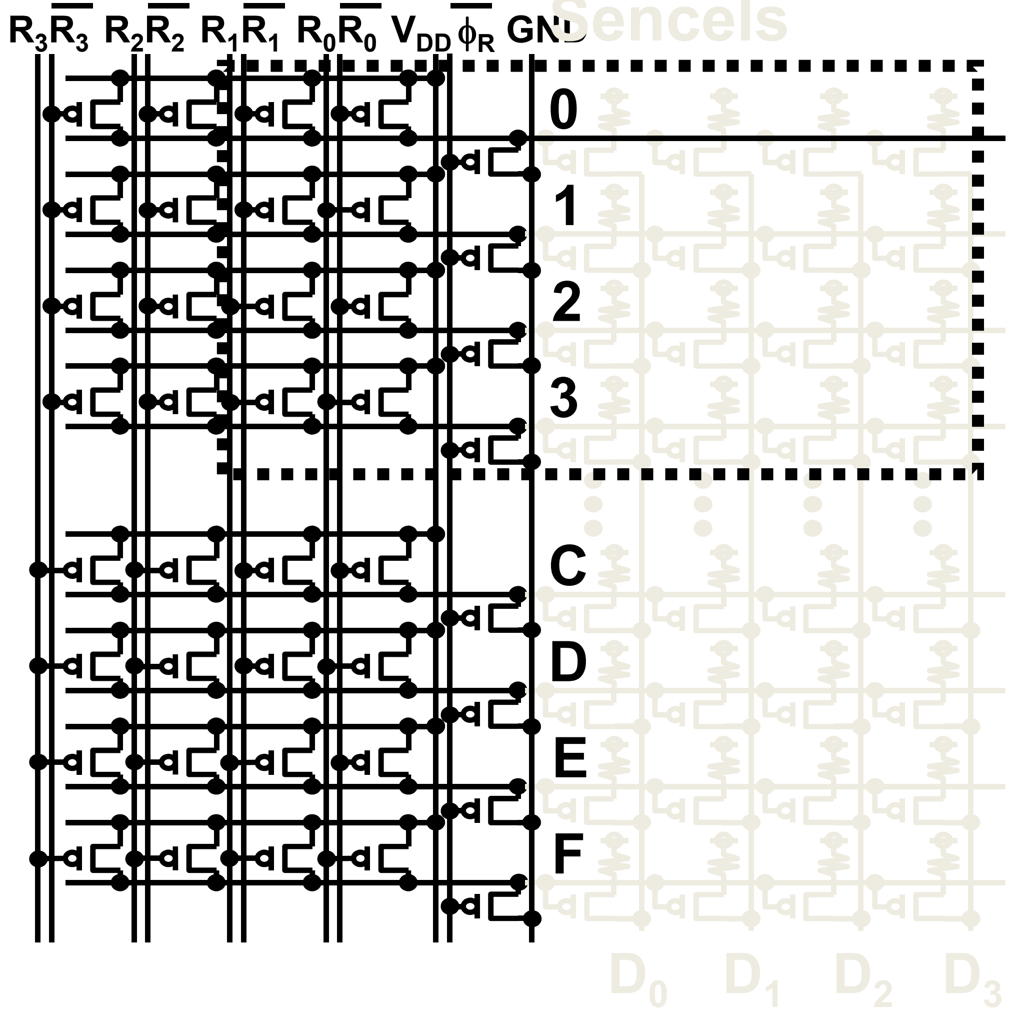




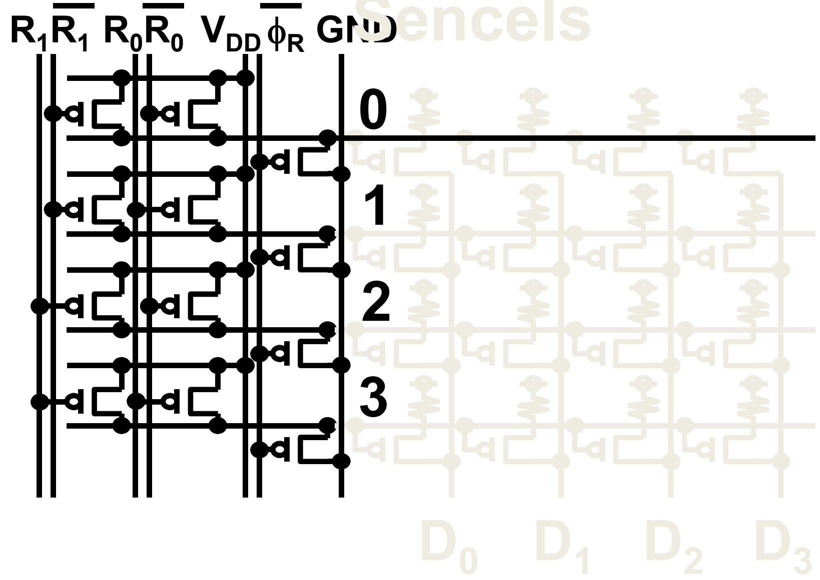
4 x 4 version

Scalable circuit (row decoder)

1 out of 16 row decoders



1 out of 4 row decoders



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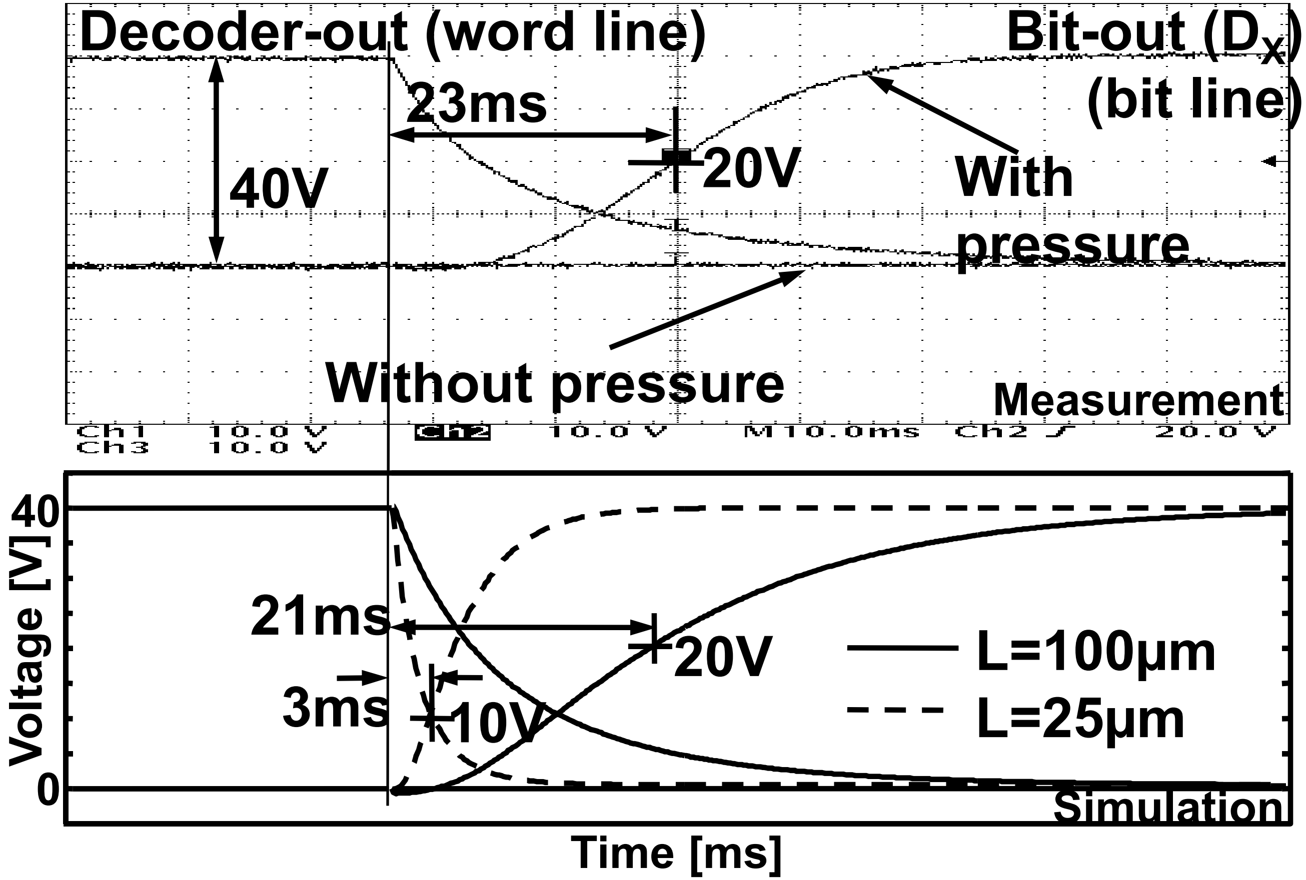
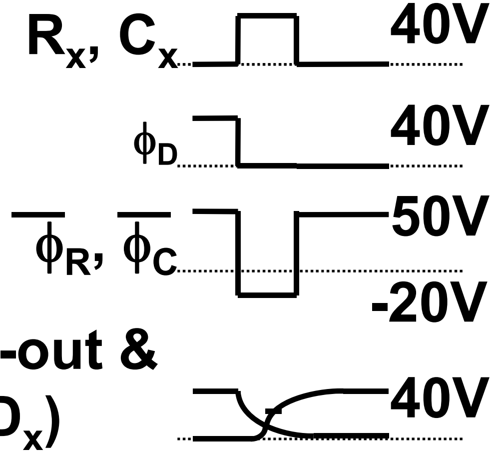
Access time measurement



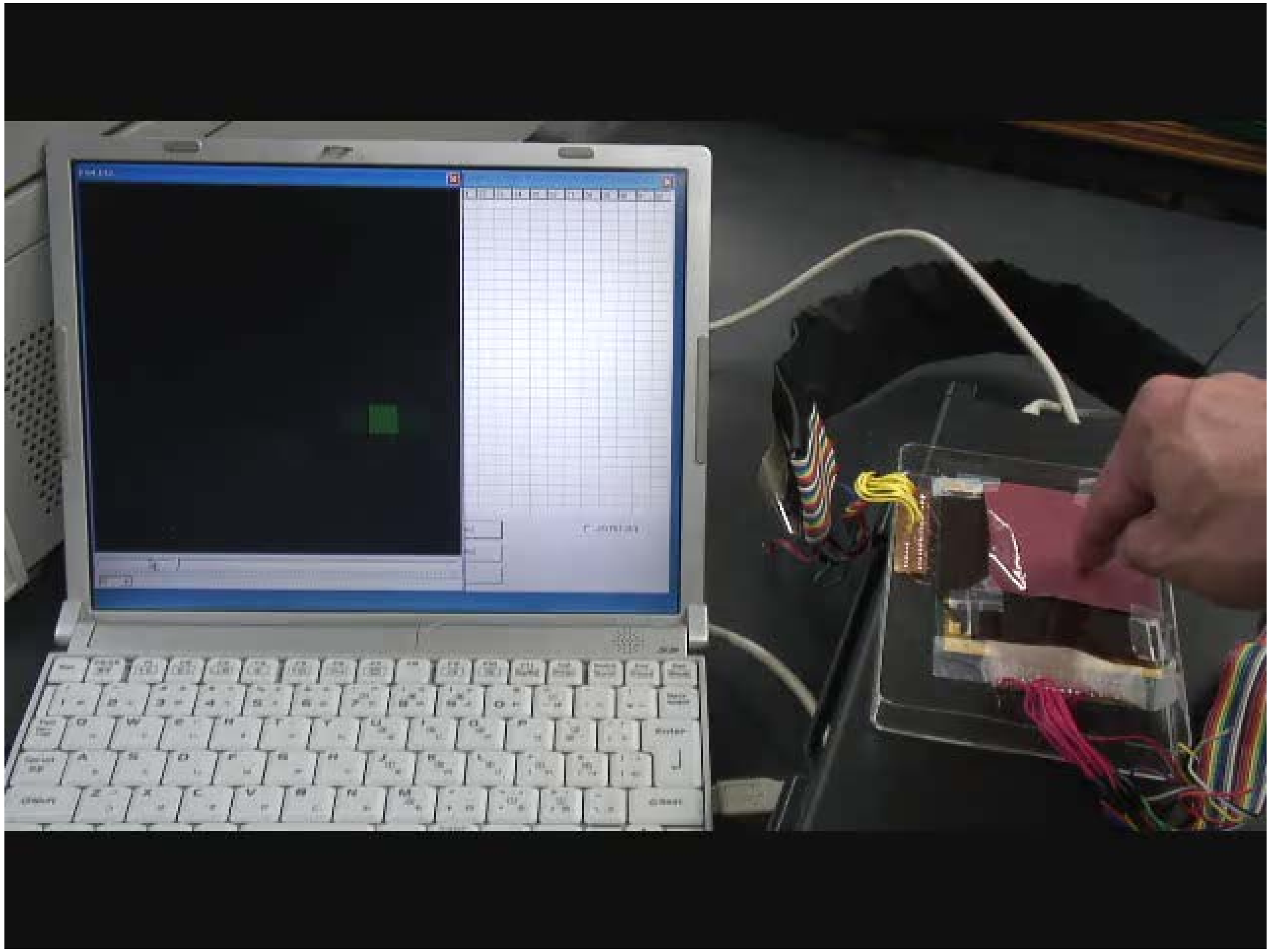


Access time in 16 x 16: 23ms

~2s (16 x 4 x 30ms) to scan sheet @ L=100μm

~0.3s to scan sheet @ L=25μm

e-skin works for years by now

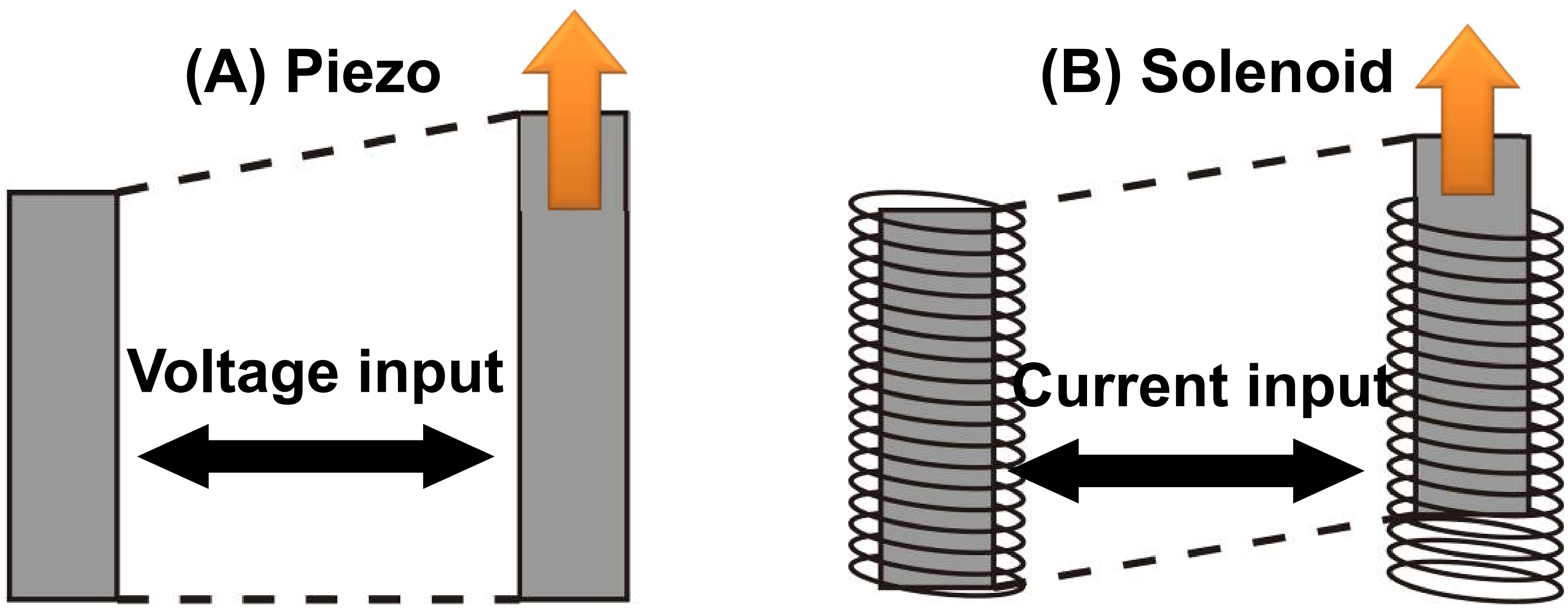


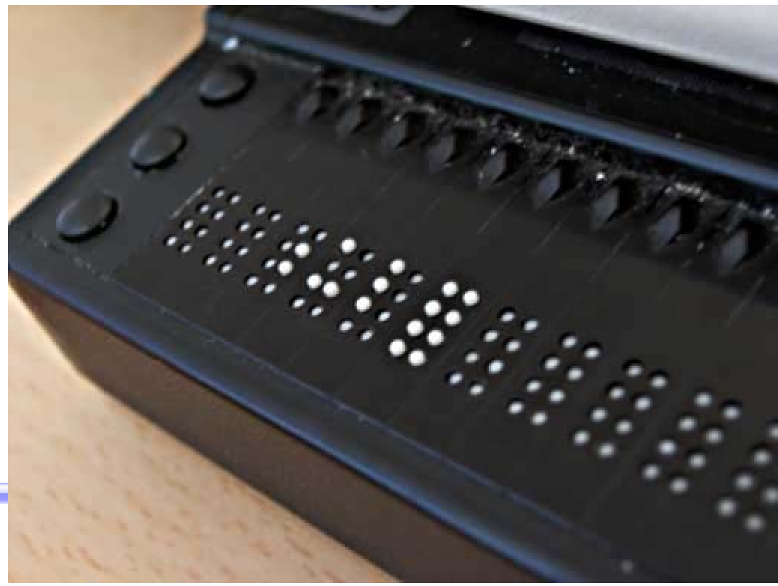
Braille display by organic FETs

Y.Kato, S.Iba, T.Sekitani, Y.Noguchi, K.Hizu, X.Wang, K.Takenoshita, Y.Takamatsu, S.Nakano, K.Fukuda, K.Nakamura, T.Yamaue, M.Doi, K.Asaka, H.Kawaguchi, M.Takamiya, T.Sakurai, and T.Someya, "A Flexible, Lightweight Braille Sheet Display with Plastic Actuators Driven by An Organic Field-Effect Transistor Active Matrix," IEDM'05, Paper #5.1, Dec.2005.

M.Takamiya, T.Sekitani, Y.Kato, H.Kawaguchi, T.Someya, and T.Sakurai, “An Organic FET SRAM for Braille sheet display with back gate to increase the static noise margin,” ISSCC’06, Paper #15.4, Feb. 2005.

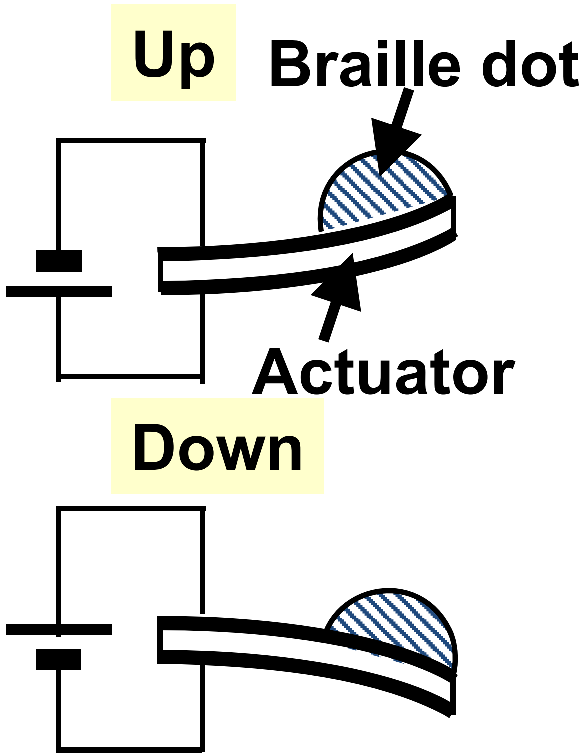
Conventional methods for Braille display

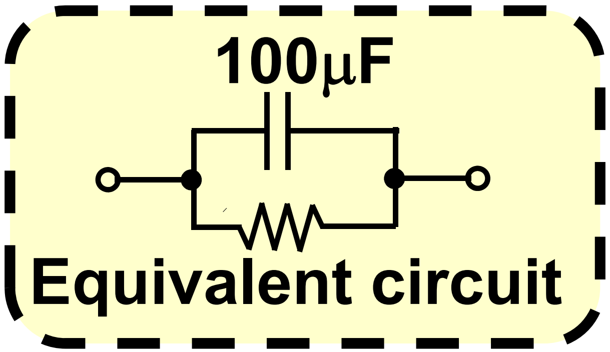


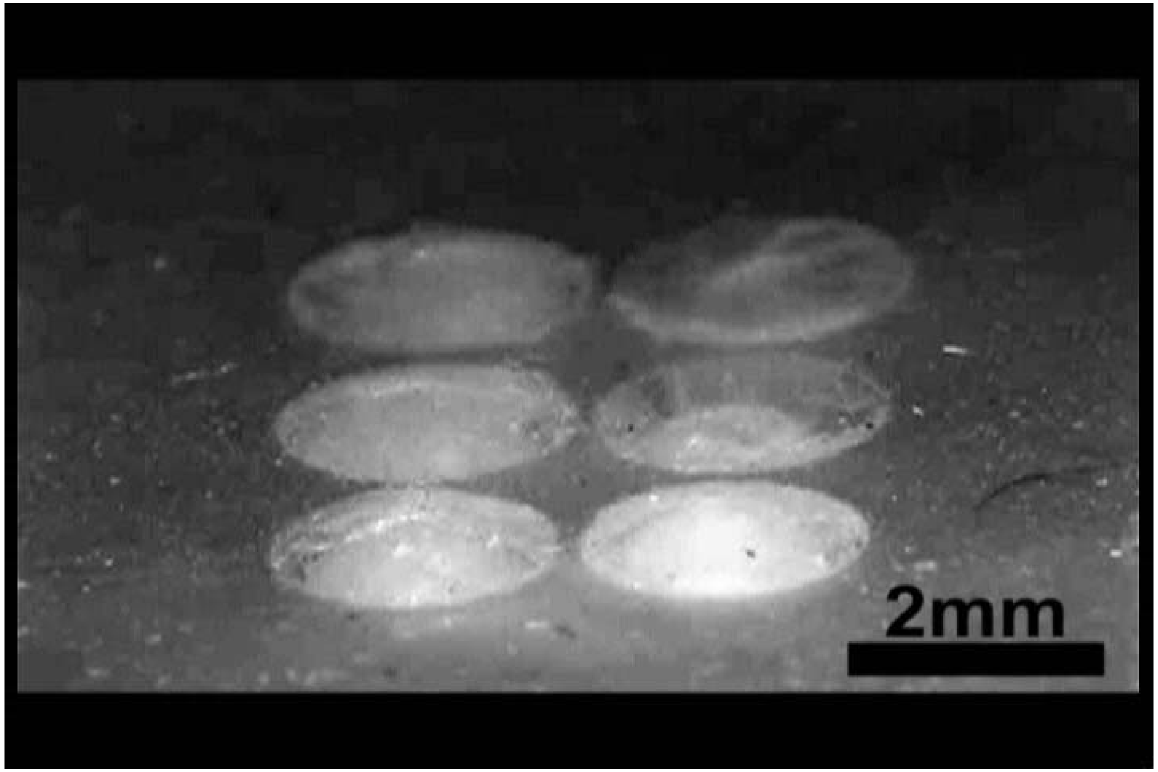


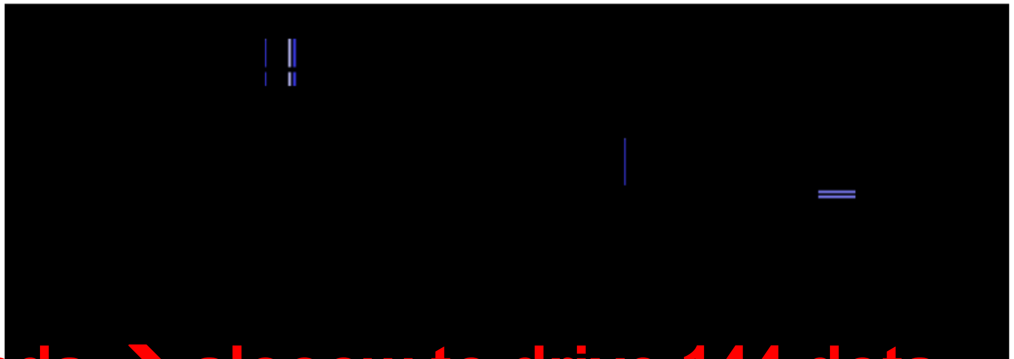
Thick and heavy
~5cm / ~1kg

Plastic actuators (artificial muscle)





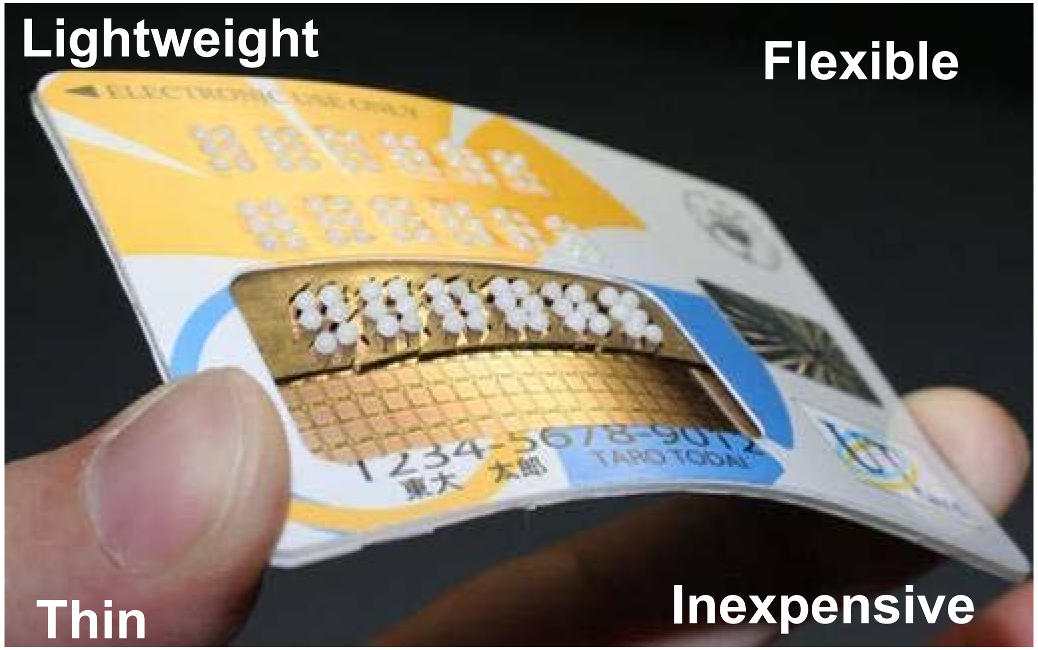


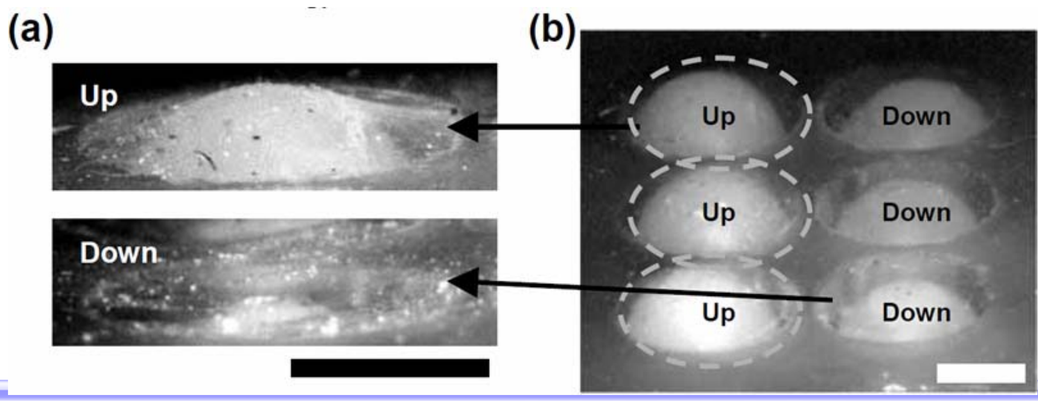


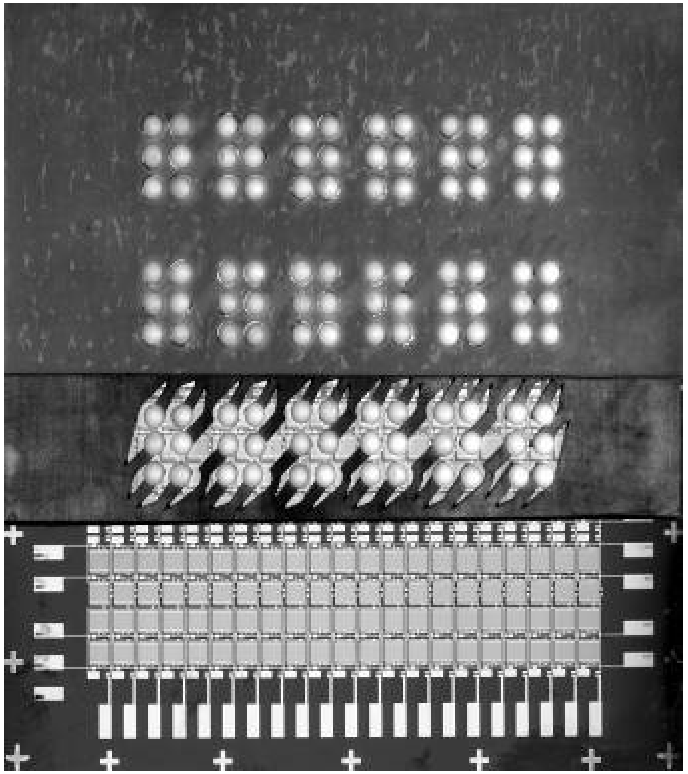
Displacement takes seconds → slooow to drive 144 dots.

Braille sheet display

Soft actuators powered by OTFT-AM







The displacement of actuators to read Braille is 0.2 mm.

Wireless power transmission sheet with plastic MEMS switches and OFETs

T.Sekitani, M.Takamiya, Y.Noguchi, S.Nakano, Y.Kato, K.Hizu, H.Kawaguchi, T.Sakurai, and T.Someya, "A large-area flexible wireless power transmission sheet using printed plastic MEMS switches and organic field-effect transistors," Paper#11.1, IEDM 2006, Dec. 2006.

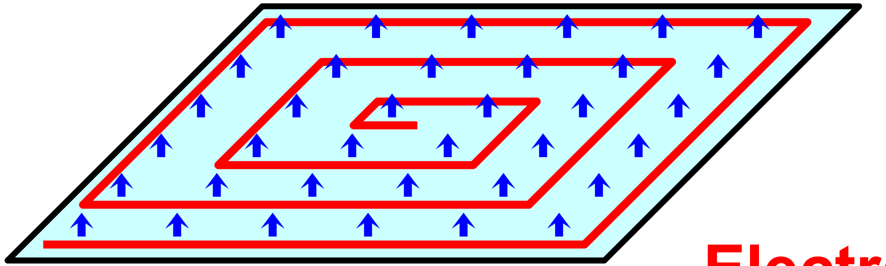
M.Takamiya, T.Sekitani, Y.Miyamoto, Y.Noguchi, H.Kawaguchi, T.Someya and T.Sakurai, "Design Solutions for a Multi-Object Wireless Power Transmission Sheet Based on Plastic Switches," Paper#20.4, ISSCC, Feb. 2007.

Position-sensing and selective activation

Large coil

Receiver coil

 **1 inch^2**



Efficiency ~ 0.1%

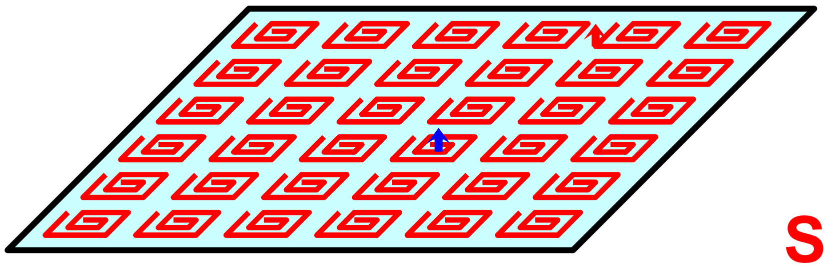
Electro- magnetic induction works

30x30 cm^2 X 1 coil

Many coils
& one selected

Receiver coil

 **1 inch^2**



Efficiency > 60%

1 inch^2 X 64 coils

Selective activation is the key.

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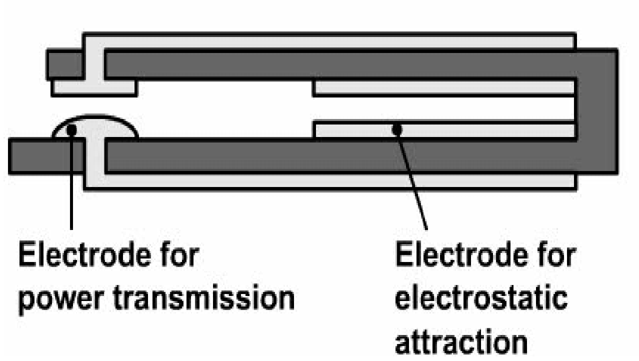
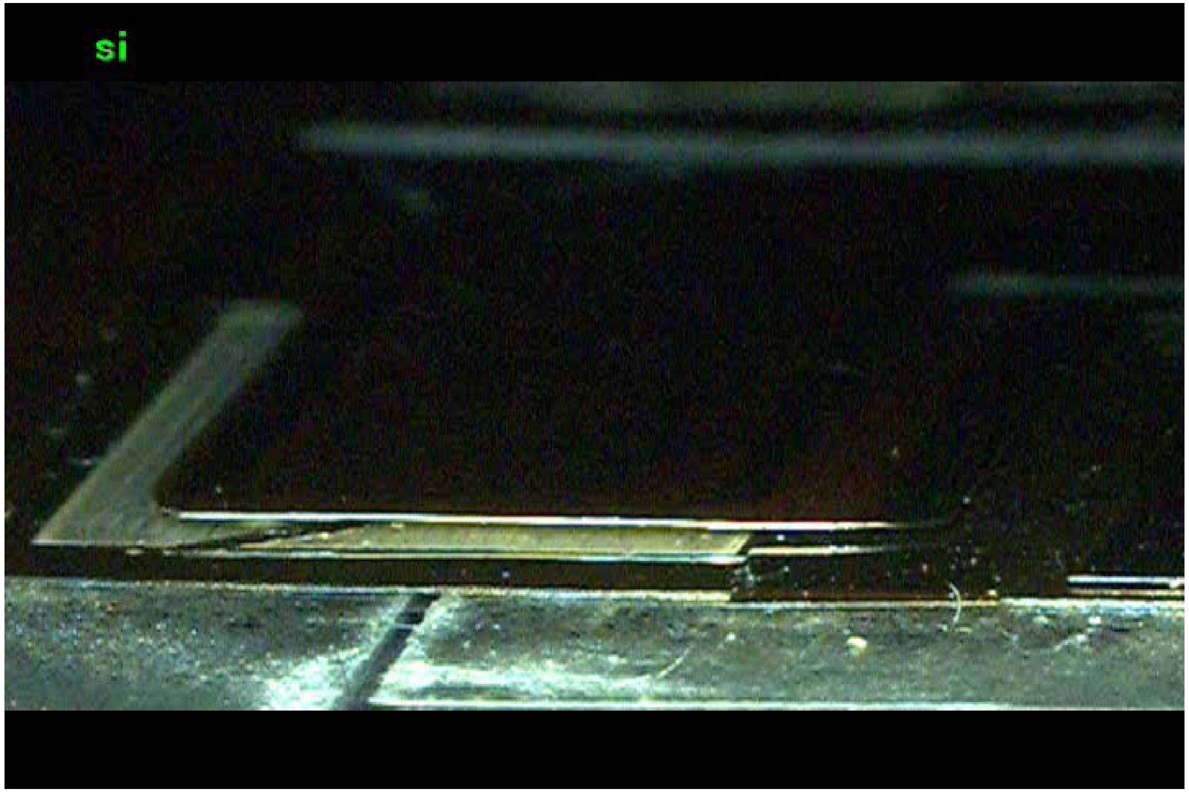
MEMS switches



~ 5mm x 10mm



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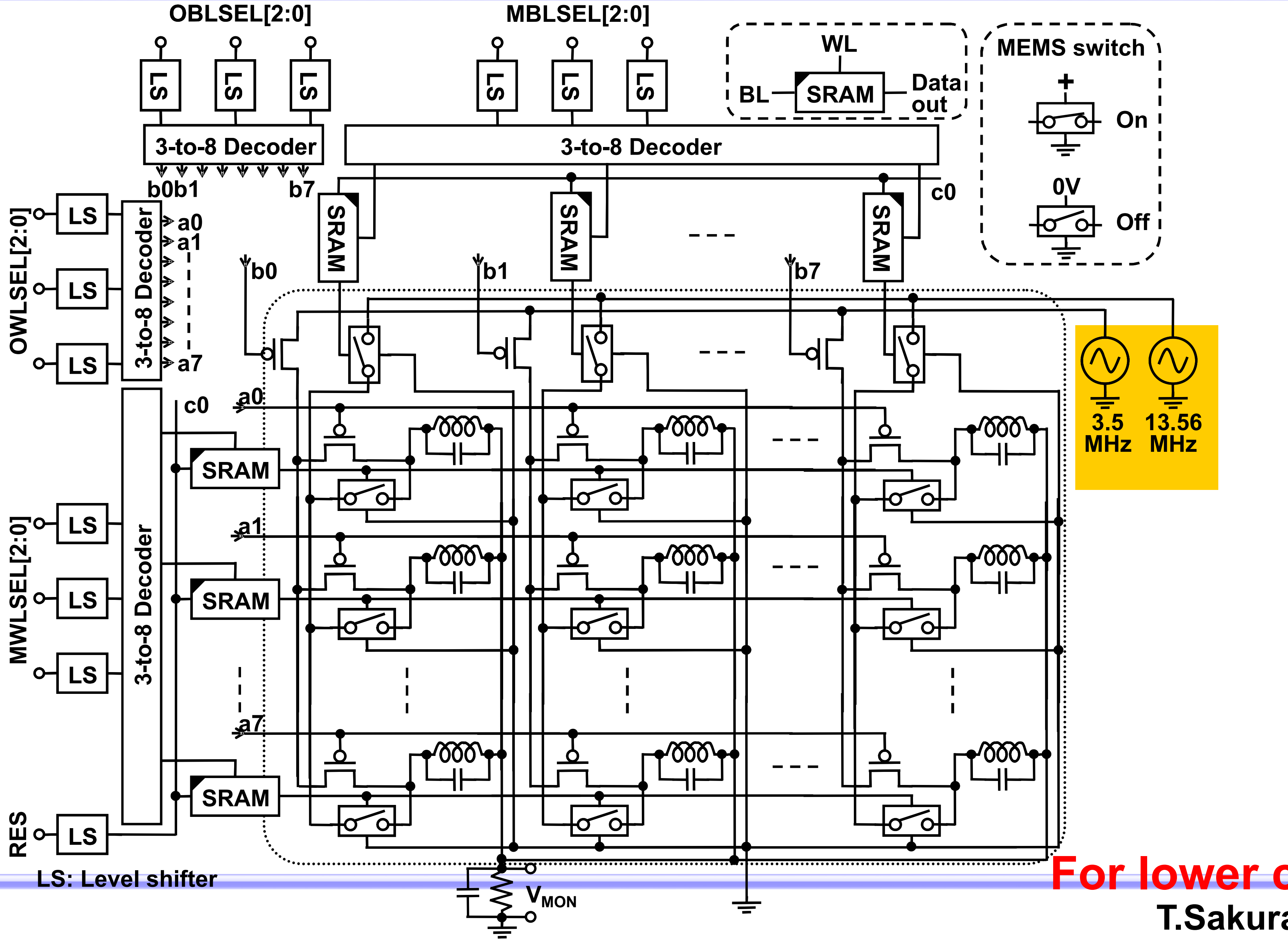
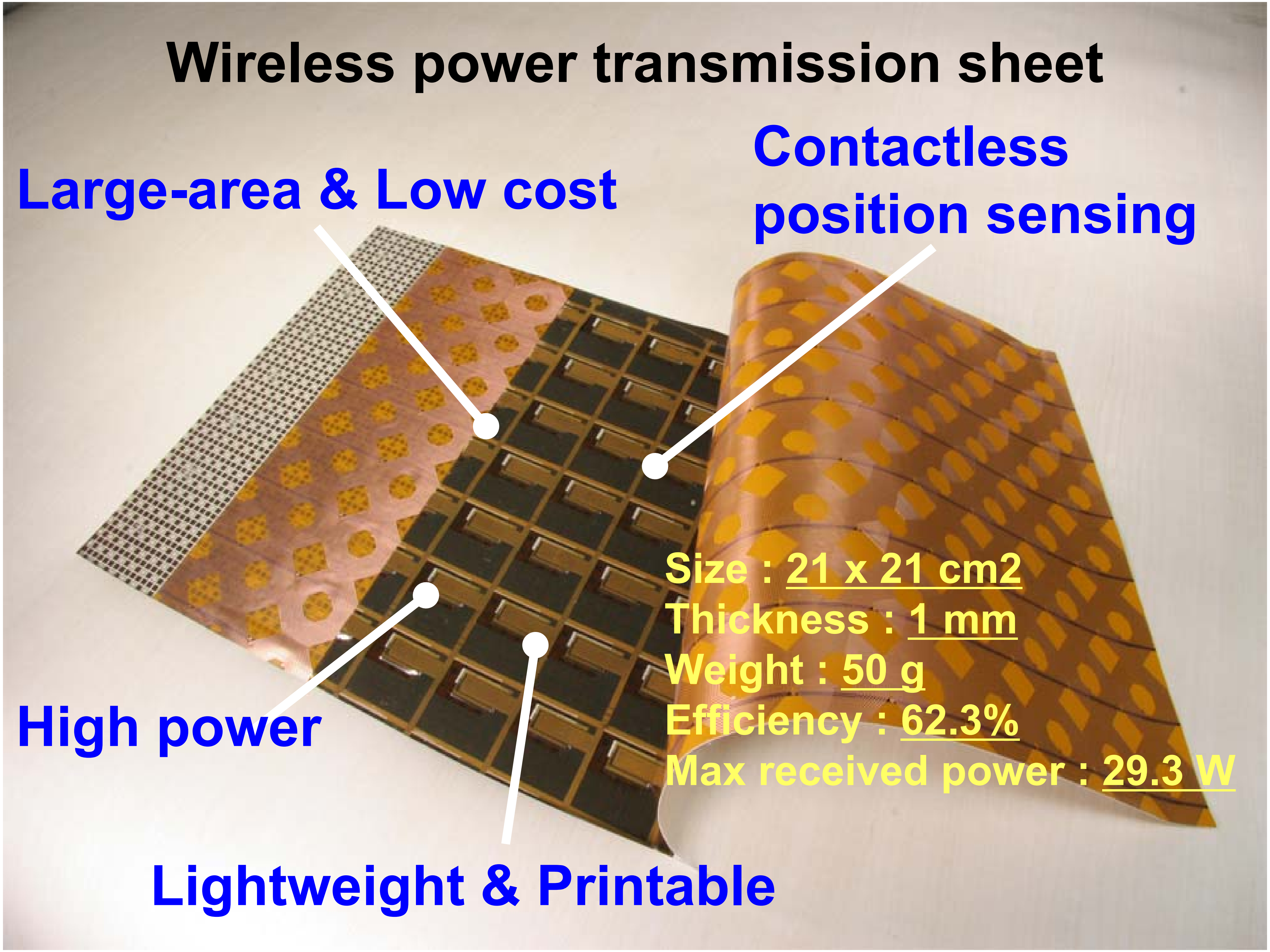
Making two coil sheets to one by circuit ideas



For lower cost

T.Sakurai


Wireless power transmission sheet
Large-area & Low cost
Contactless
position sensing
Size : 21 x 21 cm2
Thickness : 1 mm
Weight : 50 g
Efficiency : 62.3%
Max received power : 29.3 W
High power
Lightweight & Printable

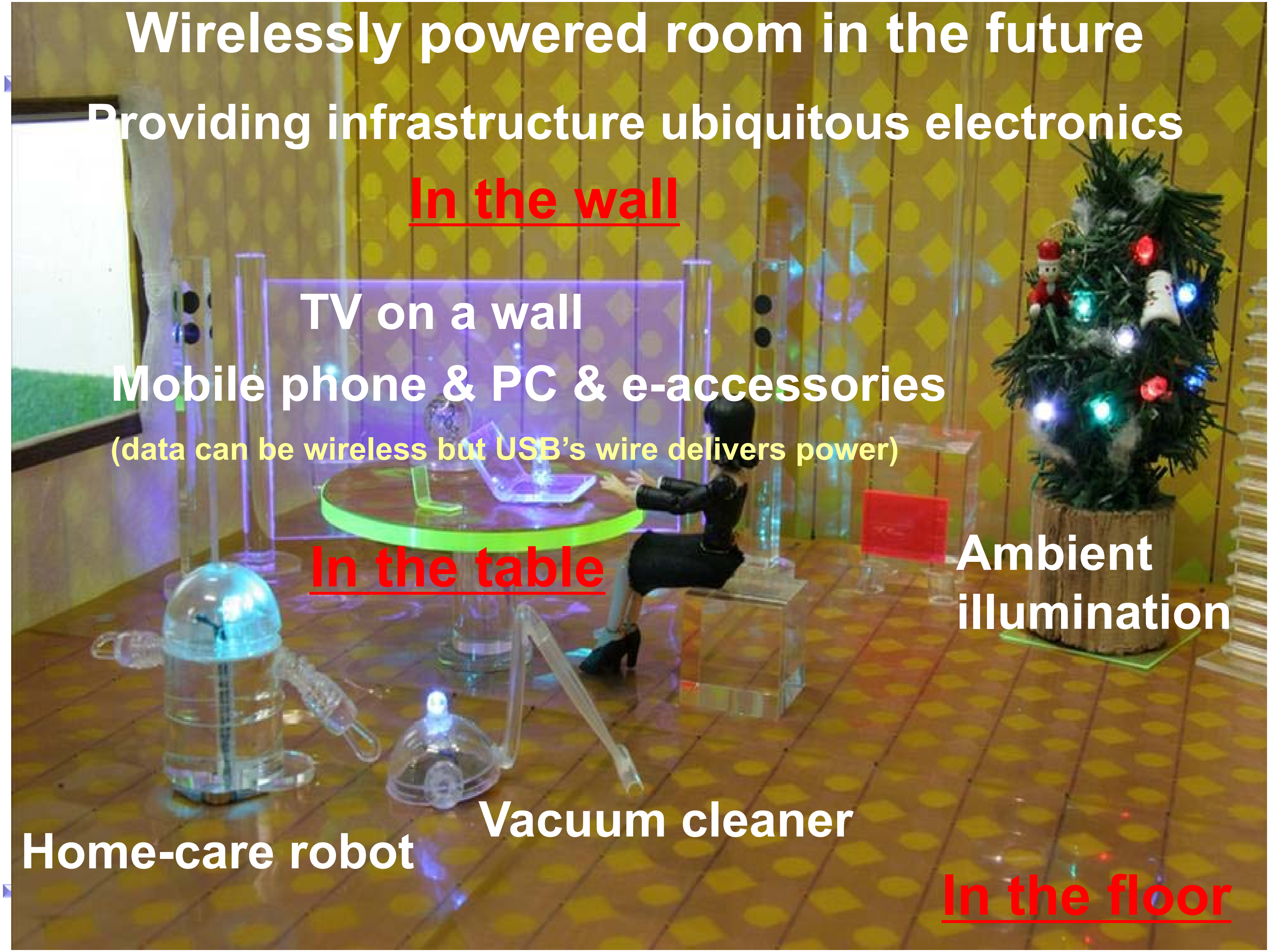
X’mas tree w/o a battery wirelessly powered

21 LEDs

13.56 MHz

Received power : 2 W

T.Sakurai


Wirelessly powered room in the future
Providing infrastructure ubiquitous electronics
In the wall
TV on a wall
Mobile phone & PC & e-accessories
(data can be wireless but USB's wire delivers power)
In the table
Ambient illumination
Home-care robot
Vacuum cleaner
In the floor

No electrical shock

I touched it by my hand. No problem ☺

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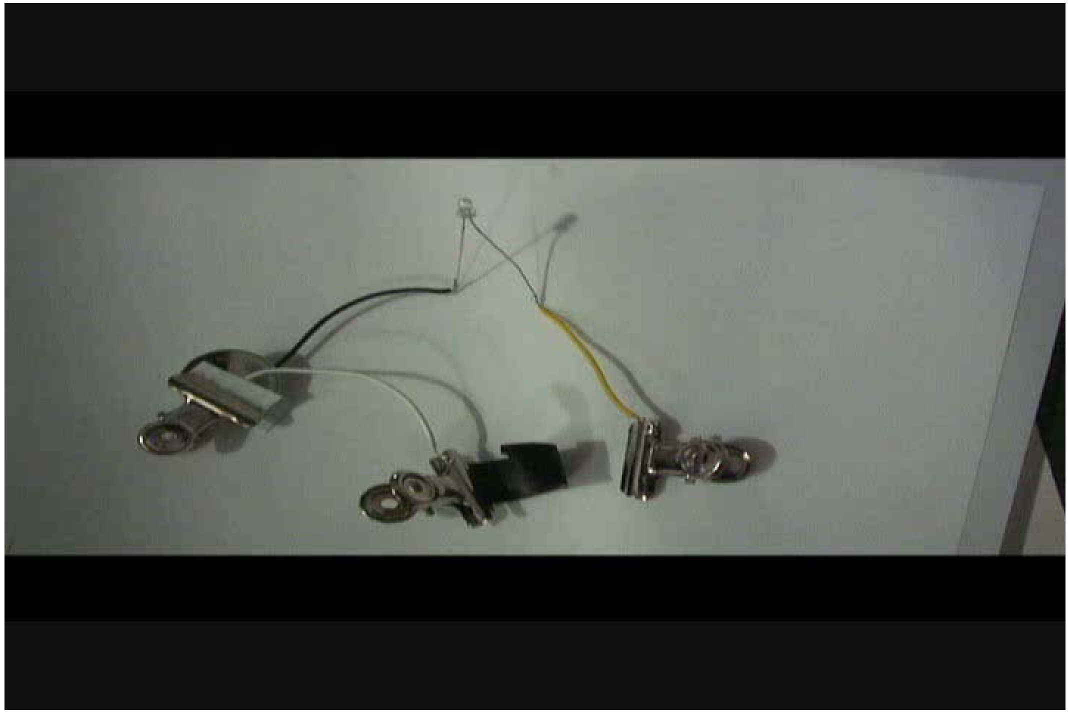
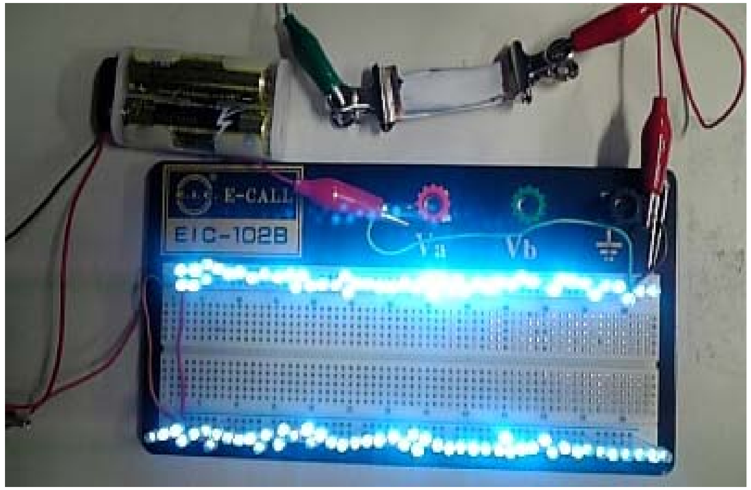
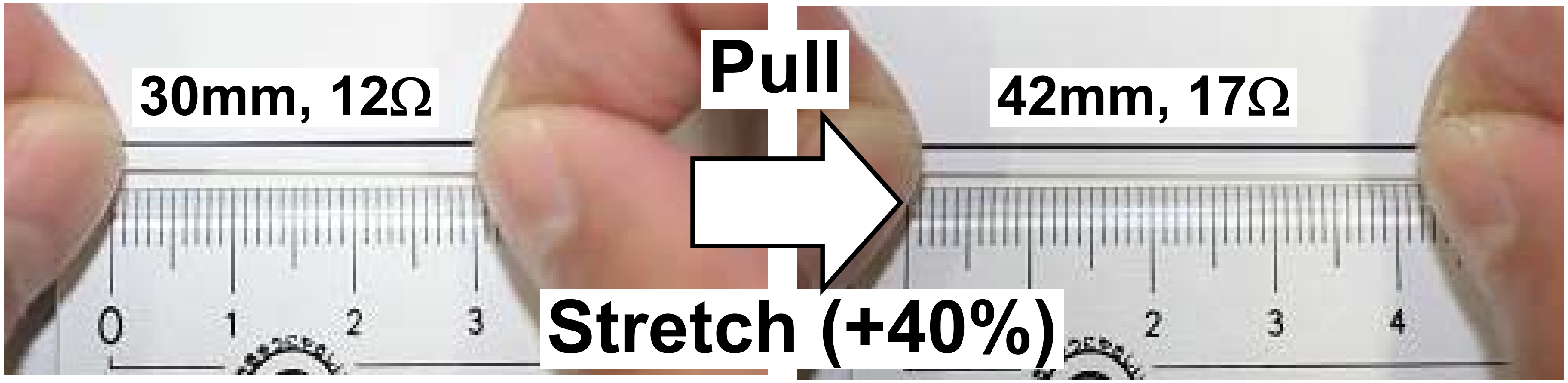
Stretchable wire with carbon nanotube

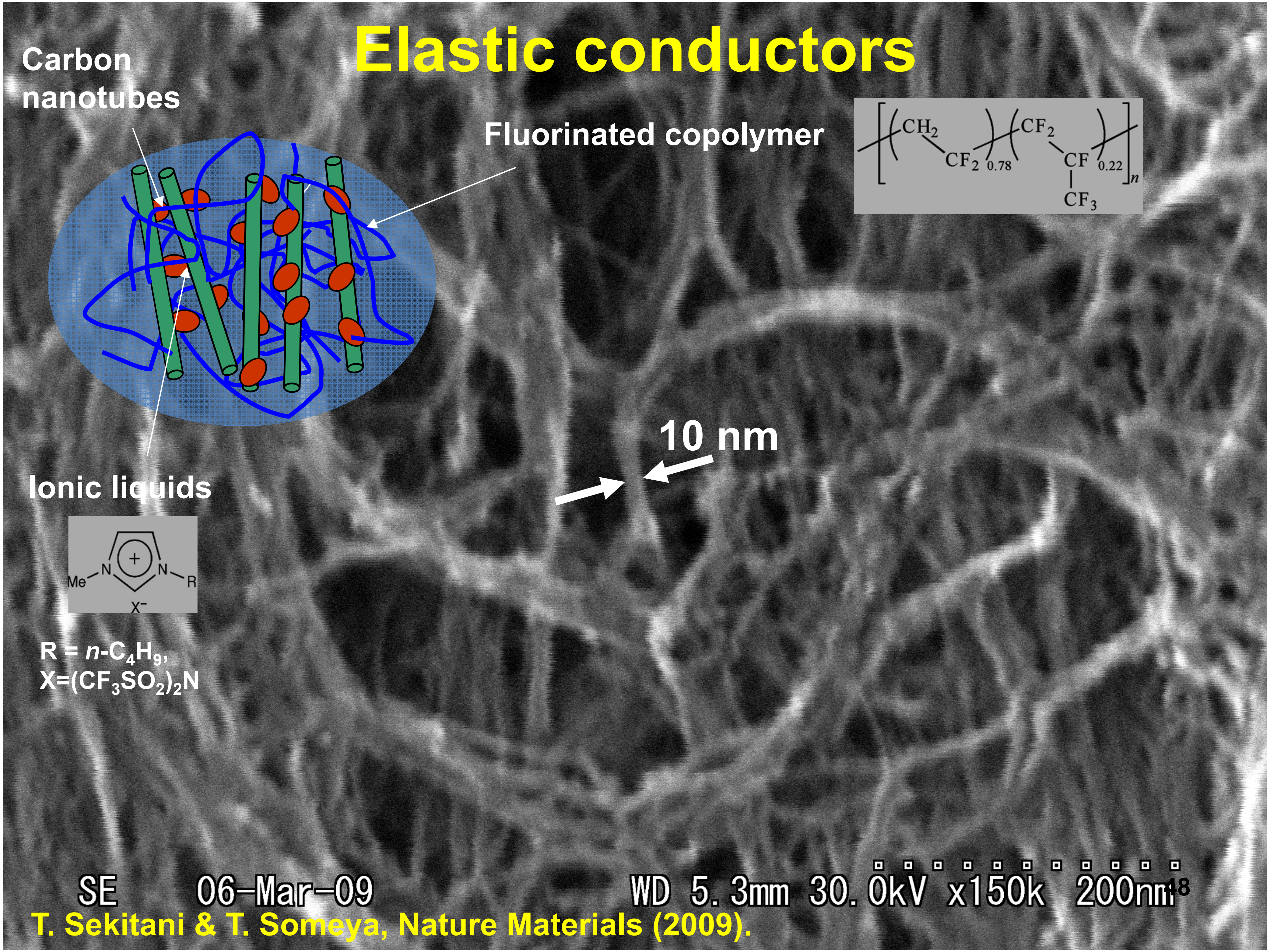




Current control > 500 mA

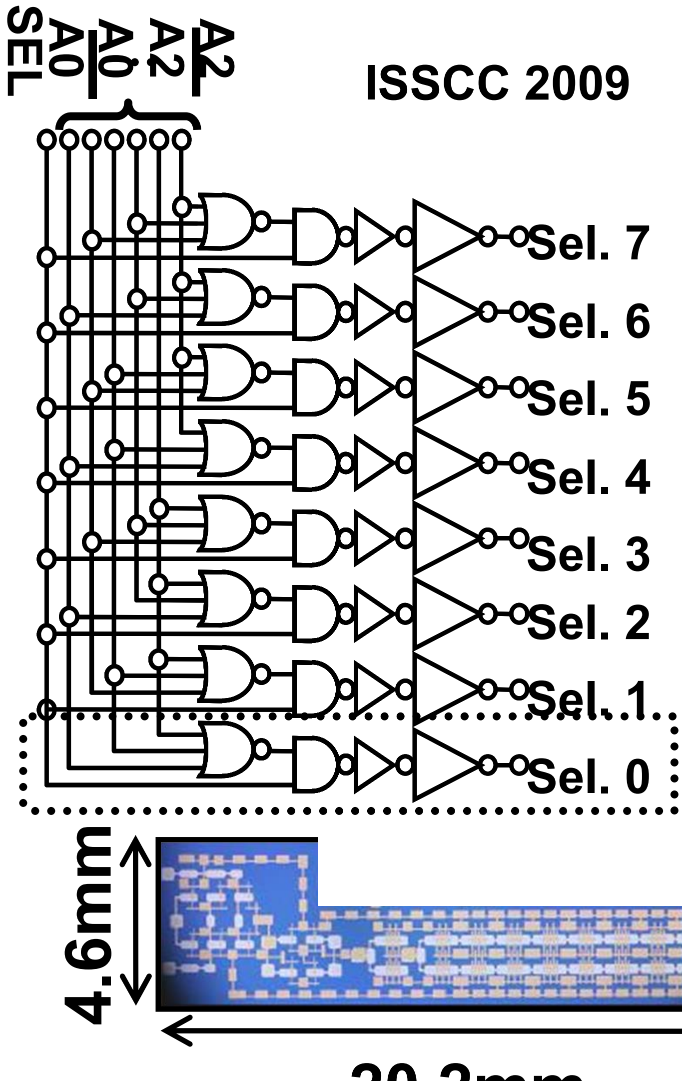


T.Sakurai

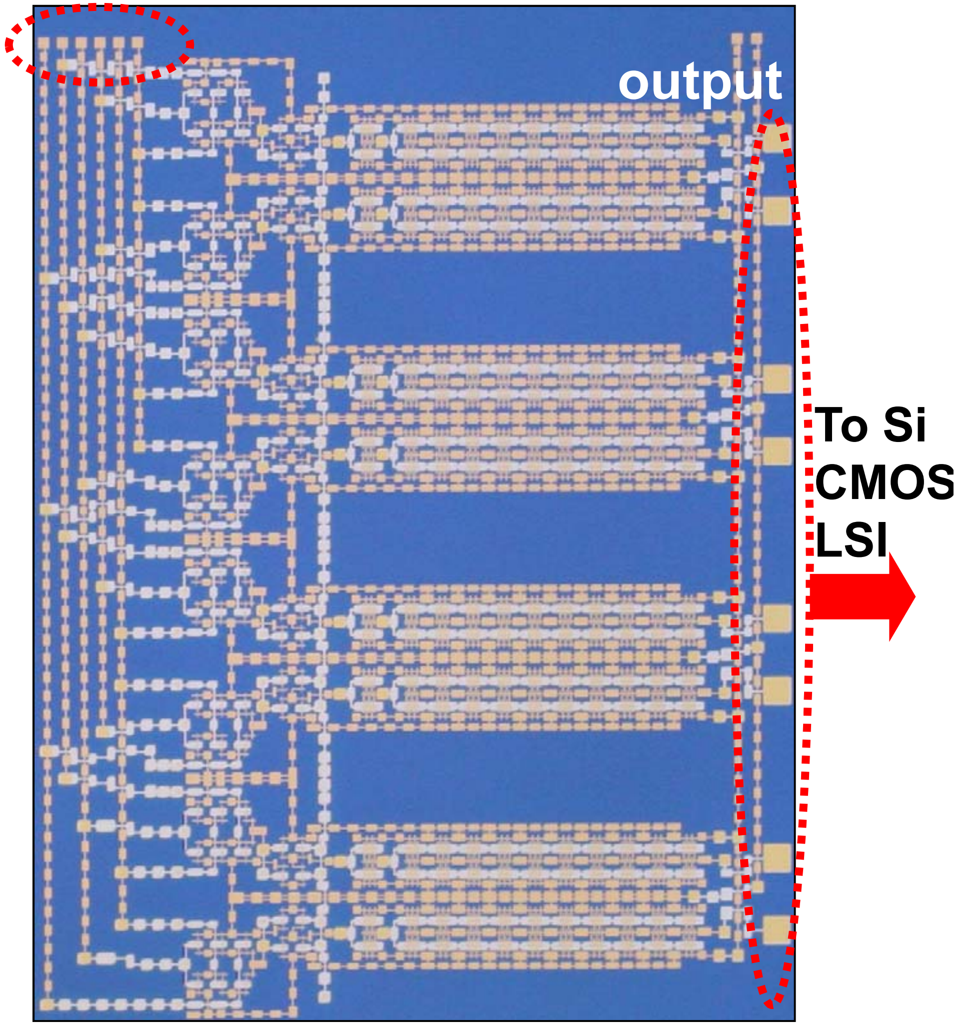

Elastic conductors
Carbon nanotubes
Fluorinated copolymer
Ionic liquids
10 nm
$R = n\text{-}C_4H_9$,
$X=(CF_3SO_2)_2N$
SE 06-Mar-09 WD 5.3mm 30.0kV x150k 200nm
T. Sekitani & T. Someya, Nature Materials (2009).

2V Organic & Si CMOS collaboration

3input to 8output CMOS decoder



Binary-code input from PC



128 CMOS (256 organic TFTs)

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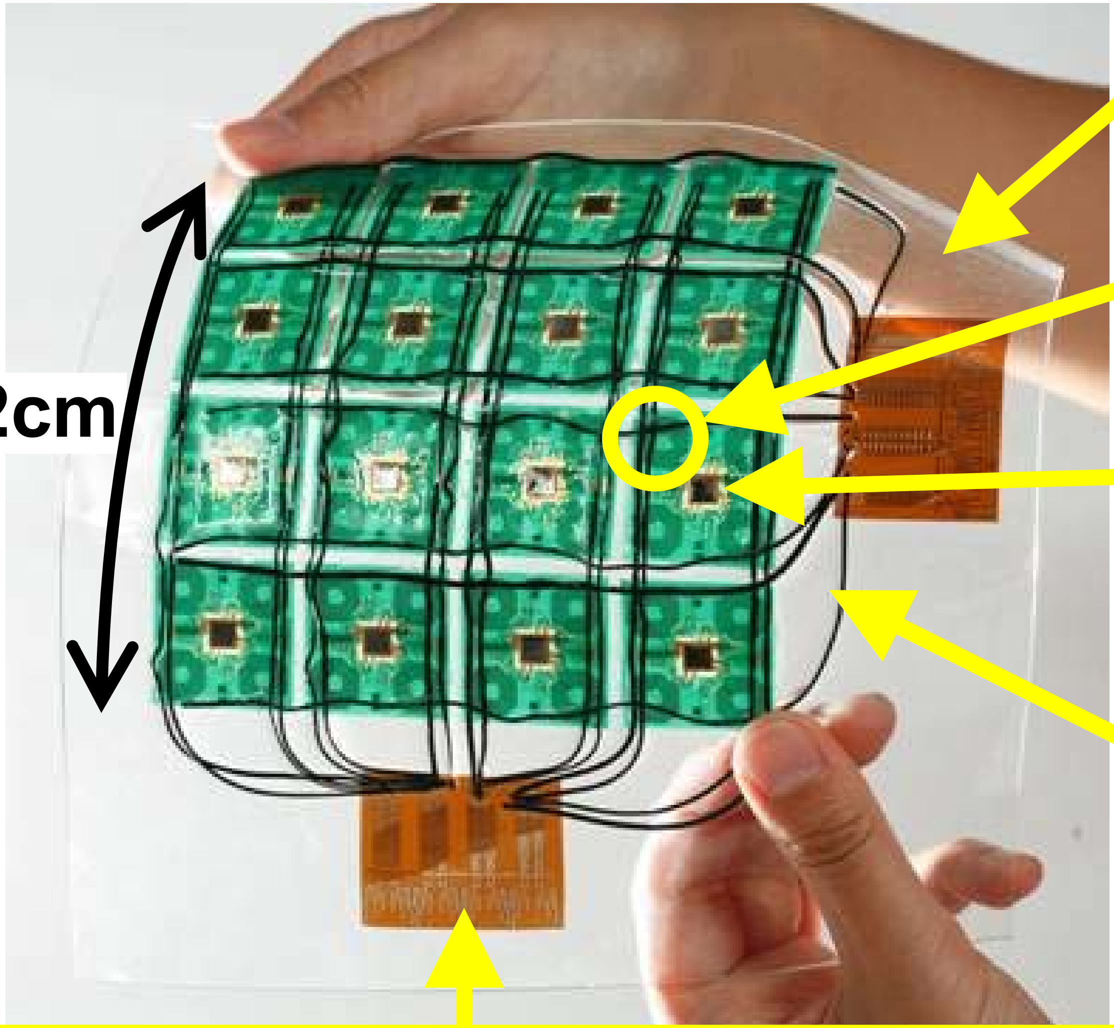
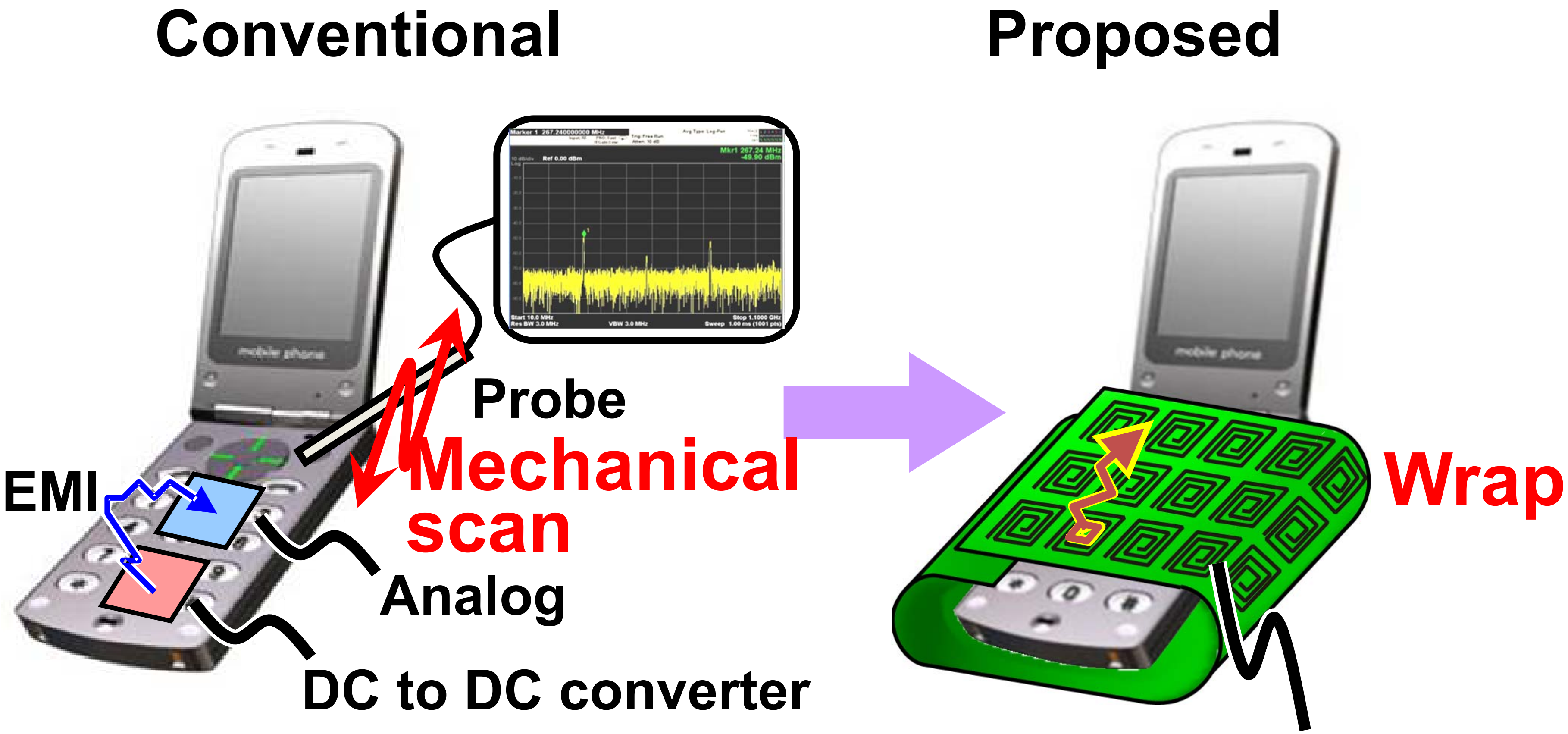
Prototype of EMI measurement sheet



K. Ishida, N. Masunaga, Z. Zhou, T. Yasufuku, T. Sekitani, U. Zschieschang, H. Klauk, M. Takamiya, T. Someya, and T. Sakurai, "A Stretchable EMI Measurement Sheet with 8 x 8 Coil Array, 2V Organic CMOS Decoder, and -70dBm EMI Detection Circuits in 0.18um CMOS," ISSCC'09, paper#28.3, Feb.2009.

EMI measurement sheet – EMI Furoshiki

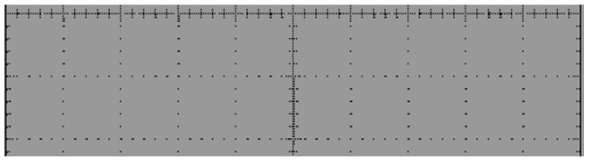


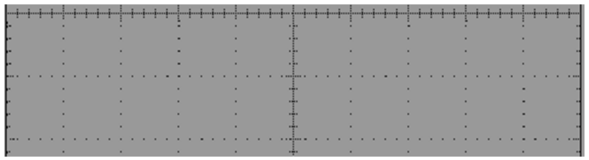
Magnetic field probe

EMI measurement sheet
Easy without mechanical scan

K. Ishida, N. Masunaga, Z. Zhou, T. Yasufuku, T. Sekitani, U.Zschieschang, H. Klauk, M. Takamiya, T. Someya, and T. Sakurai, "A Stretchable EMI Measurement Sheet with 8 x 8 Coil Array, 2V Organic CMOS Decoder, and -70dBm EMI Detection Circuits in 0.18um CMOS," ISSCC'09, paper#28.3, pp.472-473, Feb.2009.

Movie of proposed EMI measurement





No EMI **EMI detected**

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EMI measurement

Integrated circuit fabricated by home-use printer

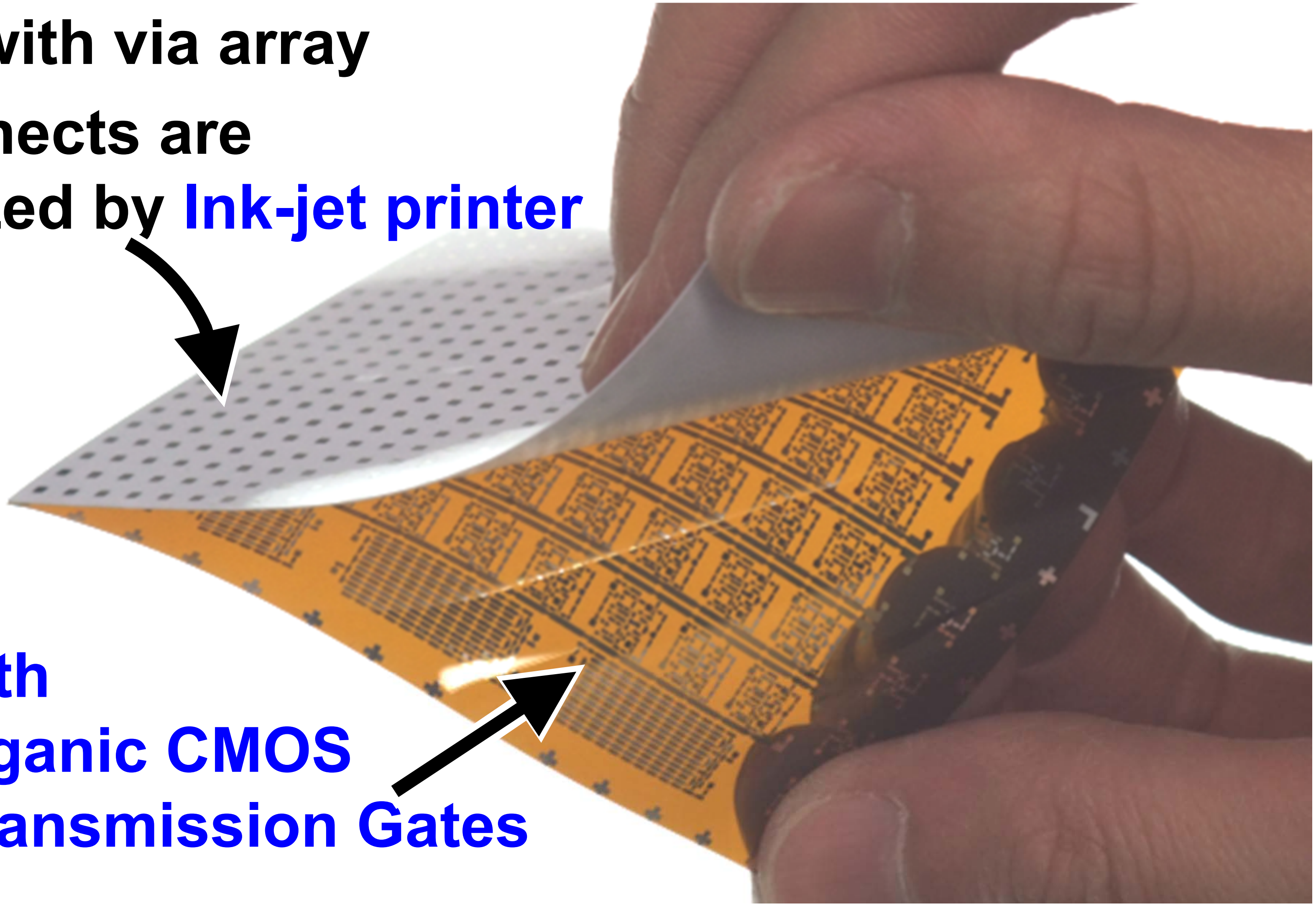
Ink is provided by Mitsubishi Paper Mills Ltd.

K.Ishida, N.Masunaga, R.Takahashi, T.Sekitani, S.Shino, U.Zschieschang, H.Klauk, M.Takamiya, T.Someya, T.Sakurai, "User Customizable Logic Paper (UCLP) with Organic Sea-of Transmission-Gates (SOTG) Architecture and Ink-Jet Printed Interconnects," ISSCC'10, Paper#7.3, Feb. 2010.

Prototype of “Logic paper”

✓**Paper** with via array

Interconnects are customized by **Ink-jet printer**



✓**Film with 10x10 organic CMOS Sea of Transmission Gates**

Each user can fabricate one’s own logic circuits by ink-jet printing interconnects on paper.

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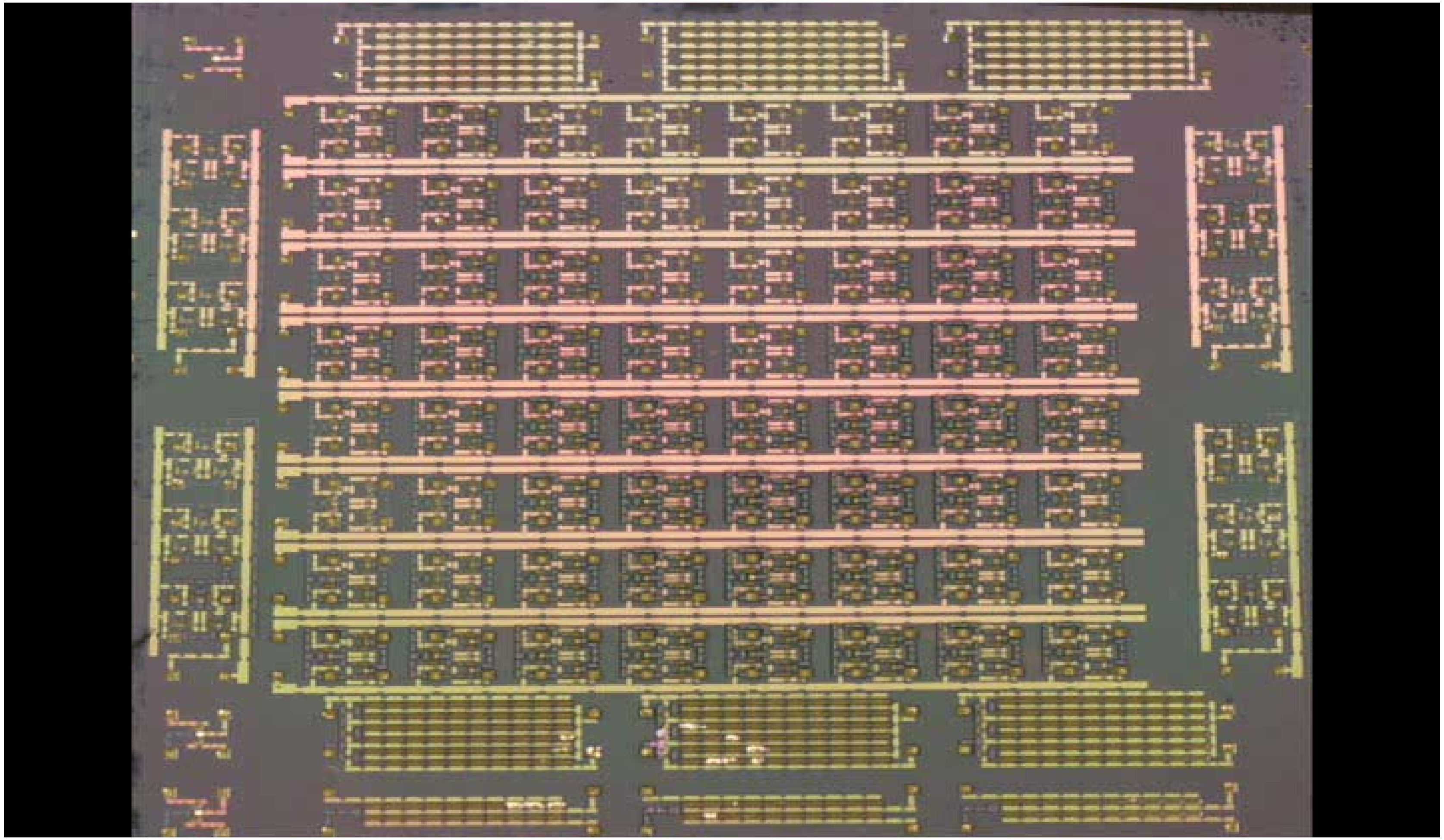
Interconnection customized paper is stacked on plastic Sea of Transmission Gates



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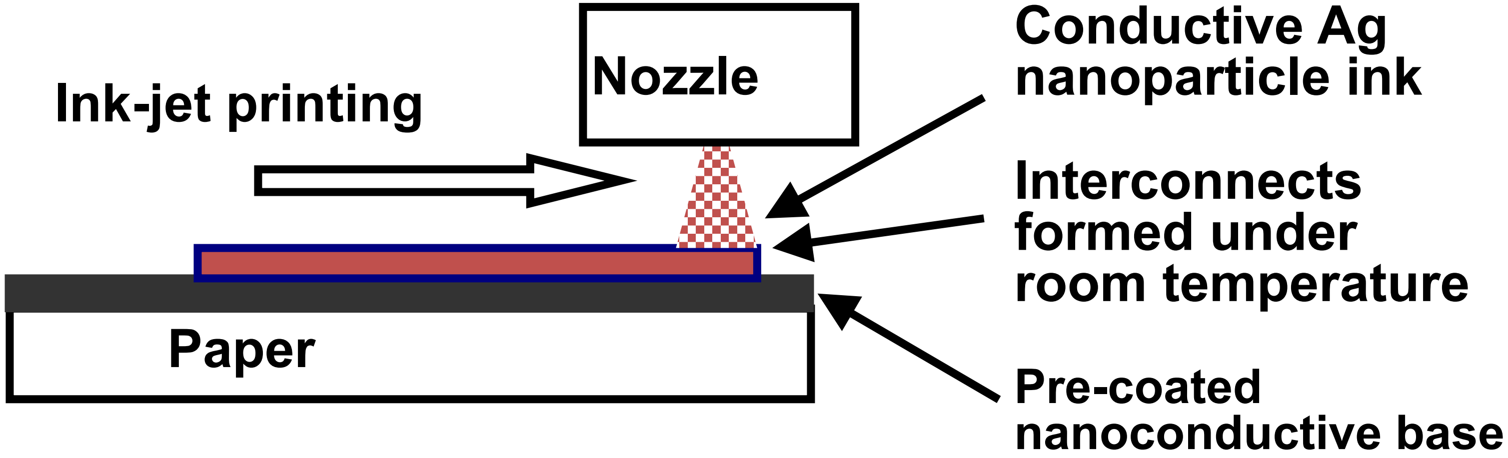
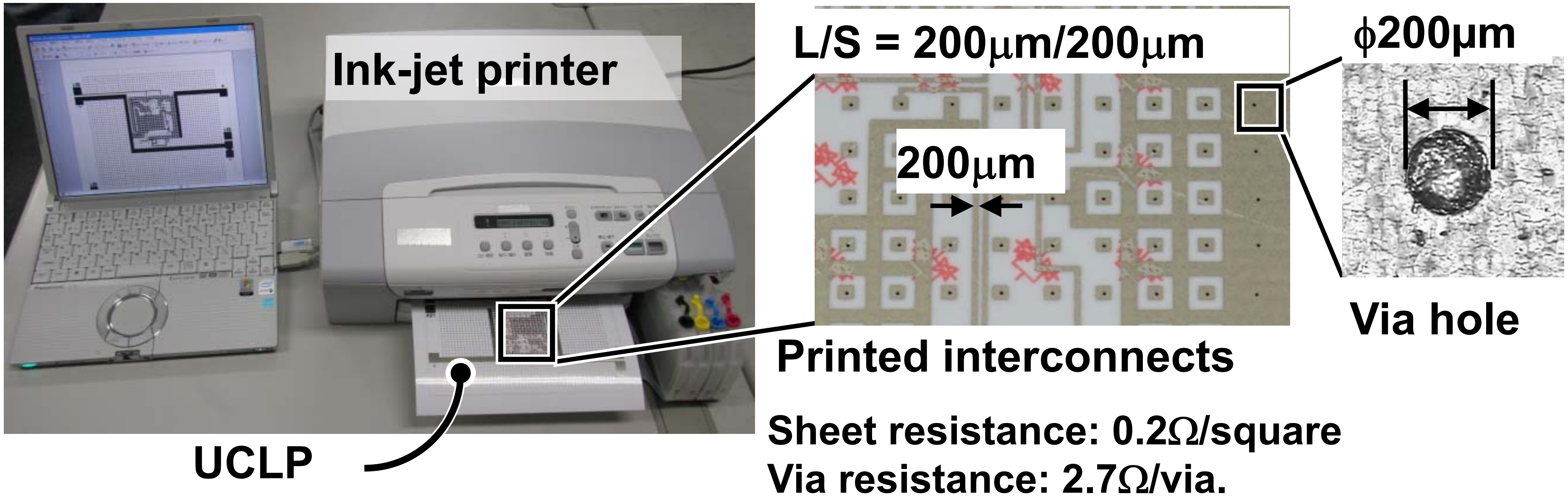
Ink-jet printed interconnects

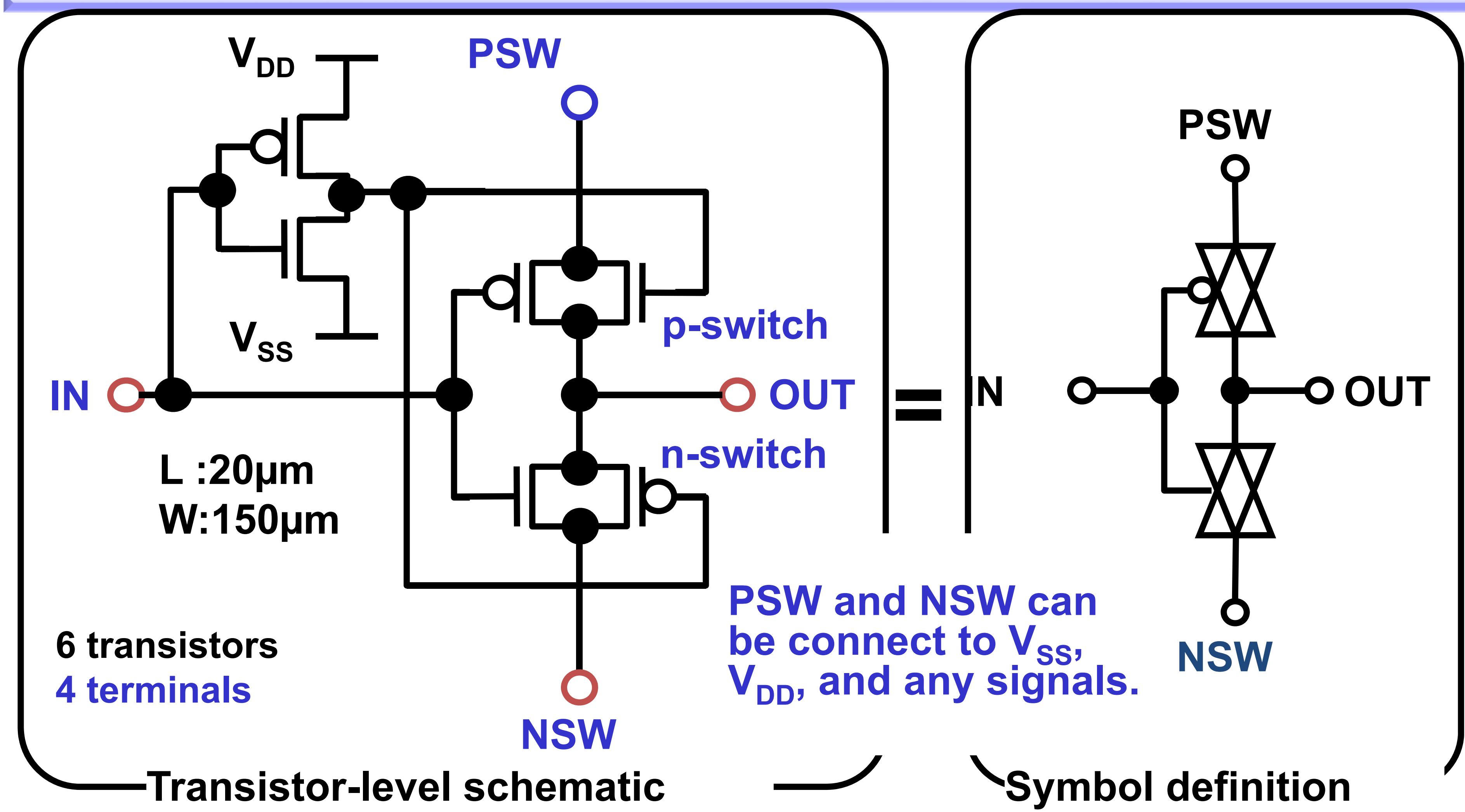




Sheet resistance: 0.2Ω/square
Via resistance: 2.7Ω/via.

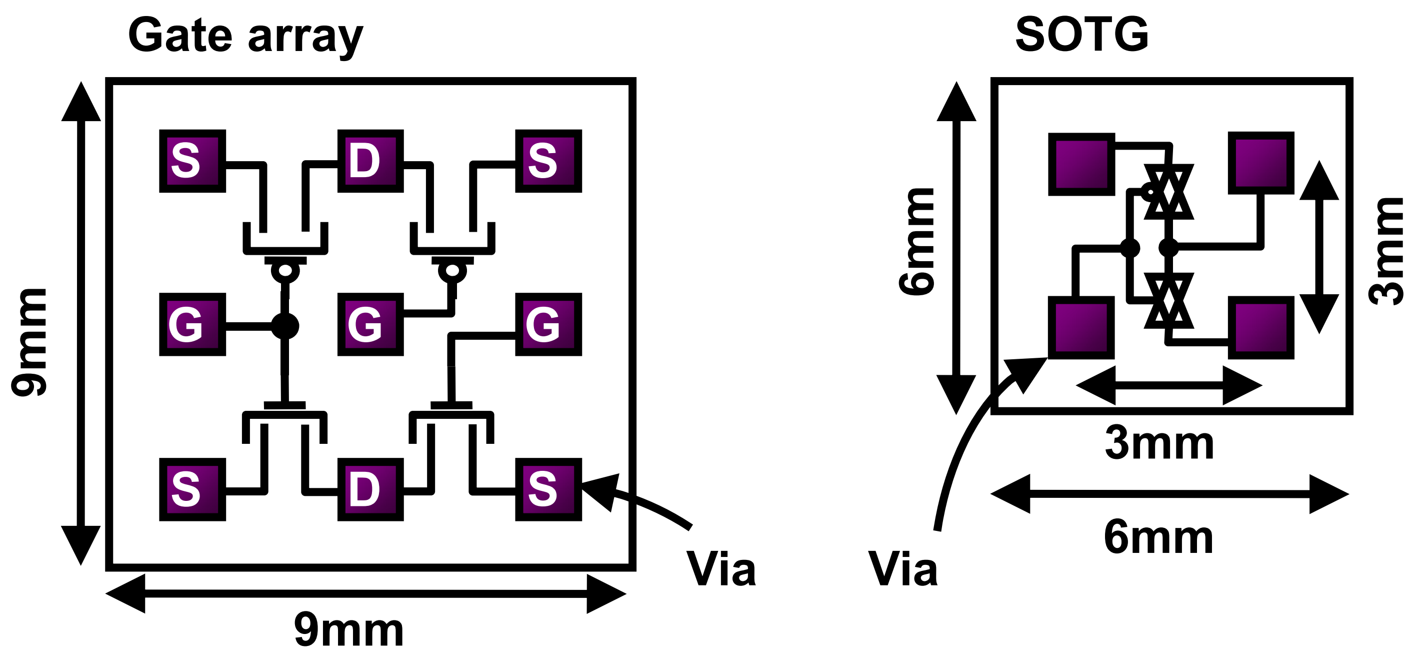
T.Sakurai

Schematic of SOTG unit cell



SOTG unit cell includes a couple of complementary transmission gates and 4 terminals.

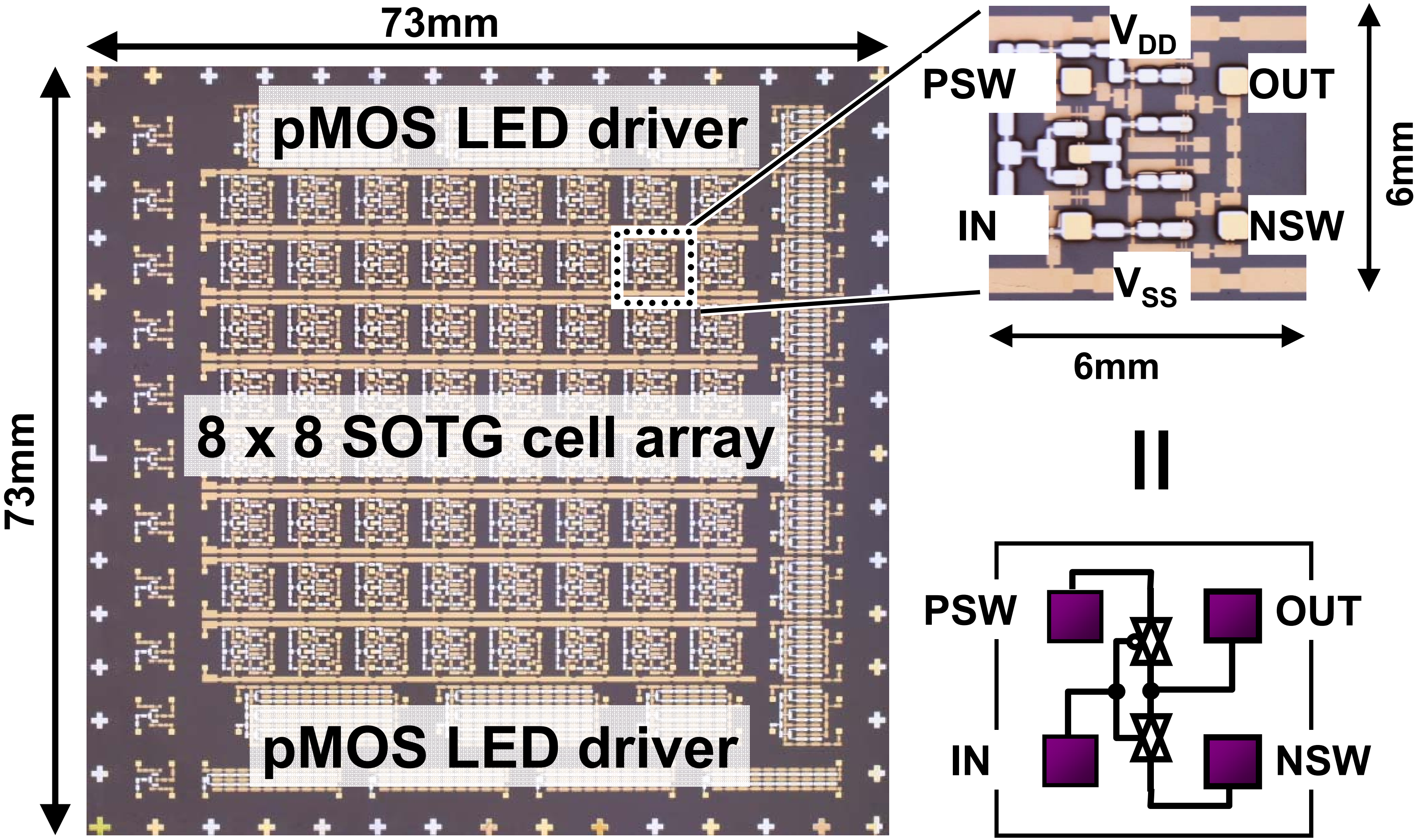
Comparison of unit logic cell



	Gate array (Conventional)	SOTG (This work)
Number of transistors	4	6
Number of vias	9	4
Area*	81mm^2	36mm^2

*Calculated on a fixed via spacing of 3mm.

8x8 SOTG cell array



Fabricated organic CMOS on polyimide film

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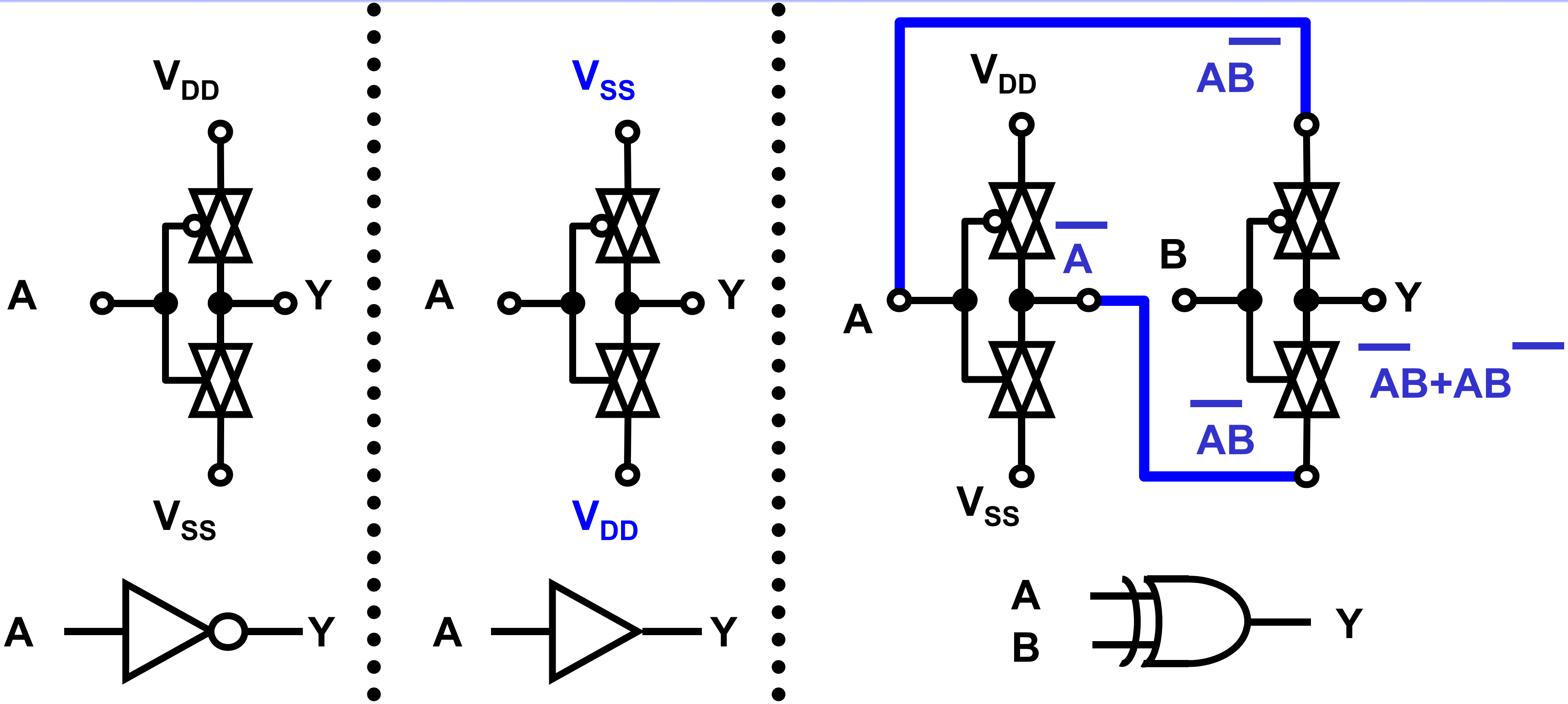
Examples of logic function in SOTG



Inverter

Buffer

Exclusive OR

Buffer can be implemented with one unit cell.
Any 2-input logic function can be implemented with only 2 cells.

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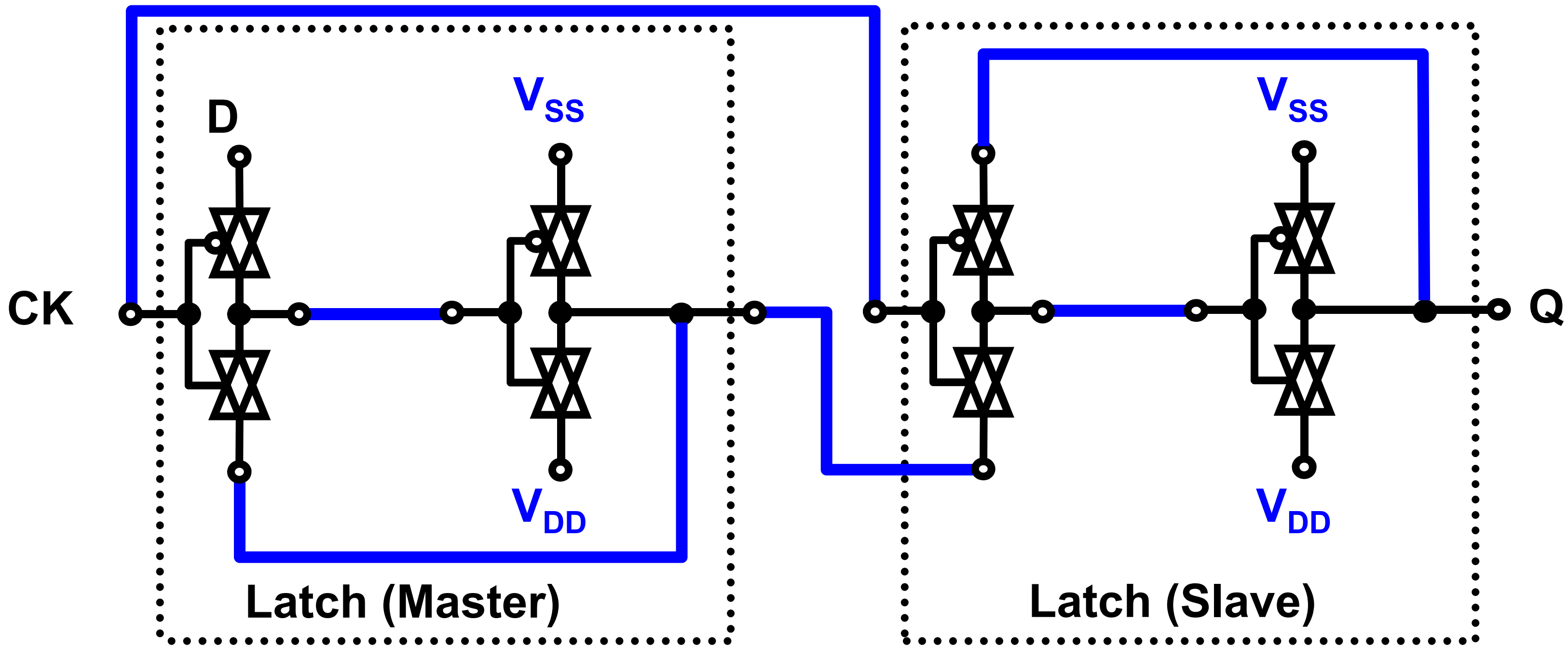
D flip flop in SOTG



Configuration of D-flip flop (Positive edge triggered)

A D-flip flop can be implemented with 4 unit cells.

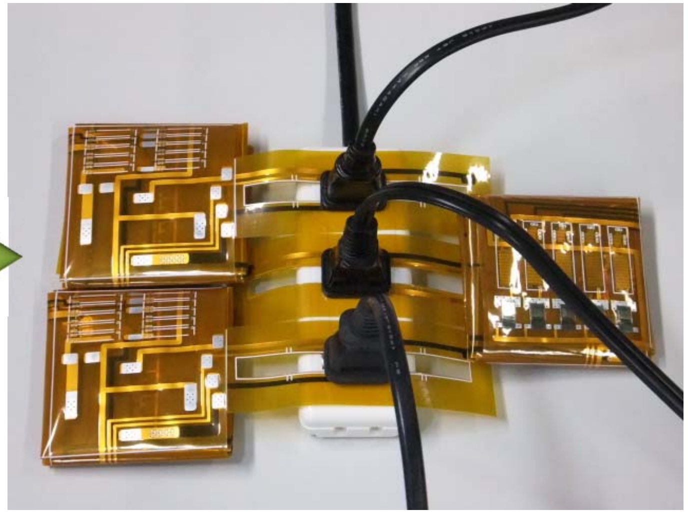
Power monitoring of each electric outlet

Past

Current commercial AC power meter

Large size, hard...

Future (This work)

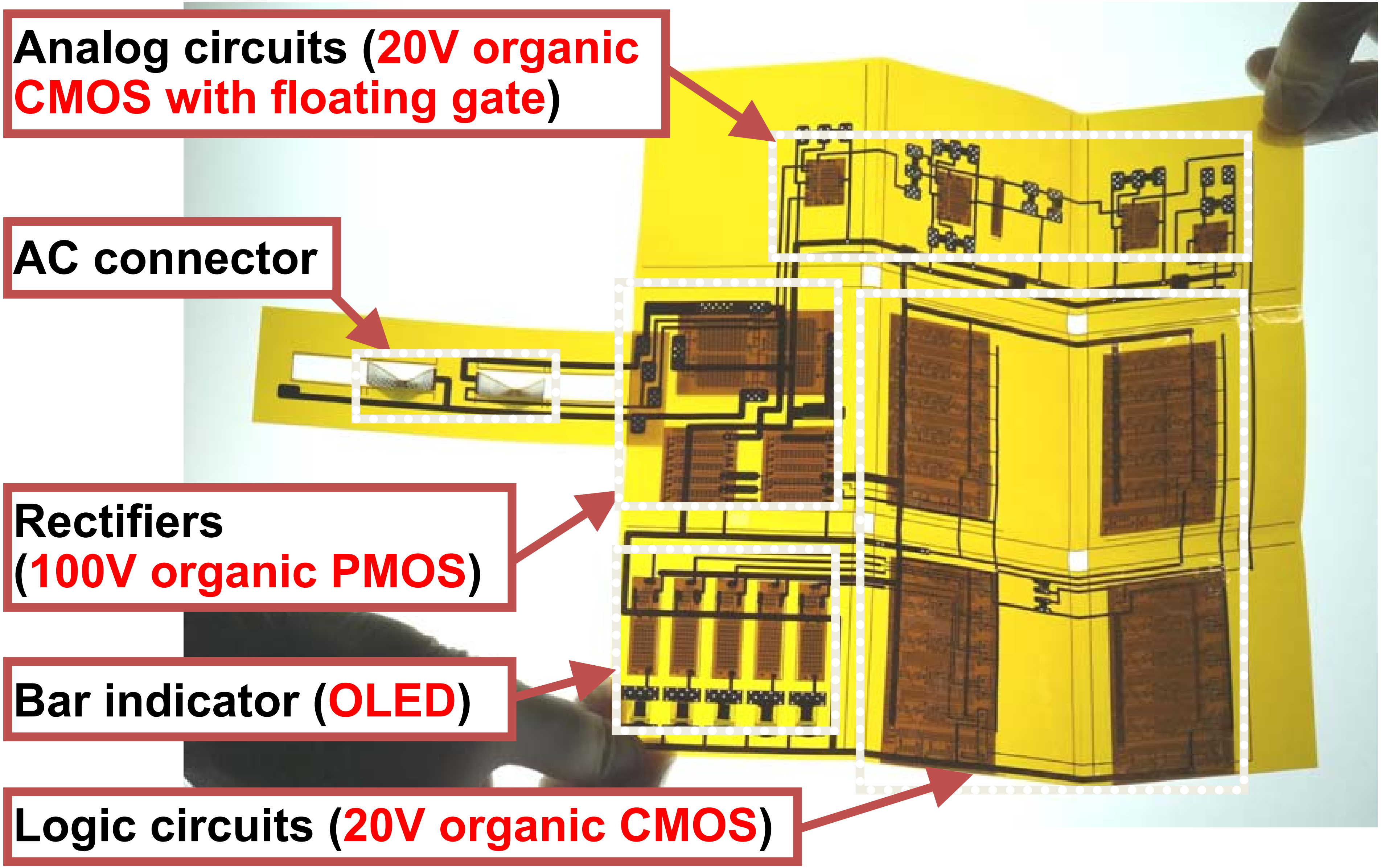


Flexible, low cost...

Printable organic devices on flexible films have potential to realize low-cost System-on-a-Film.

K.Ishida, T-C Huang, K.Honda, T.Sekitani, H.Nakajima, H.Maeda, M.Takamiya, T.Someya, T.Sakurai, "100V AC Power Meter System-on-a-Film (SoF) Integrating 20V Organic CMOS Digital and Analog Circuits with Floating Gate for Process-Variation Compensation and 100V Organic PMOS Rectifier," ISSCC'11, paper#12.2, pp.218-219, Feb.2011.

100V AC power meter: System-on-a-Film (SoF)



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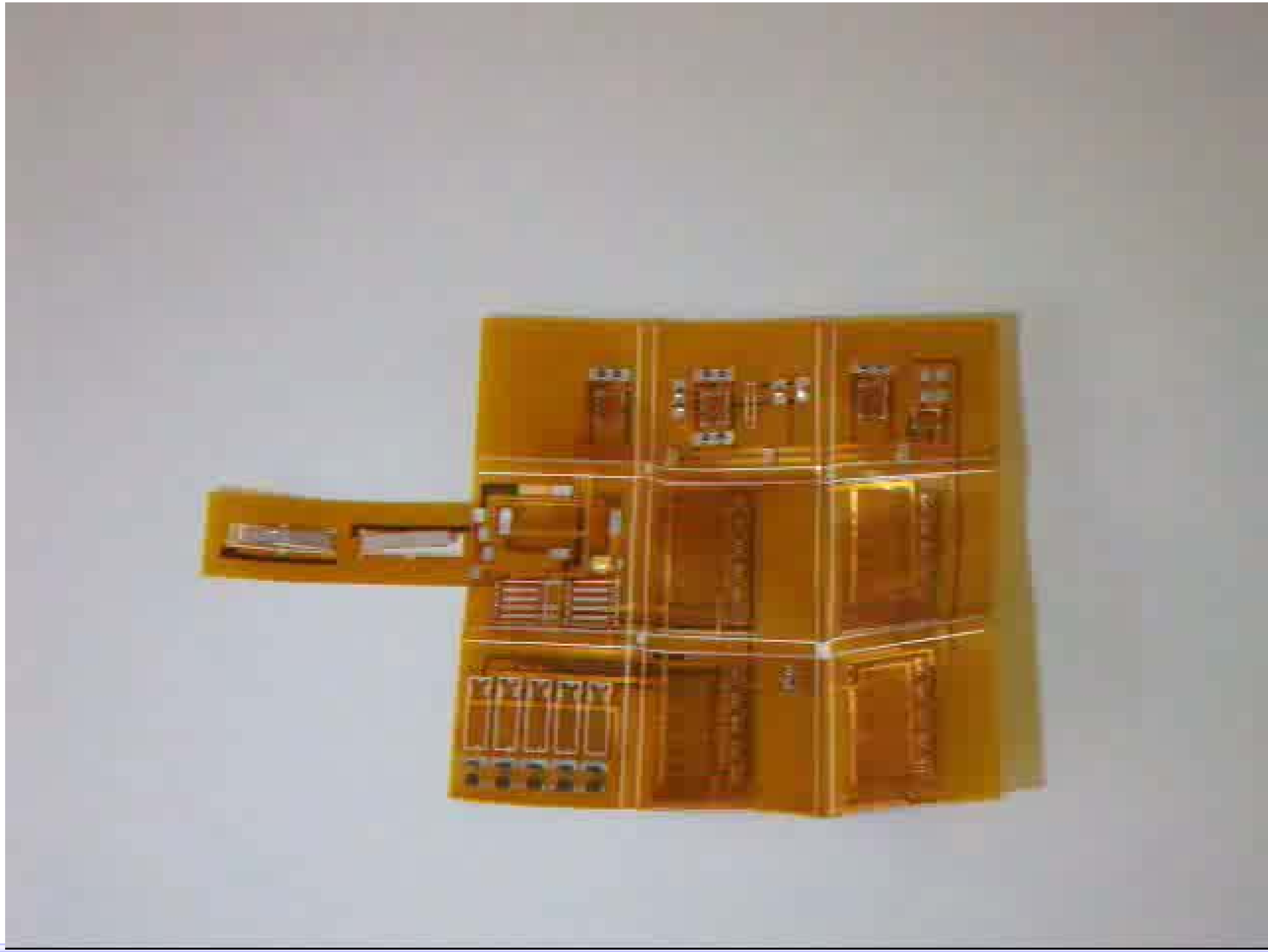
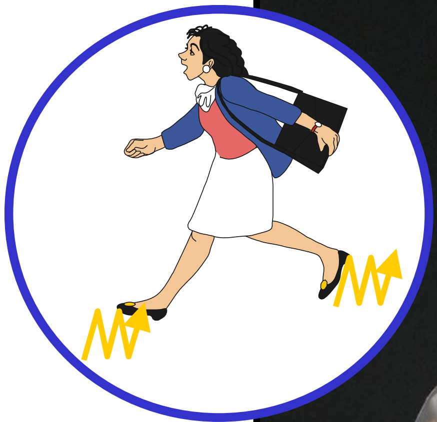
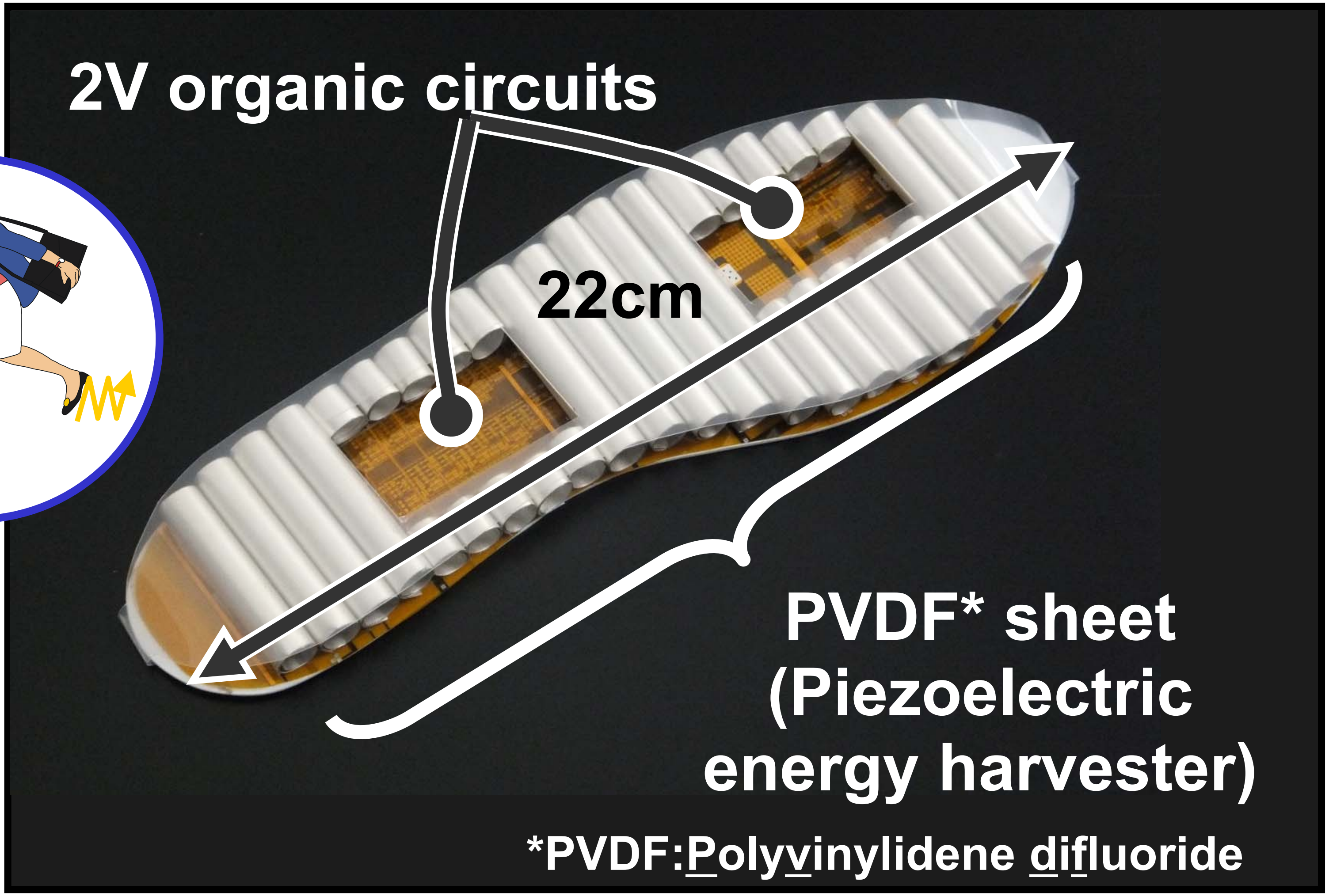
Organic 100V AC power meter (SoF)



Organic insole pedometer

Energy harvester for wearable systems

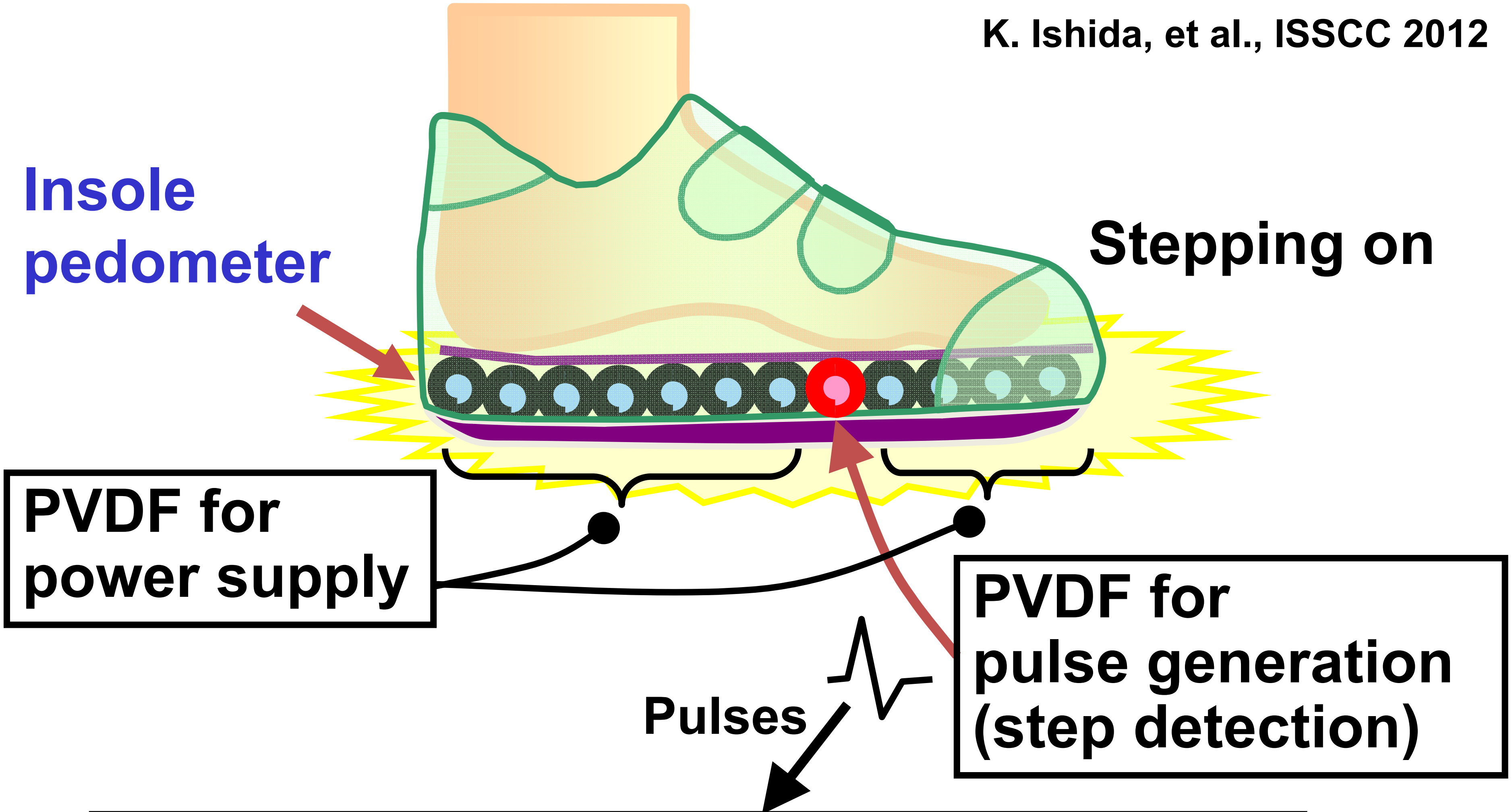




K.Ishida, T-C.Huang, K.Honda, Y.Shinozuka, H.Fuketa, T.Yokota, U.Zschieschang, H.Klauk, G.Tortissier, T.Sekitani, M.Takamiya, H.Toshiyoshi, T.Someya, T.Sakurai, "Insole Pedometer with Piezoelectric Energy Harvester and 2V Organic Digital and Analog Circuits, " ISSCC'12, Paper#18.1, Feb. 2012.

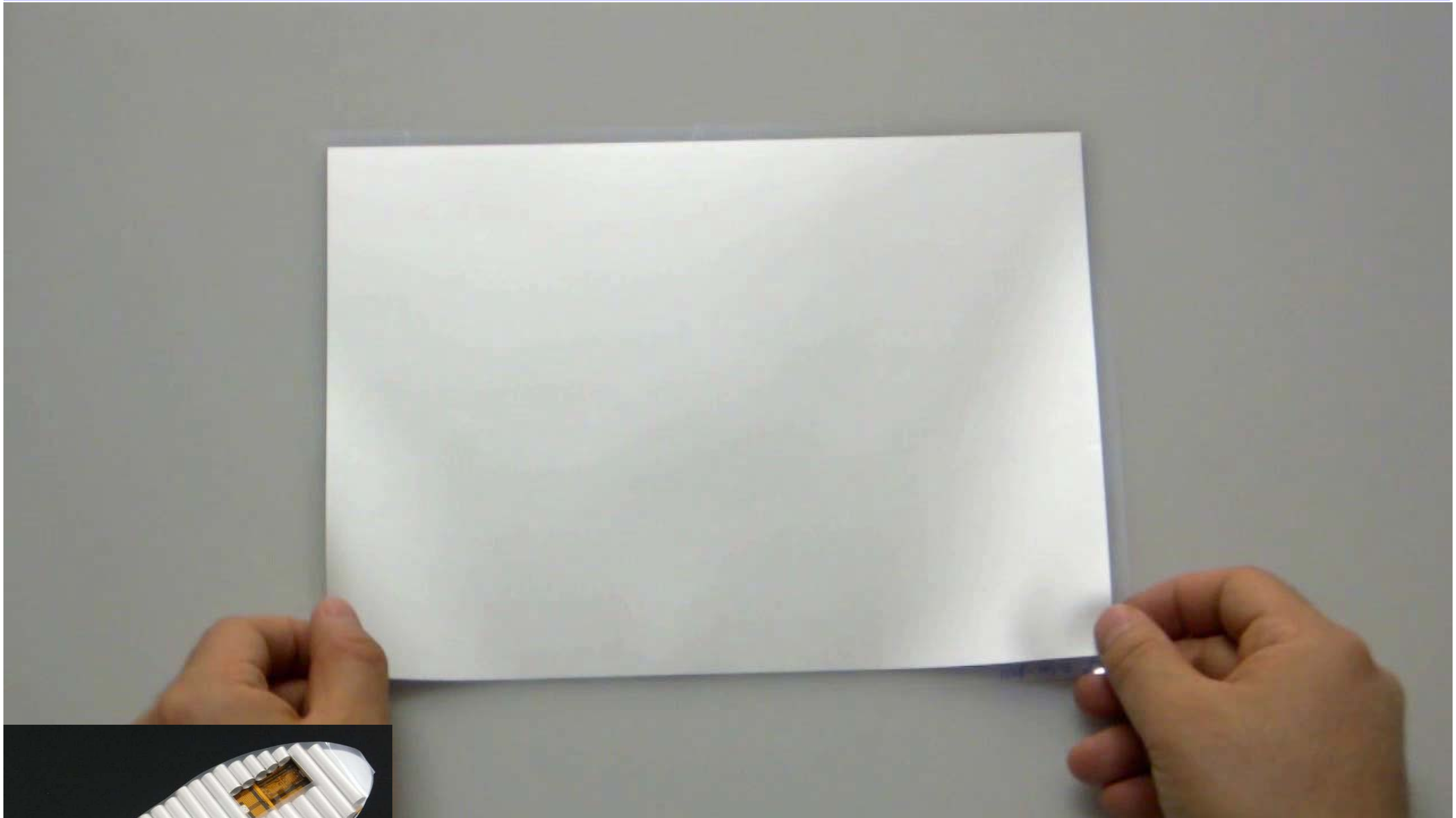
Proposed insole pedometer

K. Ishida, et al., ISSCC 2012



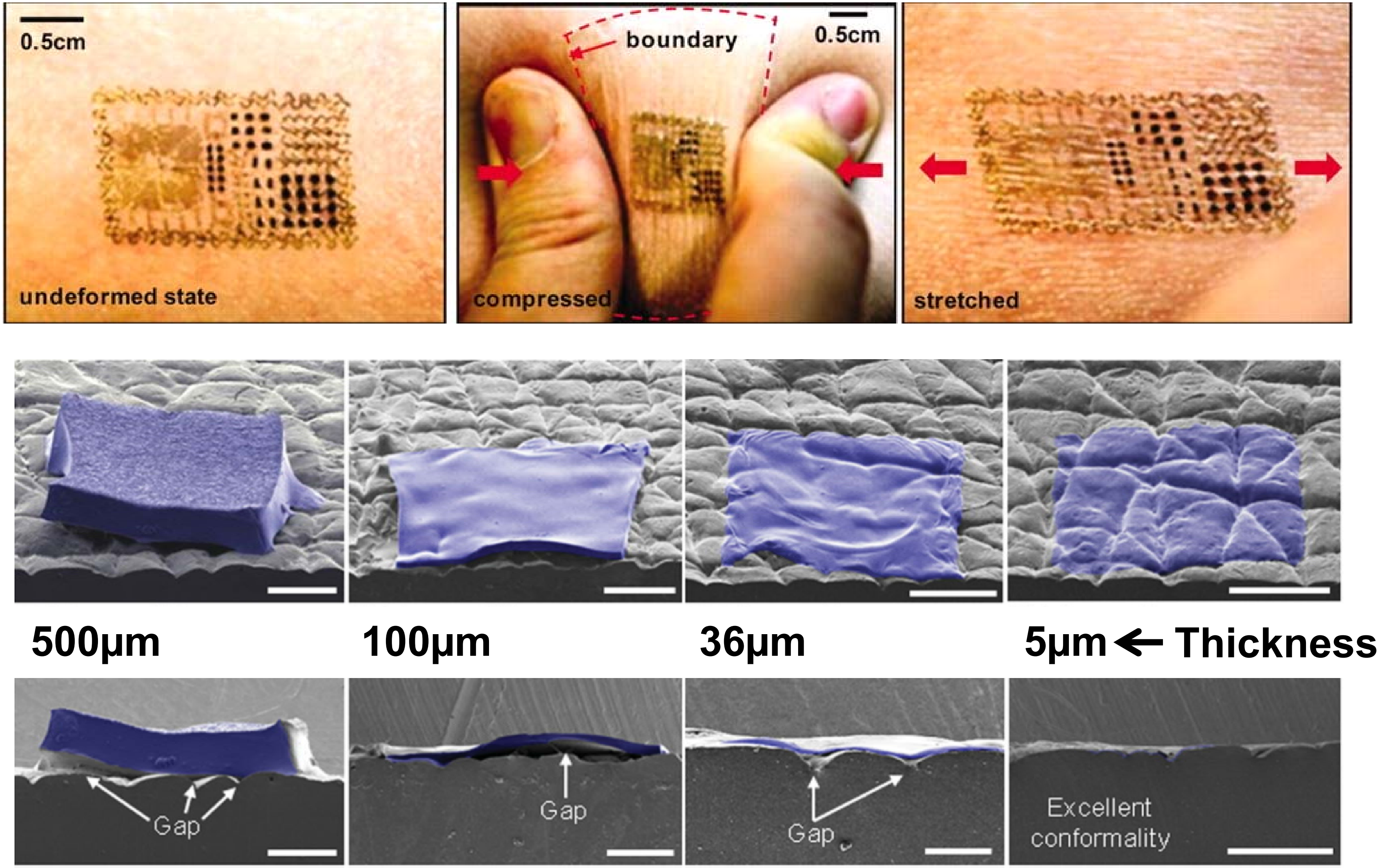
Pulse shaping
Count up the number of pulses (=steps)

Harvesting experiment



Bio-compatible applications with flexible OFETs

Integrated on skin with 5μm thickness



Dae-Hyeong Kim, John A. Rogers, et al., Science 333, 838 (2011).

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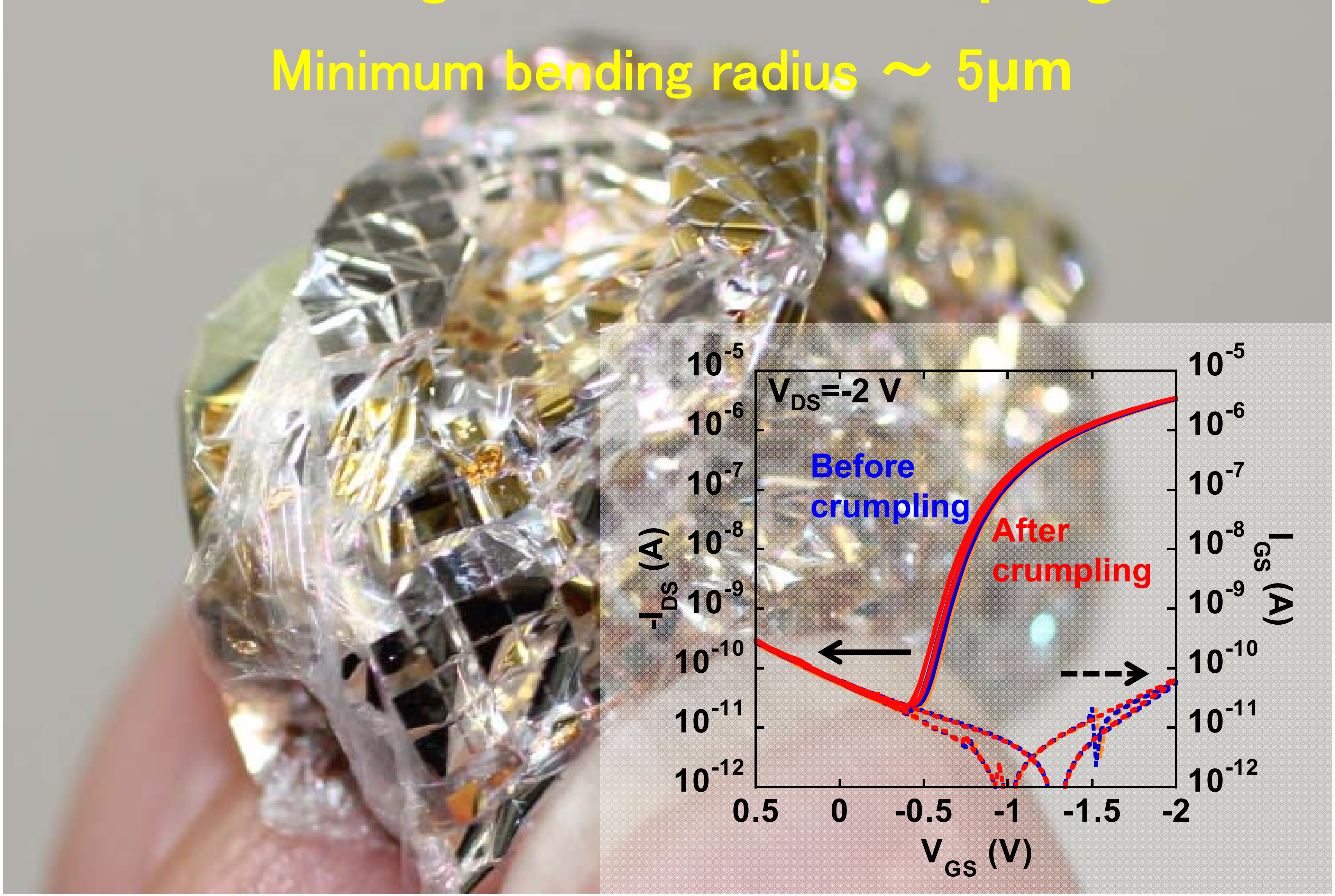
Amazing robustness: Crumpling

Minimum bending radius ～ 5µm



From Robotics to Human

Robotics E-skins
(2003)

t=1～2 mm

T. Someya et al., IEDM #8.4, 203 (2003).
T. Someya et al., PNAS 101, 9966 (2004).
T. Someya et al., PNAS 102, 12321 (2005).

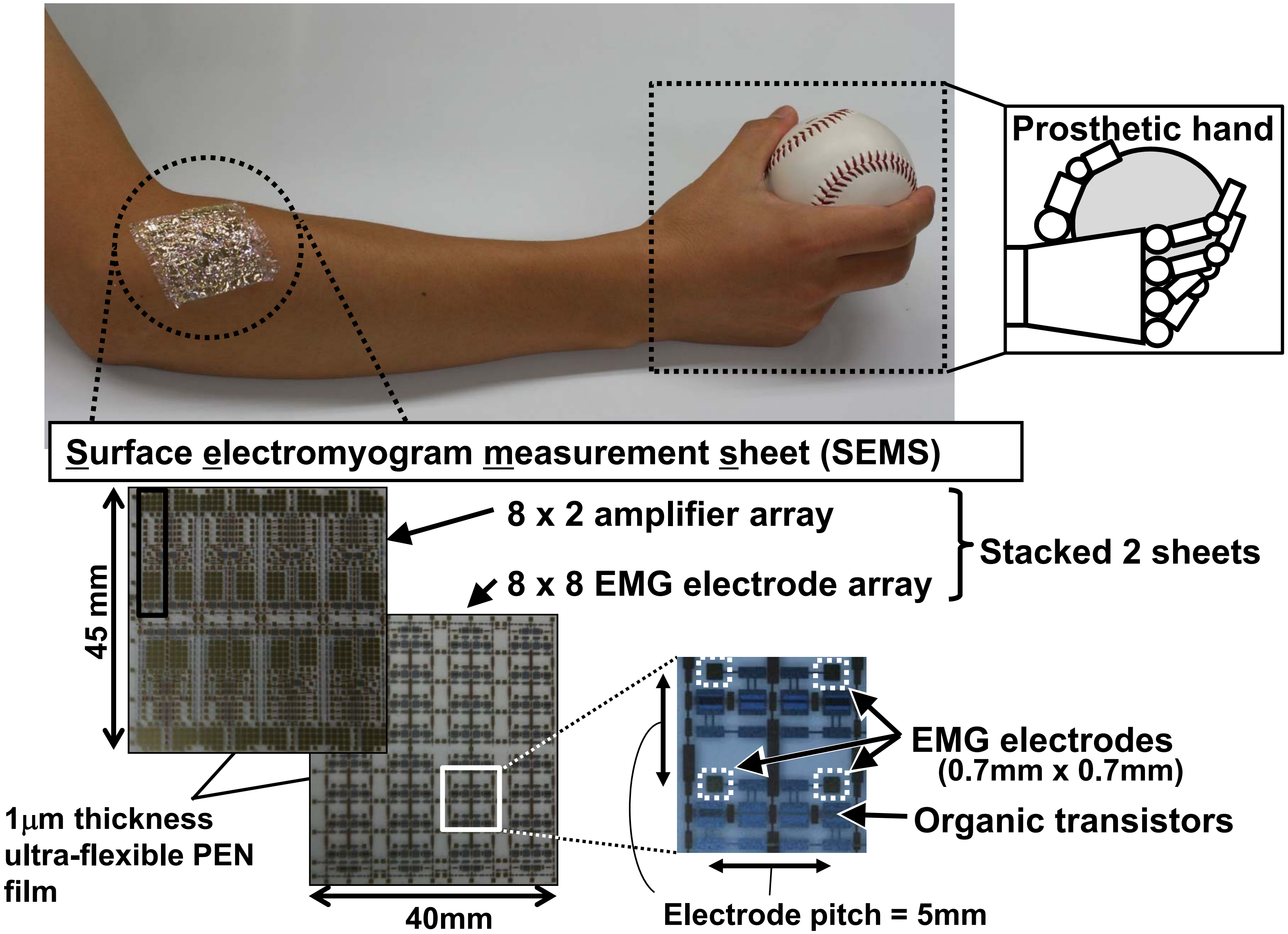
Thickness：1/1000

Bionic Skins
(2013)

t=2μm

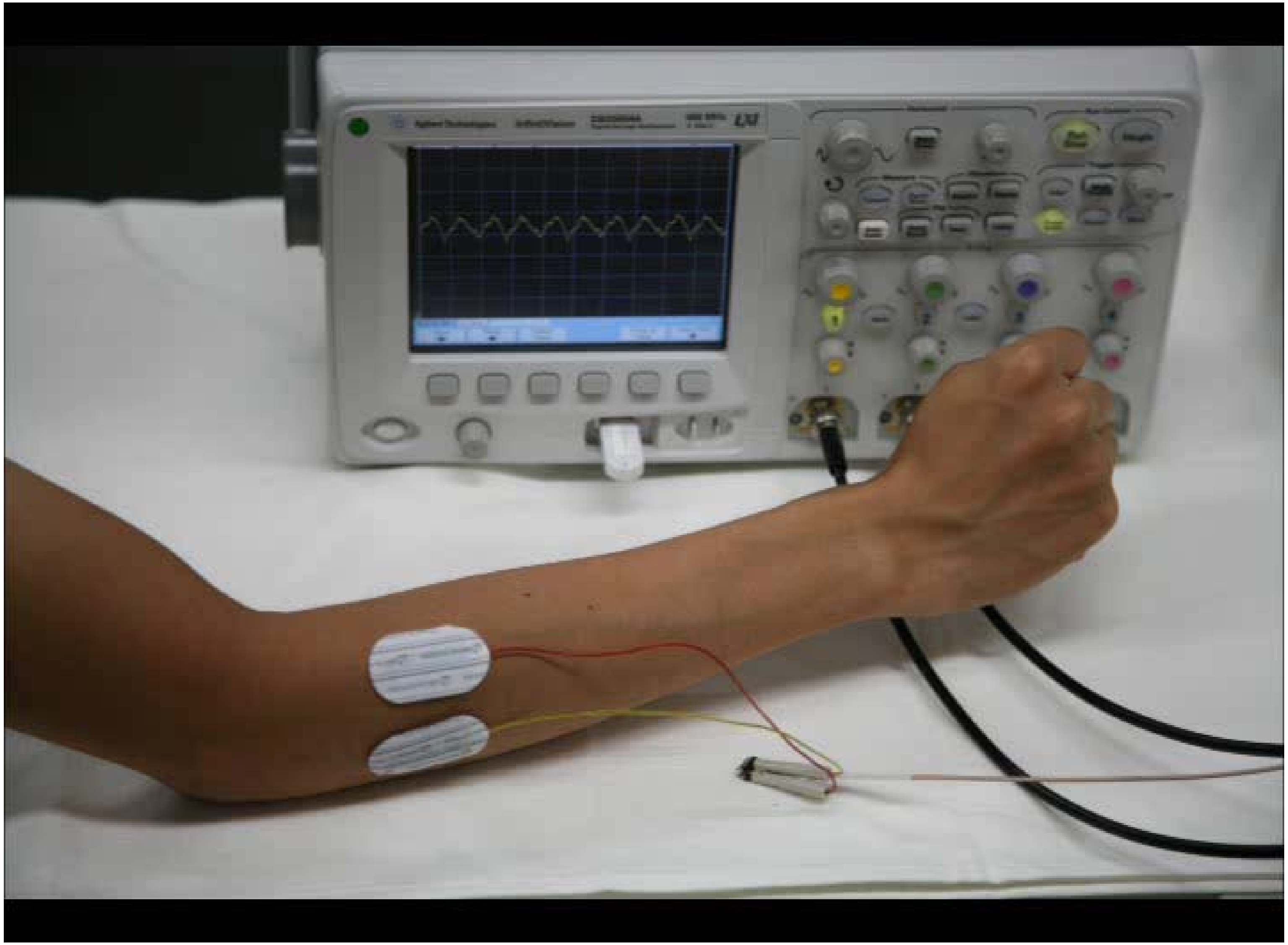
M. Kaltenbrunner, et al., Nature 499, 458 (2013).

Electromyogram measurement sheet



H. Fuketa, K. Yoshioka, Y. Shinozuka, K. Ishida, T. Yokota, N. Matsuhisa, Y. Inoue, M. Sekino, T. Sekitani, M. Takamiya, T. Someya, T. Sakurai, "1um-Thickness 64-Channel Surface Electromyogram Measurement Sheet with 2V Organic Transistors for Prosthetic Hand Control," ISSCC, paper#6.4, 2013.

Electromyogram (EMG) measurement



Electronic Diaper: Background

Wet sensor for biomedical, nursing-care, elderly-care, etc.

- **Thin and mechanically flexible**
- **Wireless power and data transmission**
- **Low-cost (disposable)**

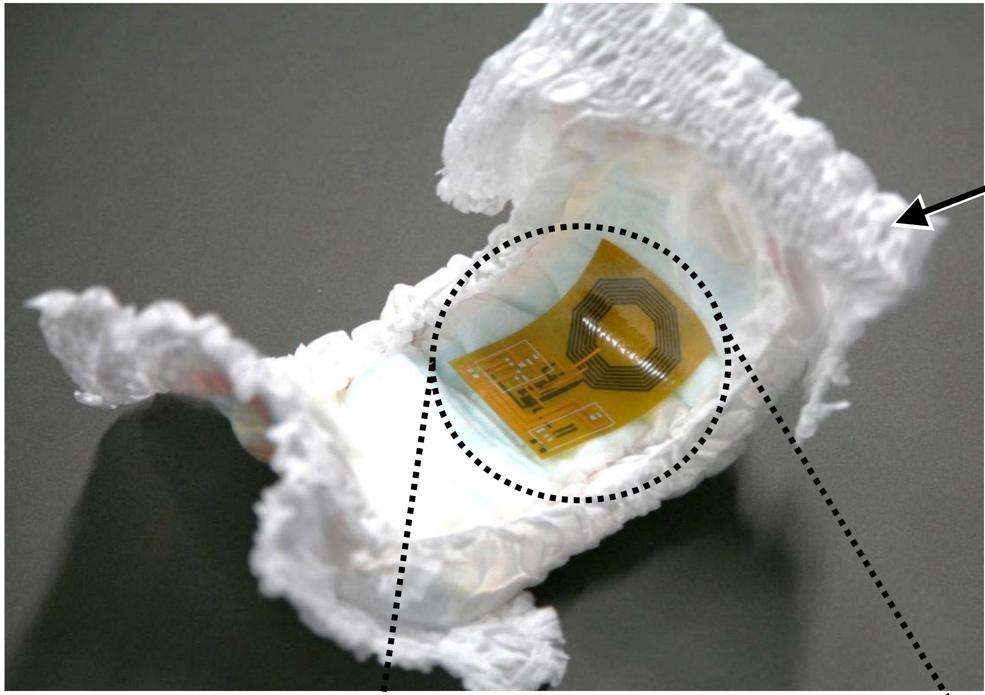
➔ **Organic flexible fully integrated circuit**

➔ **Can be applied to various bio-sensors**

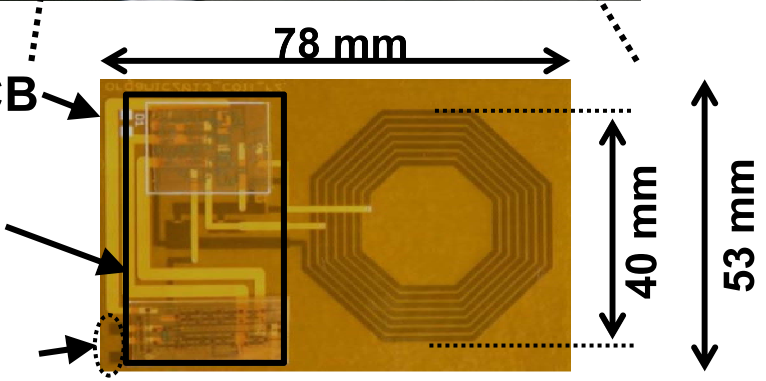
Elderly care

For babies

Electronic diaper



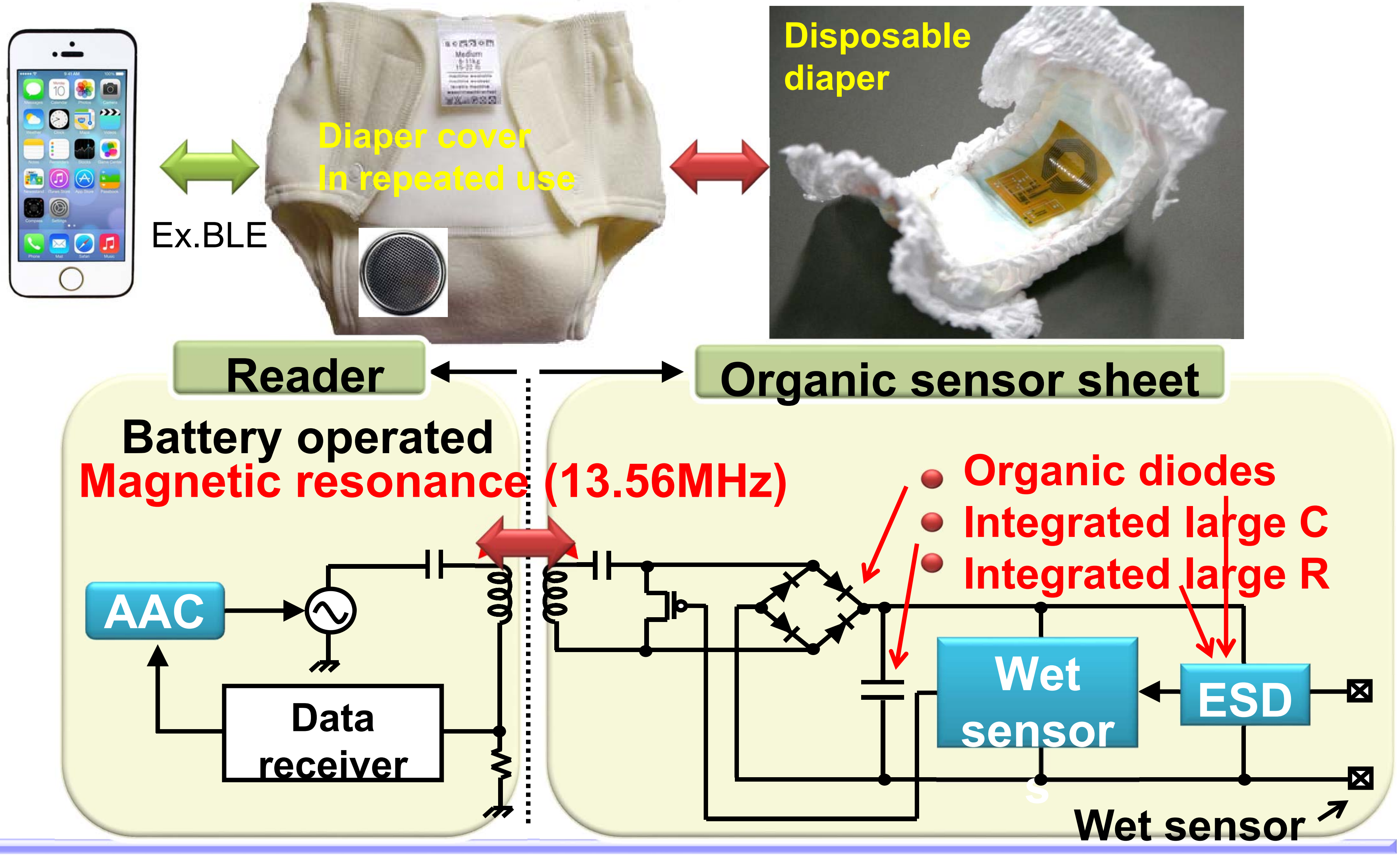
- Sensing
- Wireless power
- Wireless data
- ESD



Fully integrated thin and flexible system w/o external components

H. Fuketa, K. Yoshioka, T. Yokota, W. Yukita, M. Koizumi, M. Sekino, T. Sekitani, M. Takamiya, T. Someya, T. Sakurai, "Organic-Transistor-Based 2kV ESD-Tolerant Flexible Wet Sensor Sheet for Biomedical Applications with Wireless Power and Data Transmission Using 13.56MHz Magnetic Resonance," IEEE ISSCC'14, Feb. 2014.

Electronic diaper use-case

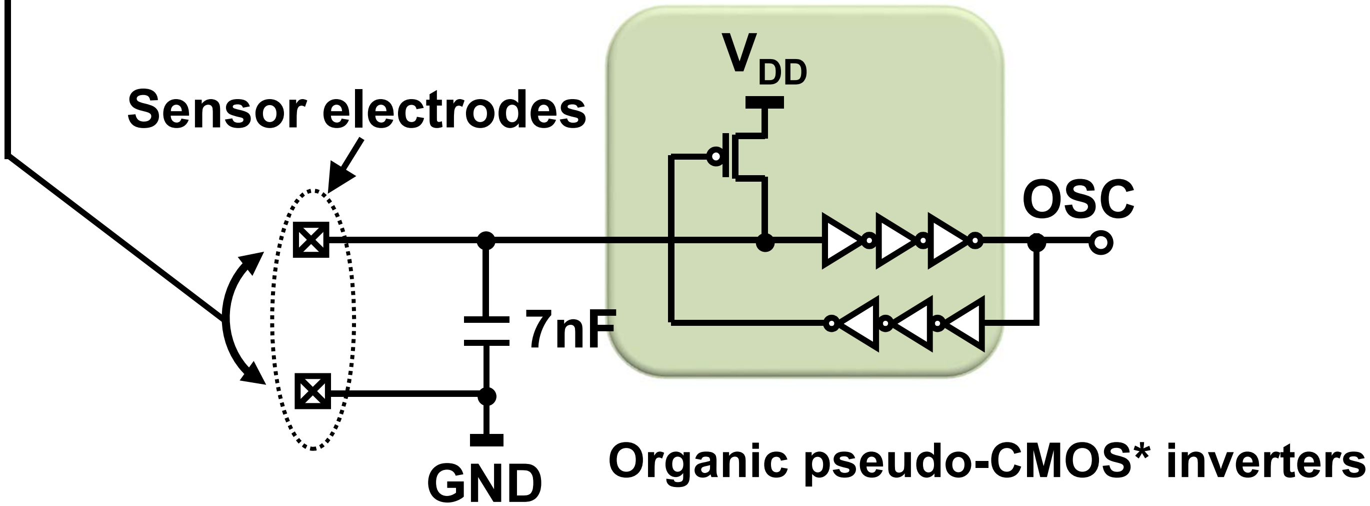


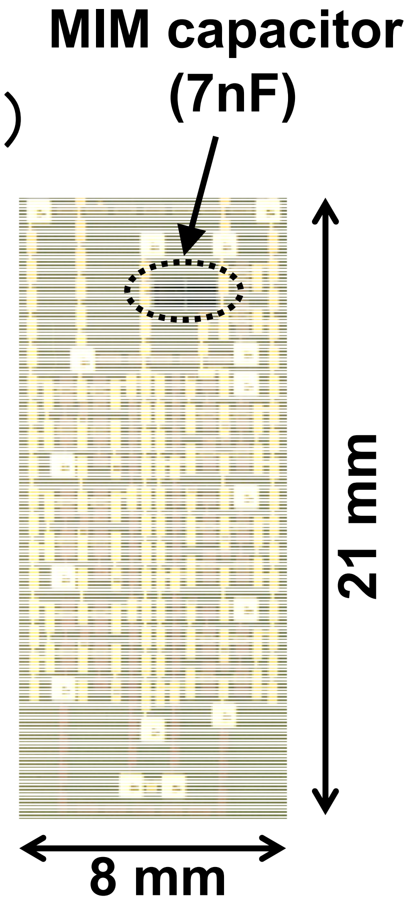
T.Sakurai

Sensing: RC oscillator

Dry : R_{SENSE} ➔ ∞
➔ **No oscillation**

Wet : R_{SENSE} ➔ MW (normal saline)
➔ **Oscillation**

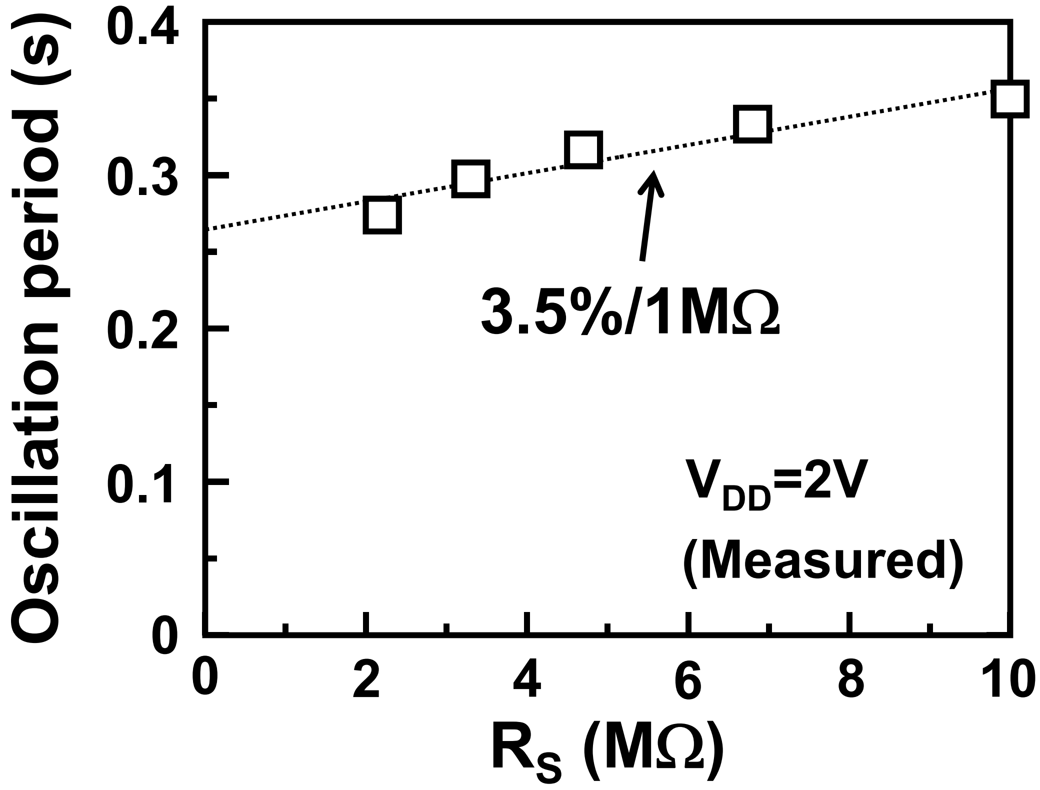




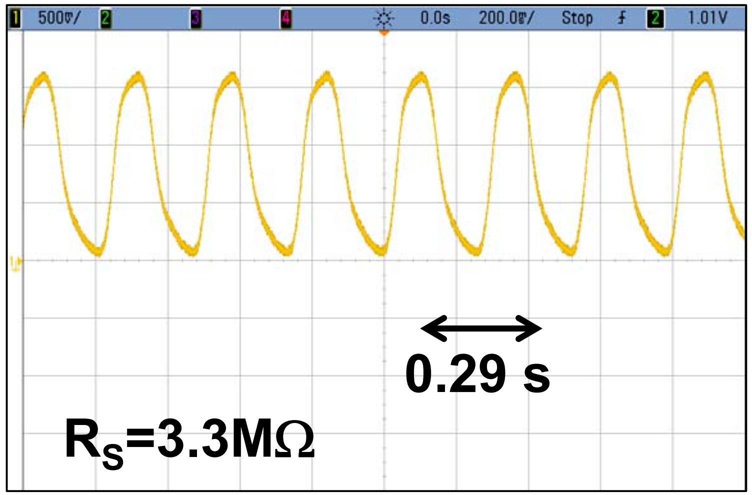
* T.-C. Huang, et al., DATE 2010.

Sensing with RC oscillator

Resistance dependence of oscillation period



Measured waveform



- Oscillation period is proportional to R_S.
- Power dissipation: 1.4μW @ 3Hz

Wireless power transmission

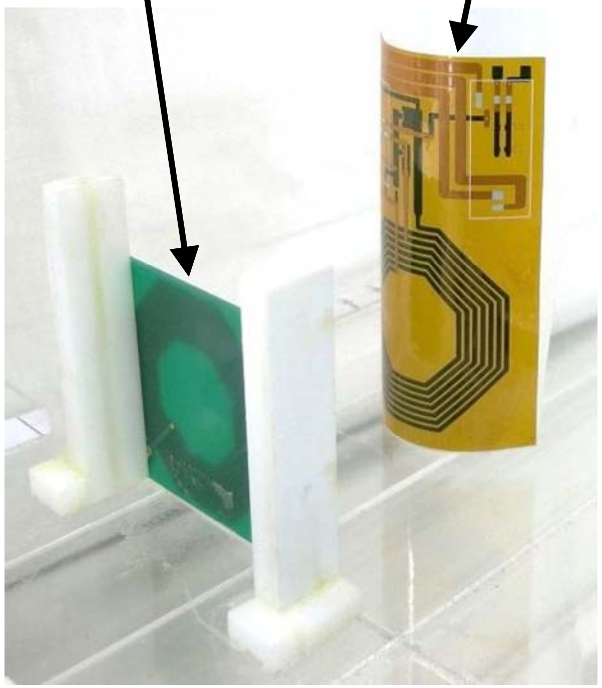
Magnetic resonance (13.56MHz)

Power transmission efficiency varies due to:

- Increase in distance between reader coil (L_1) and sensor sheet coil (L_2)
- Bend of sensor sheet coil (L_2)

L_1 coil (Reader)

L_2 coil (Sensor sheet)

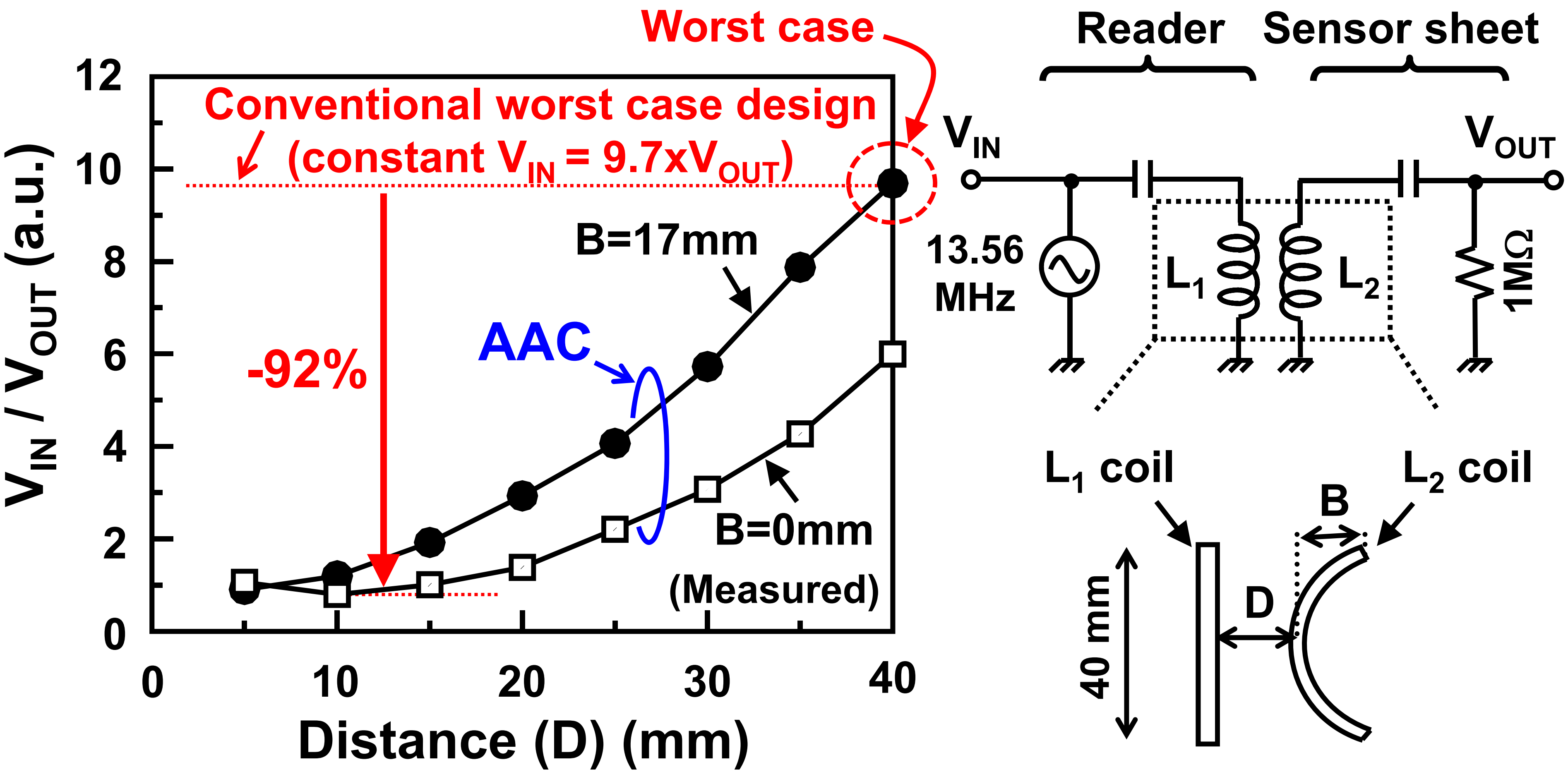


To reduce power consumption of battery-operated reader

↓

Reader should transmit **minimum necessary power.**

Adaptive amplitude control (measured)



- AAC reduces amplitude up to 92% compared with conventional worst case design.

ESD protection

Sensor electrodes may experience high voltage (2kV) by charged-up human body.

➔ ESD protection is imperative in sensor sheet.

ESD protection has not been taken into account for organic circuits.

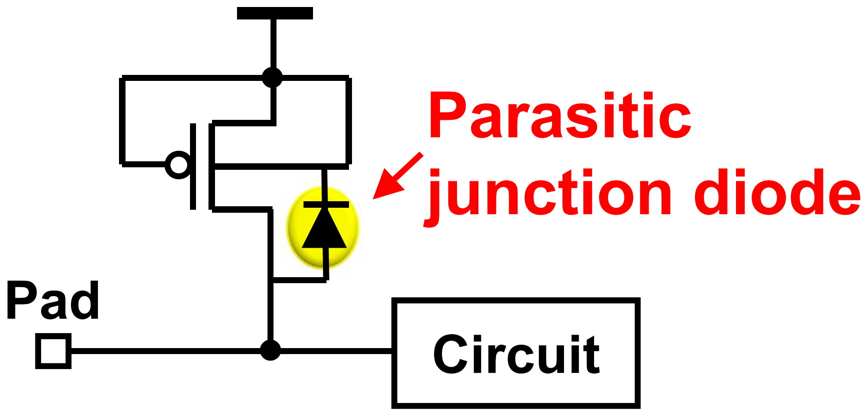
- ESD protection circuit is investigated for organic circuits.
- ESD tolerance is checked according to ESD standard of IEC 61000-4-2.

Problem of ESD in organic transistors

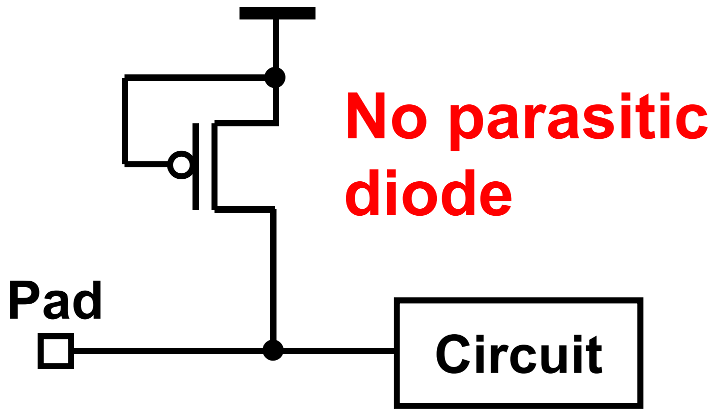
Organic transistors are fabricated on insulating film.

➔ ESD protection in organic transistors is difficult.

ESD in Si transistors



ESD in organic transistors

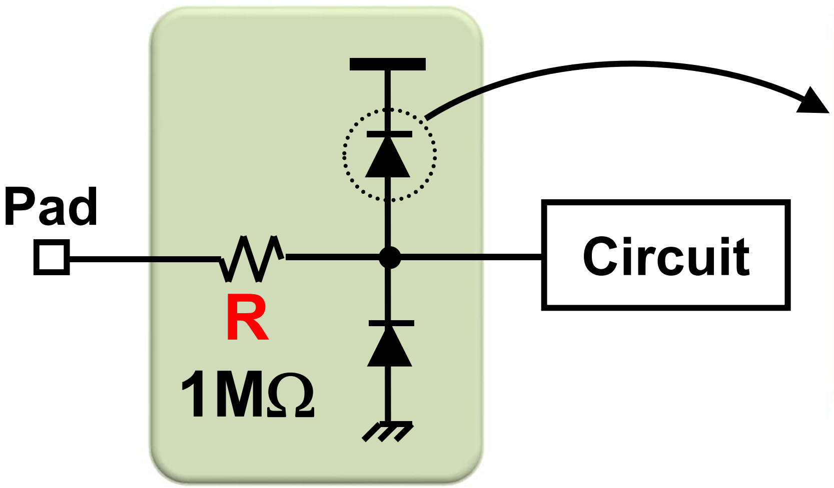


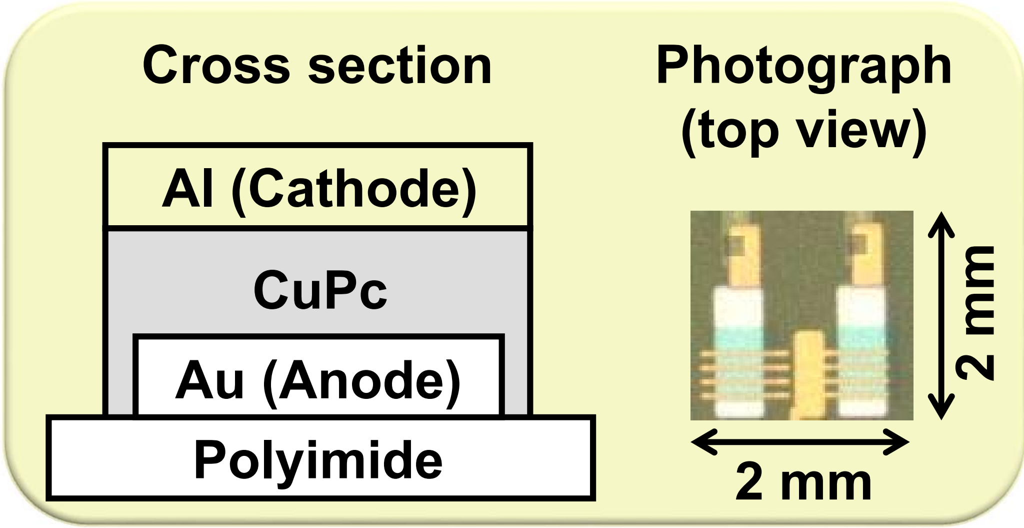
ESD protection with organic diodes

Schottky diode with copper phthalocyanine (CuPc)

- Vertical structure *

→ { - Larger current drivability
  - Better frequency characteristic
  (→ Also used for rectifier)





Large resistance can be used due to slow speed

→ Limit diode current

* Y. Ai, et al., Appl. Phys. Lett. 90, 262105 (2007).

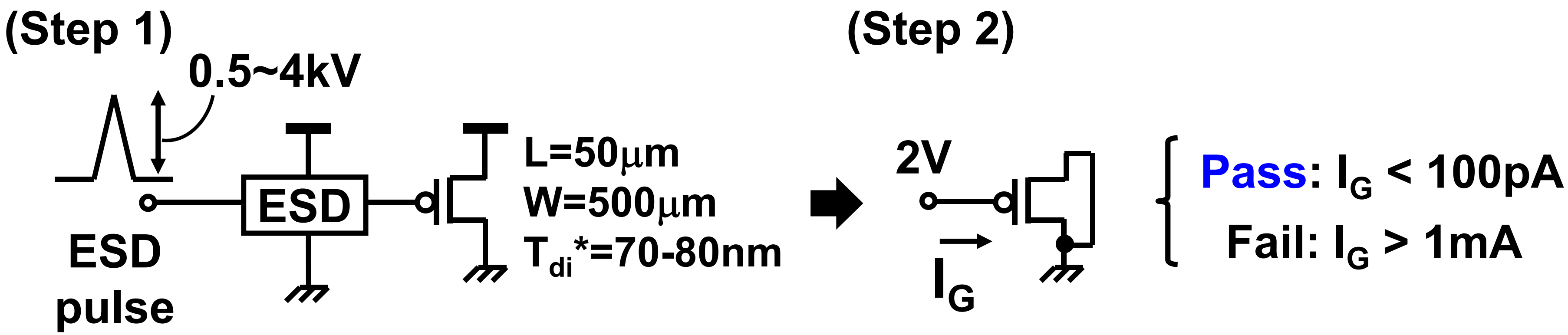
T.Sakurai

ESD protection with organic diodes

ESD measurement (IEC 61000-4-2)

- ESD tolerance is checked by measuring gate current.

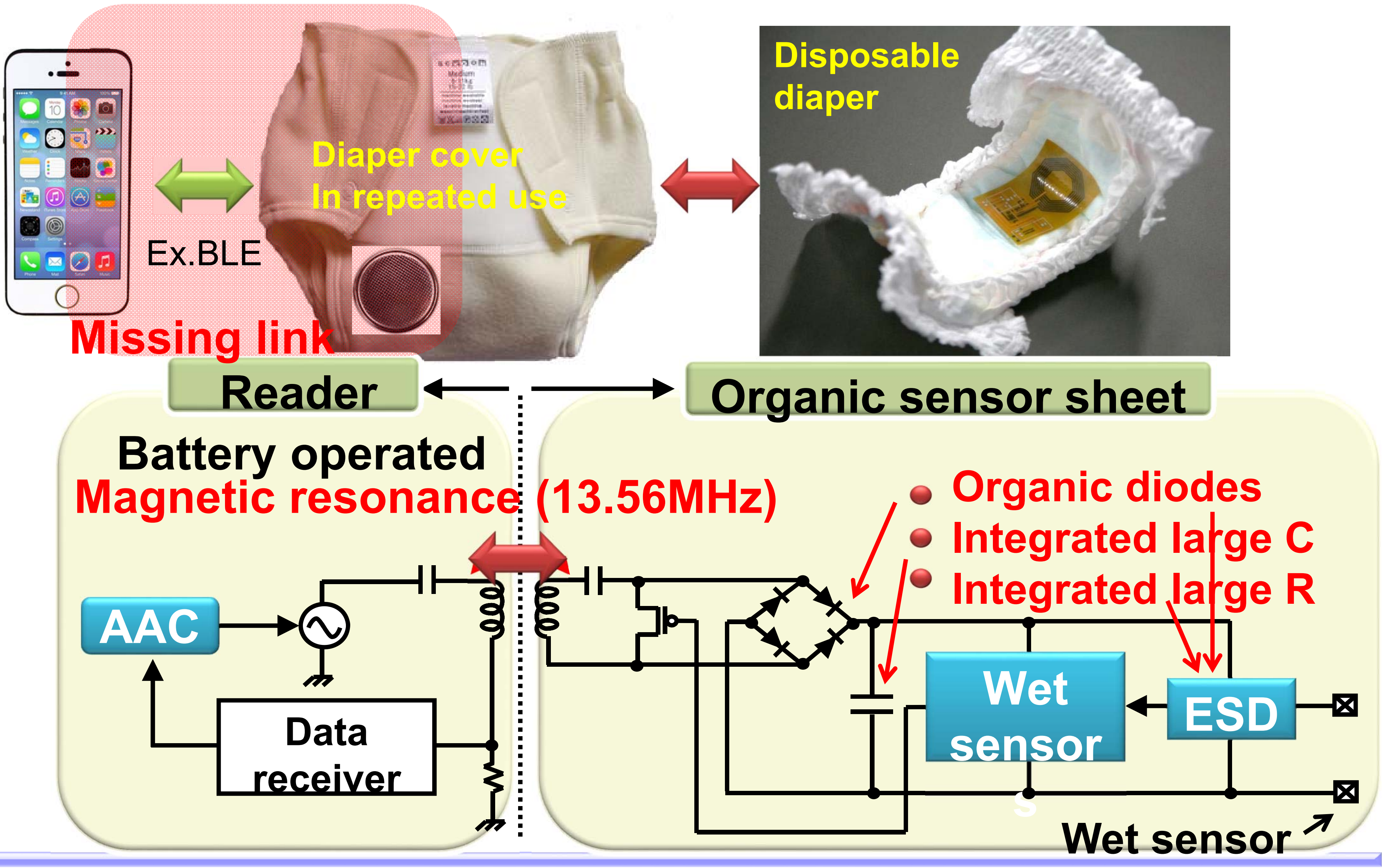
➔ 2kV ESD tolerance is achieved.



	Initial	0.5kV	1kV	2kV	4kV
Without ESD Protection	Pass	Fail	Fail	Fail	Fail
With ESD Protection	Pass	Pass	Pass	Pass	Fail

(*) T_{di}: Thickness of gate dielectric (parylene)

Electronic diaper use-case



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Outline

- Organic transistor based systems
  - Large-area electronics applications
  - Bio-compatible applications
- Other nano-electronics devices
- What is lacking : Platform for systems

Japan's National Projects for Next-Generation Nano-electronics Devices

2006	2007	2008	2009	2010	2011	2012	2013	2014	2015

METI / NEDO MIRAI Ⅲ project

EIDEC (Advanced Mask & Resist)

METI Nanoelectronics project
(Non-Si channel, Nanowire, XMOS)

JST Watanabe-CREST project (2007start)

Cabinet's Sai-sentan Research Support Program

METI, MEXT, AIST, NIMS, Tsukuba Univ.
Tsukuba Innovation Arena (TIA)

NEDO ASET 3D Dream Chip Project

Innovative Nano-electronics through Interdisciplinary Collaboration among Material, Device and System Layers

Started 2013 for 7 years.

JST's New Nano Program
Sakurai-CREST

Courtesy: Seiichiro Kawamura (JST)

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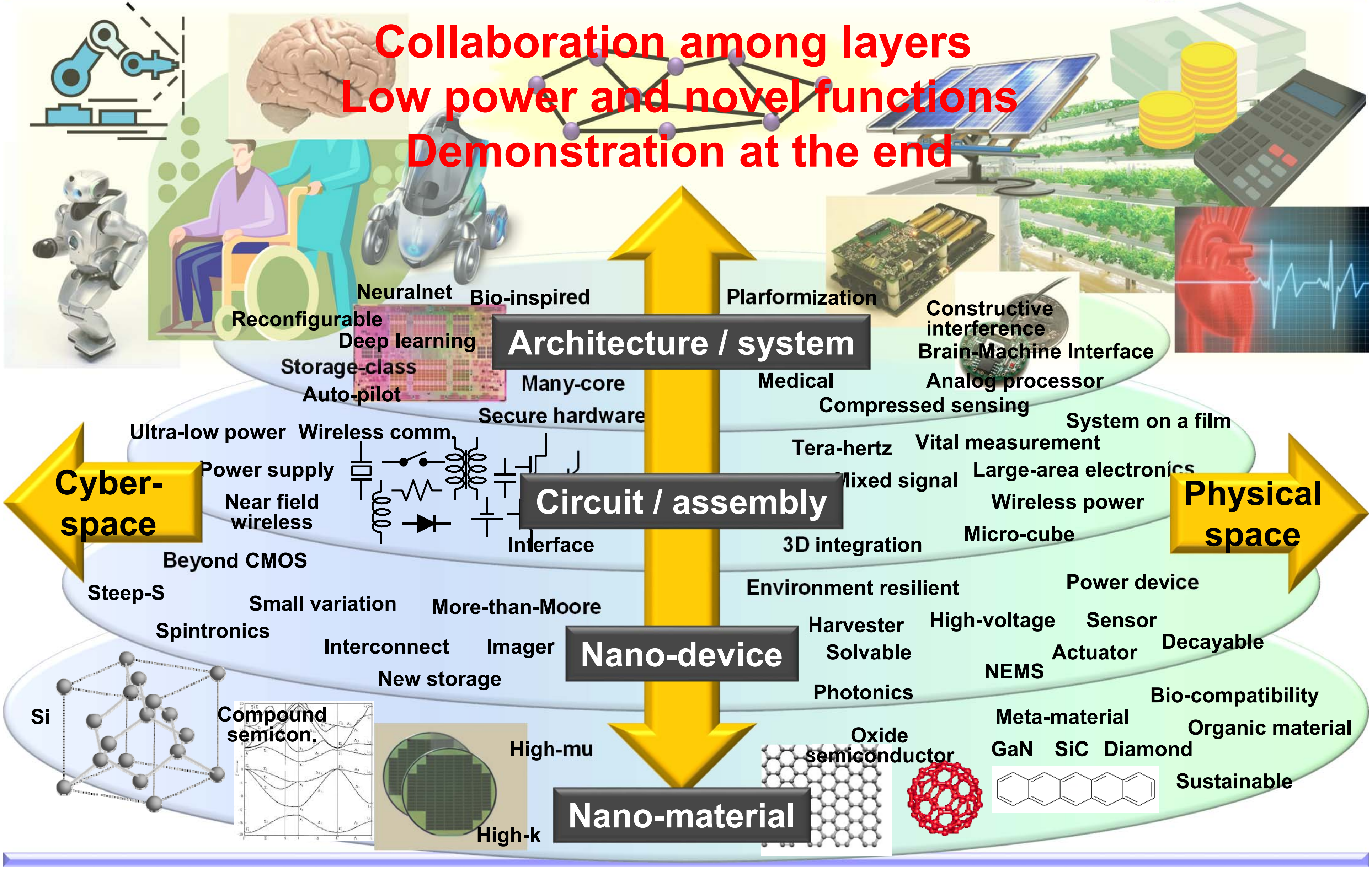
Nano-electronics CREST

Core Research for Evolutional Science and Technology



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6 projects on-going so far

Multi-functional sensor platform by nano electric channel and thermal management (Prof. Ken Uchida)

TFET for integrated circuits with ultra-low power consumption (Shinichi Takagi)

Innovative magnetic image sensors and app. based on carbon nano-electronics (Prof. Mutsuko Hatano)

- **Tera-hertz video imaging device (Prof. Tanemasa Asano)**
- **Computing by via-switches (Prof. Masanori Hashimoto)**
- **Nano inertia measurement device and system (Prof. Kazuya Masu)**

Open to international proposals

http://www.jst.go.jp/kisoken/crest/en/research_area/ongoing/areah25-2.html

Outline

- Organic transistor based systems
    - Large-area electronics applications
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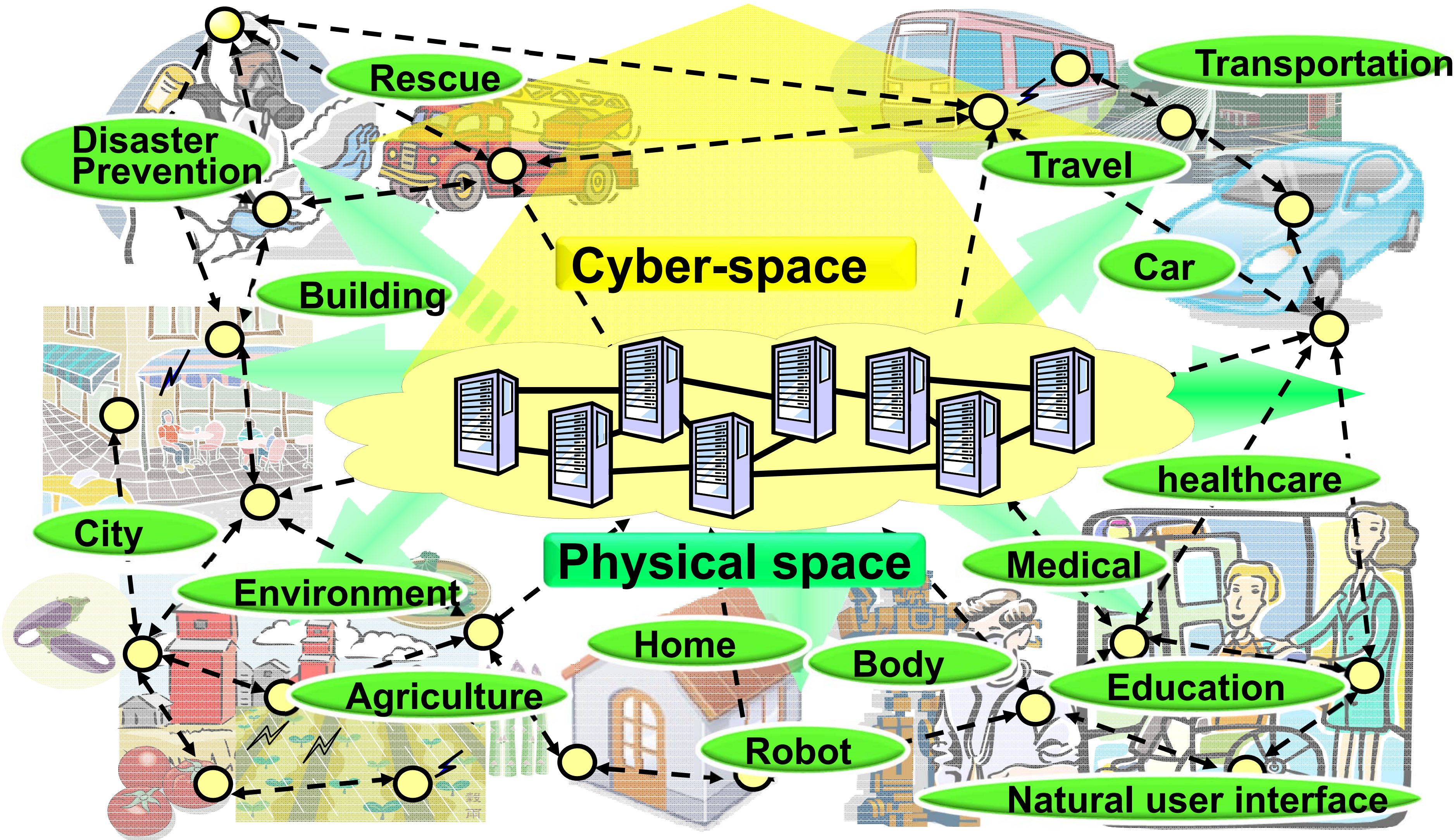
- Other nano-electronics devices
- What is lacking : platform for systems

Electronics to support people's life

Organic electronics: more physical-space apps



IoT, IoE, CPS, M2M, Ambient, Swarm, whatever you name it

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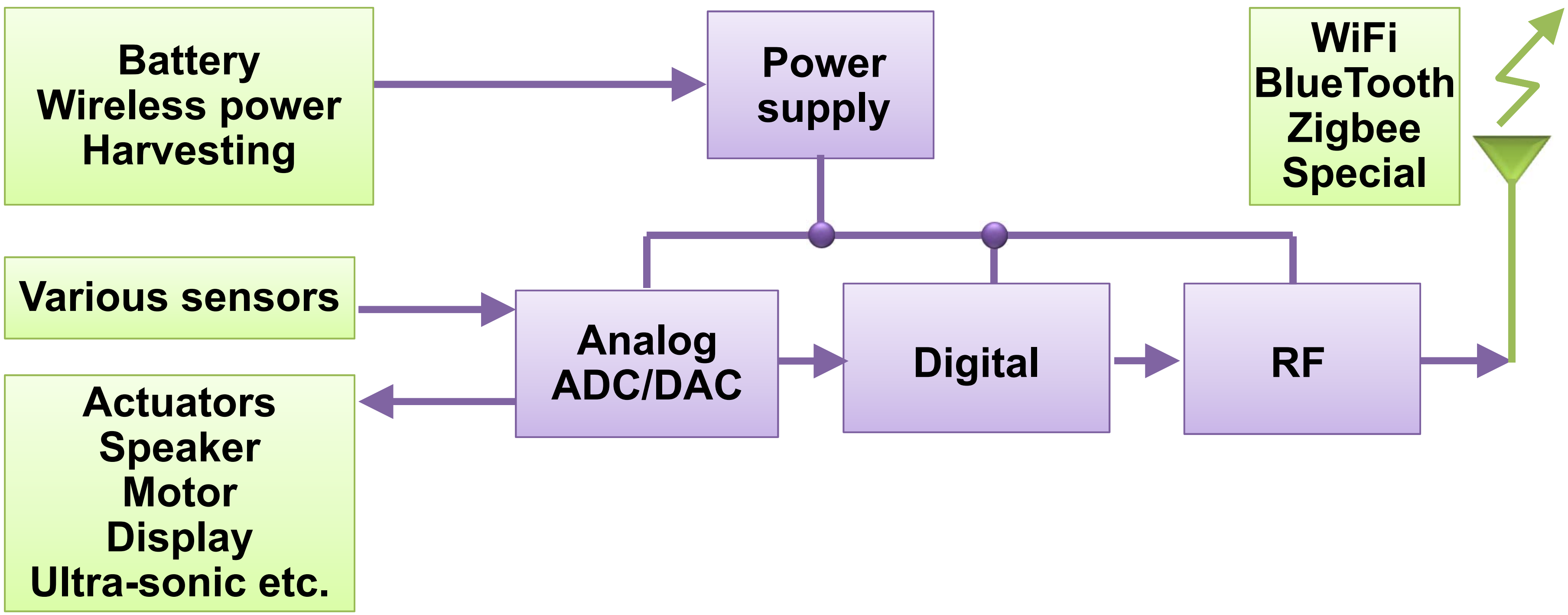
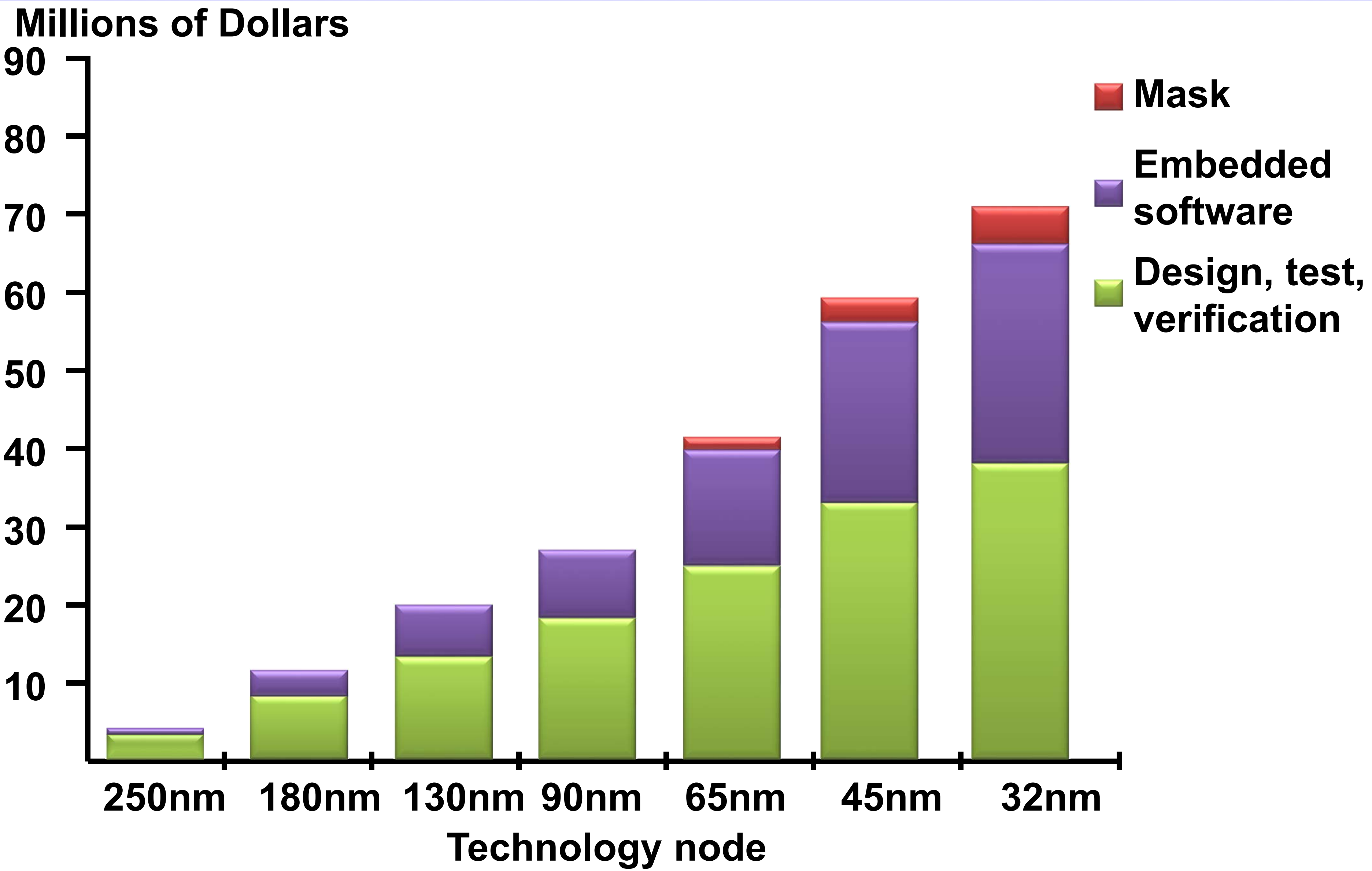
Wide variety in small quantities

Typical IoT nodes



Various combinations of non-digital and non-IC components.

High NRE cost



P. Garrou, "3D Drivers," Tutorial at 3D System Integration Conference, p.12, Sept. 2009.

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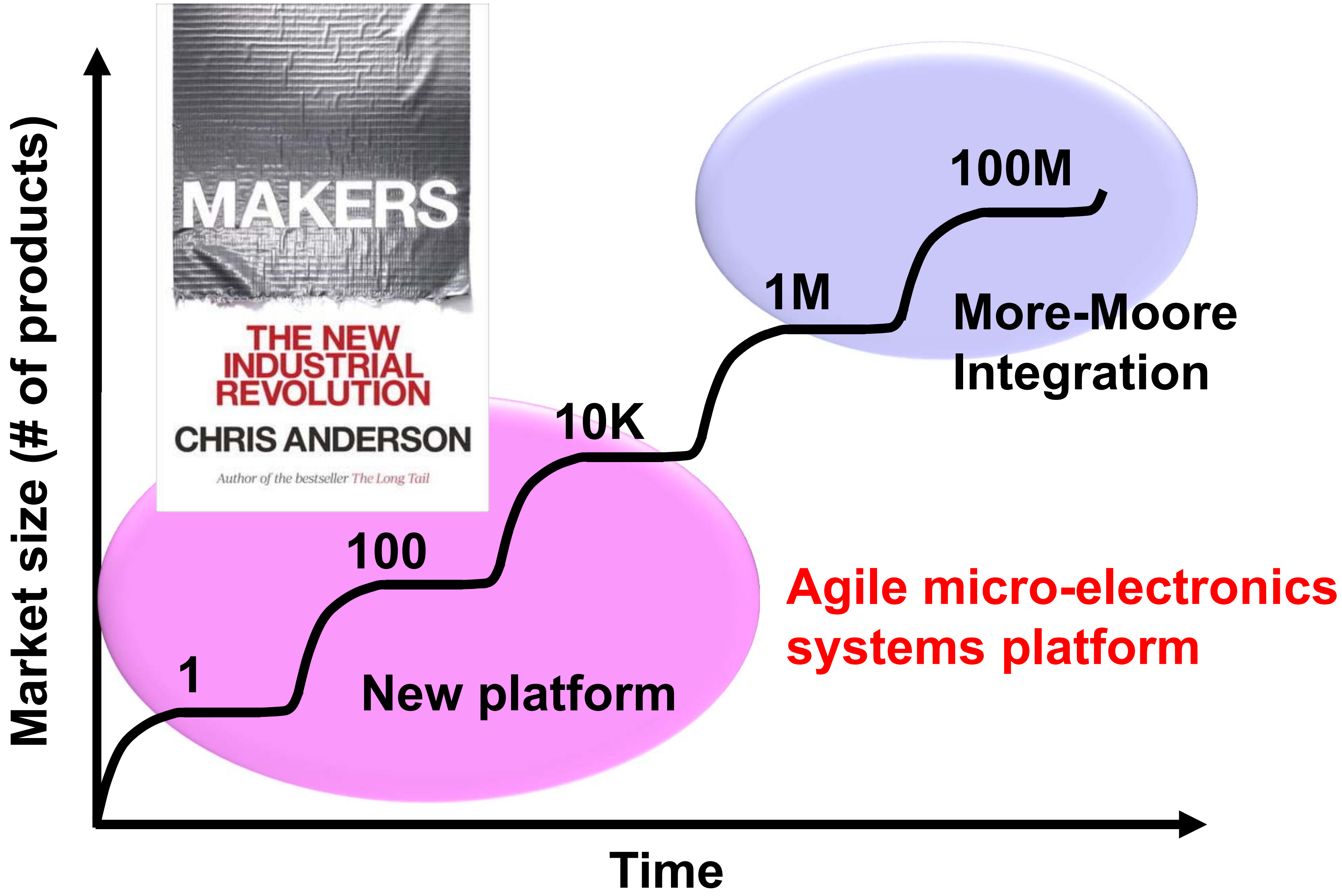
Integration technology to create new services



Electronic system platform example

Arduino (+ Shield)

>100mW, > 5 x 5 x 5cm^3

mbed

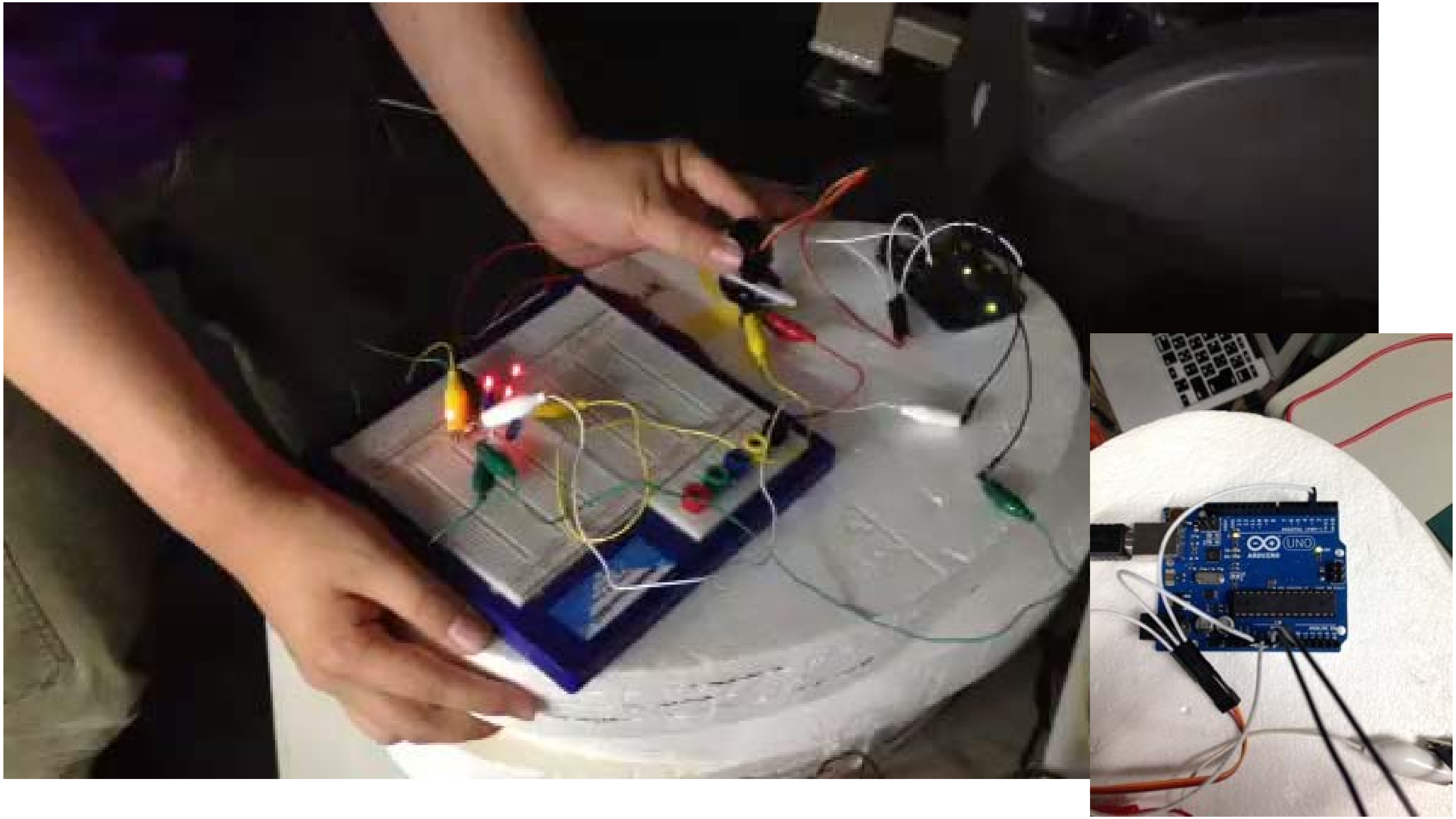
Edison (Intel)

- Non-experts make systems
- Non-experts use software
- Issue is not on digital nor IC's

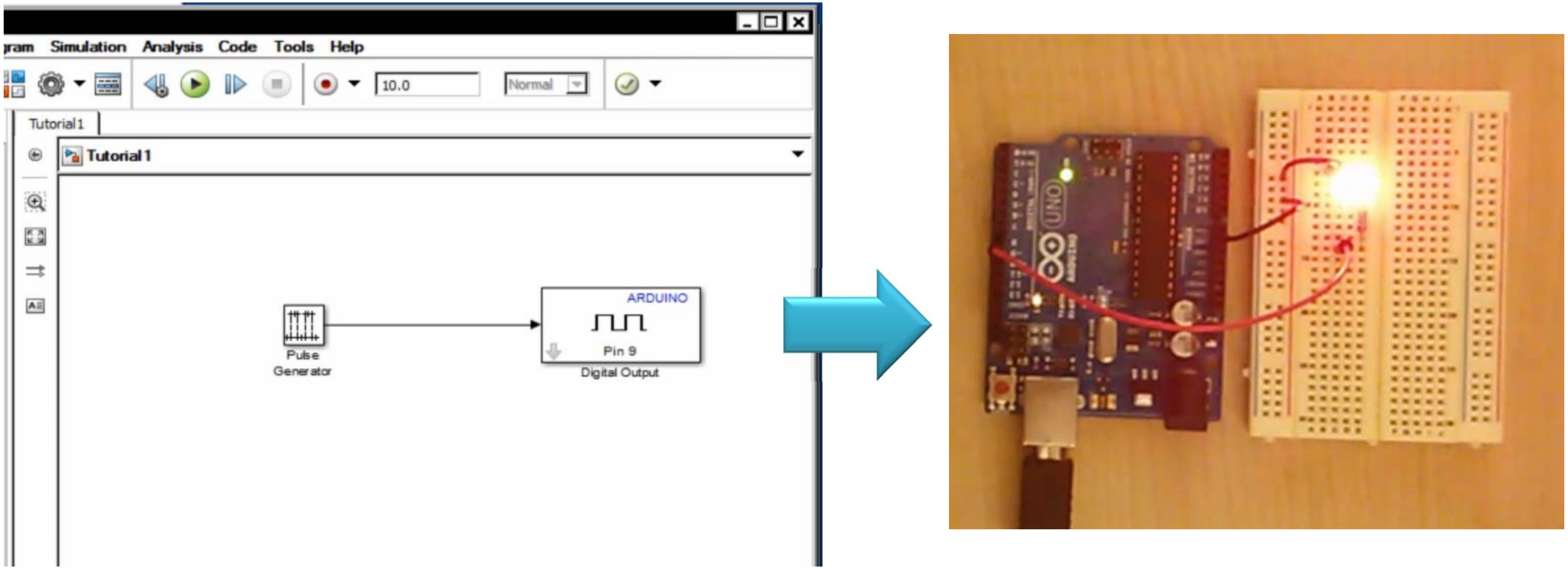
http://www.tabroid.jp/news/2014/04/google-ara-project.html
http://www.moff.mobi/
http://www.microfan.jp/booster/clcd-booster

Arduino

Experiment of student: Months ➔ A couple of days

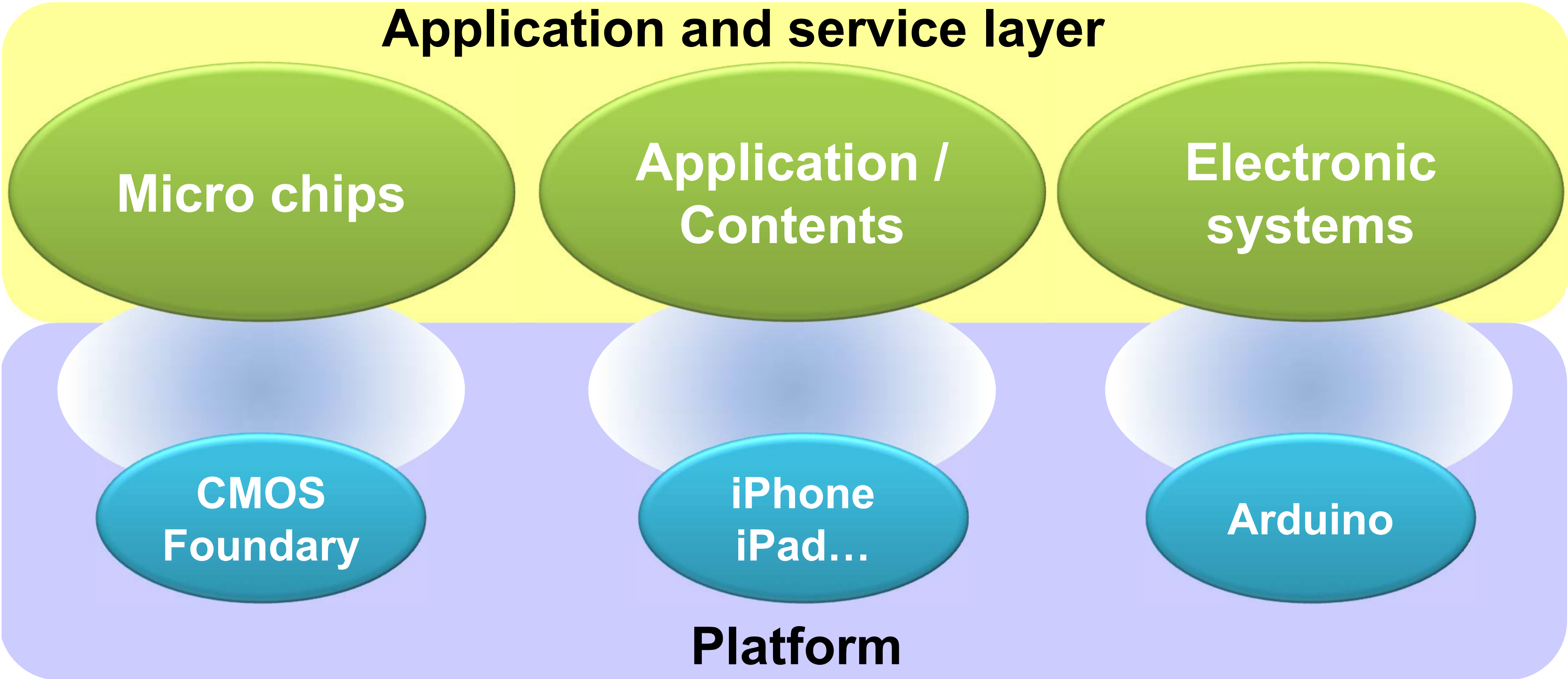


Arduino support package from Simulink



- **Programming without coding**

Platform to deliver technologies to services



- Components easily combinable to stimulate user's creativity
- Difficult technologies are made transparent to users

Summary

- **Organic-transistor based systems are good for:**

  Large-area electronics

  Bio-compatible applications

- **New nano-technologies will be coming in.**
- **Agile micro-electronics system platform is needed for emerging technologies to be delivered to people's life.**