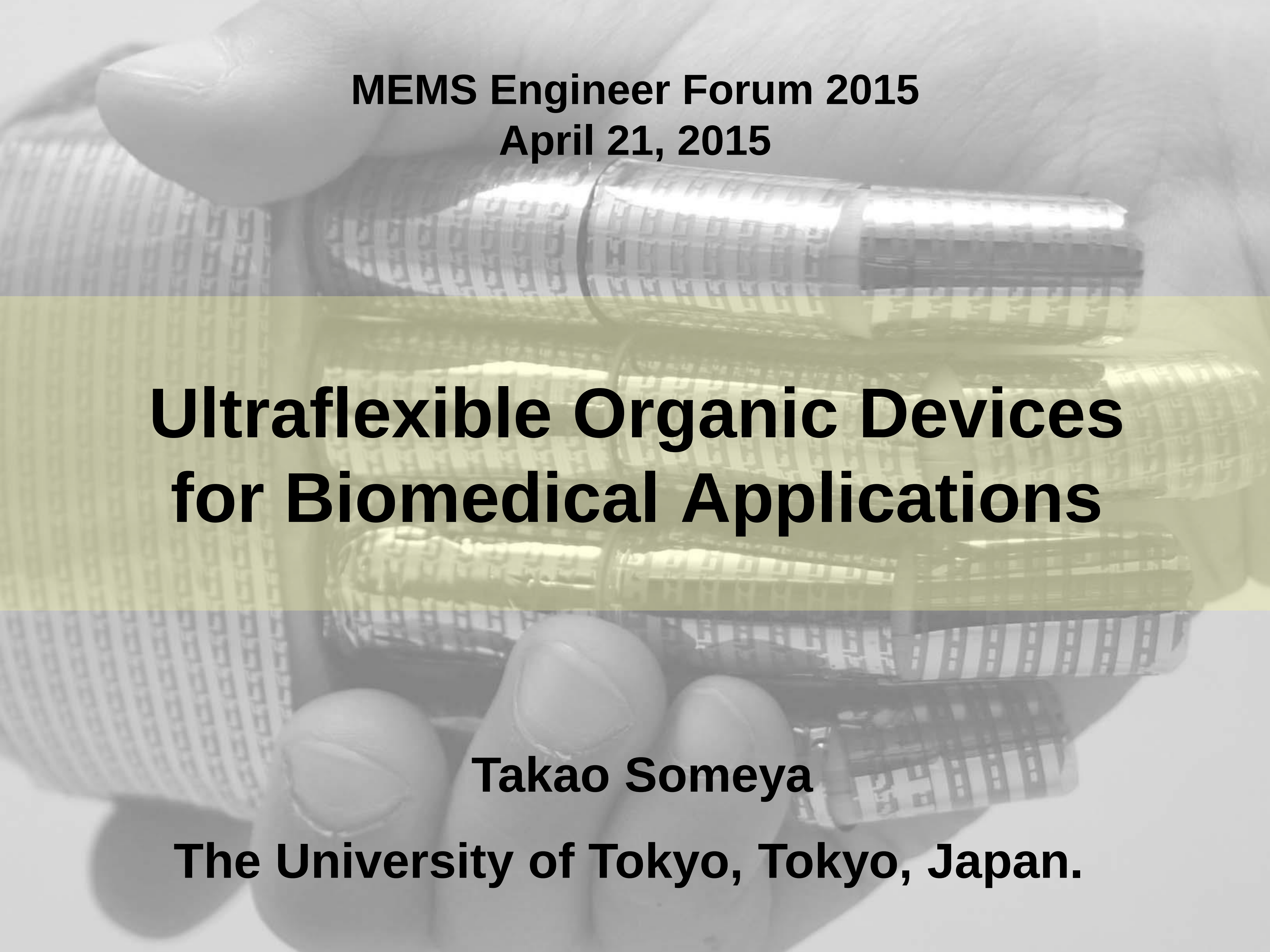

MEMS Engineer Forum 2015
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Ultraflexible Organic Devices for Biomedical Applications

Takao Someya

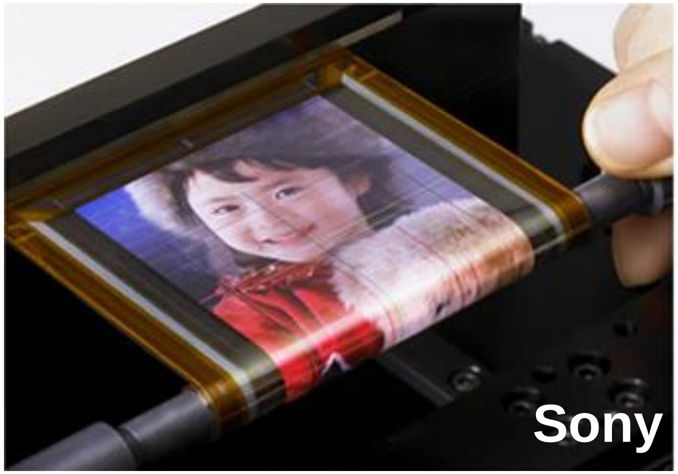
The University of Tokyo, Tokyo, Japan.

Outline

- Introduction
- Ultrathin OTFT, OPV & OLED
- Emerging applications
- Summary

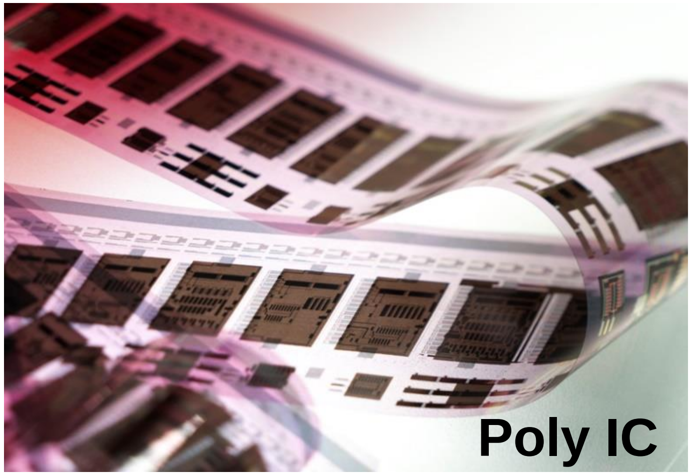
Flexible Organic Electronics

OLED display



OLED lighting

Organic RFID tag



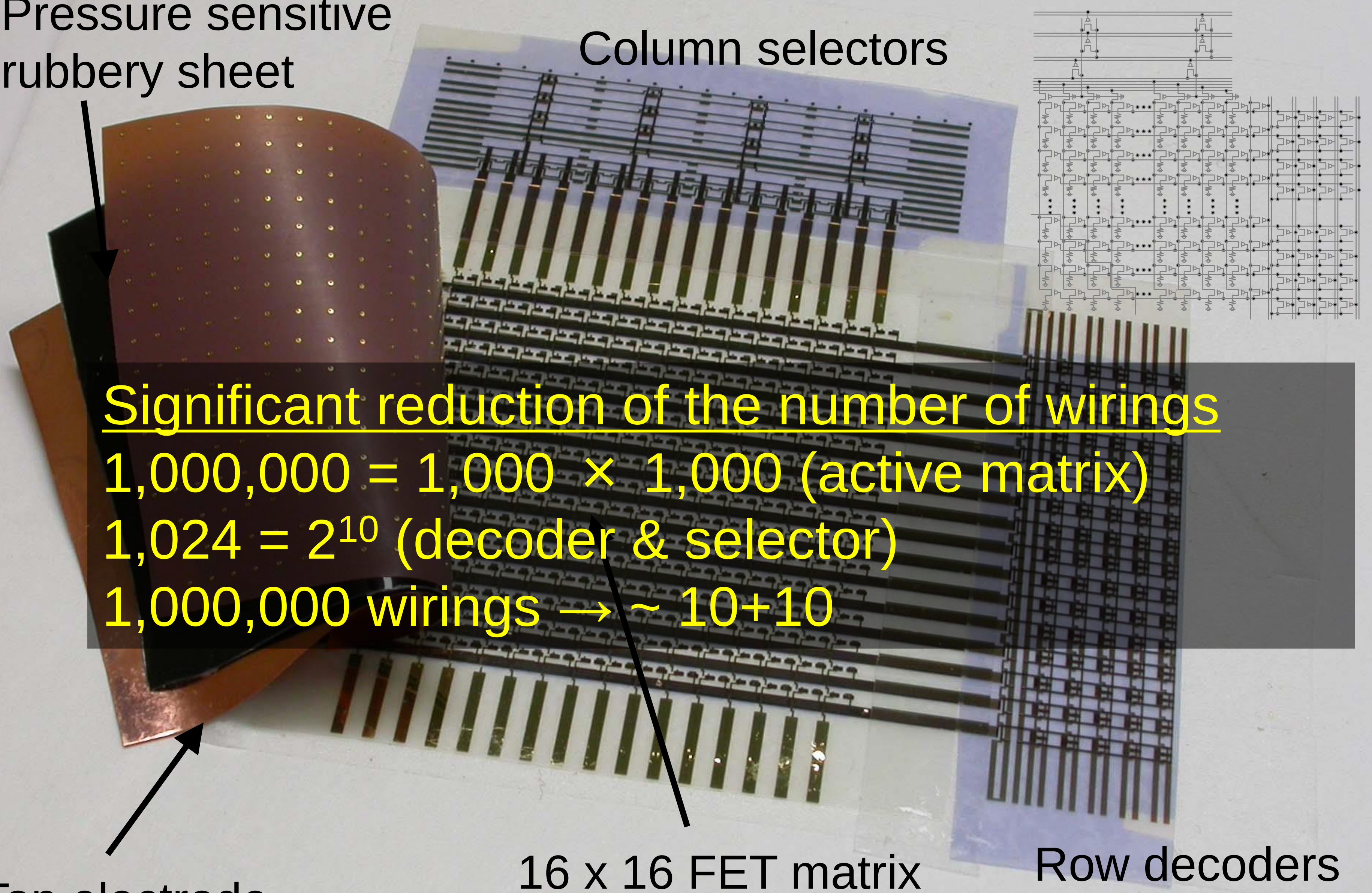
Organic Photovoltaic

Robotic E-skin

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).
T. Sekitani, et al., Nature Mat. 6, 413 (2007).
T. Sekitani, et al., PNAS 105, 4976 (2008).
T. Sekitani, et al., Science 321, 1468 (2008).

In 2003

E-skin System



<u>Significant reduction of the number of wirings</u>

1,000,000 = 1,000 × 1,000 (active matrix)

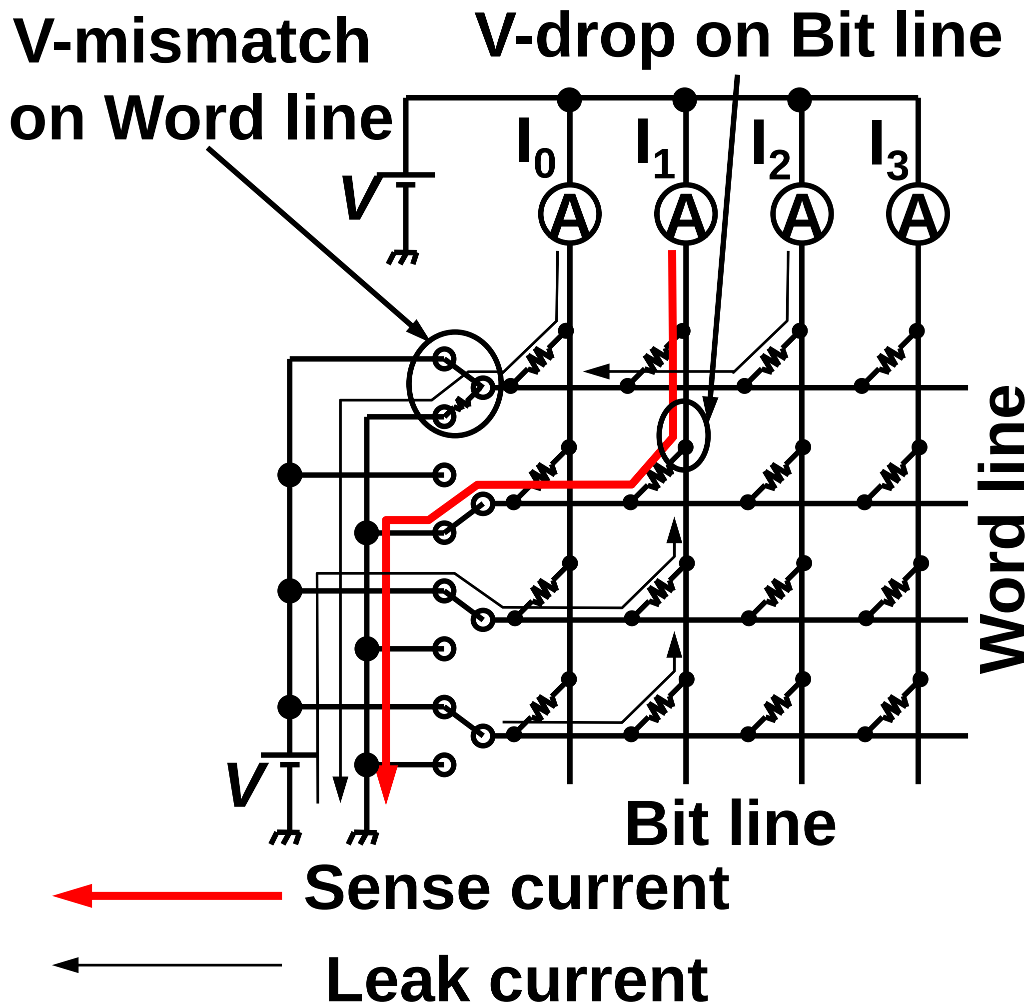
1,024 = 2^{10} (decoder & selector)

1,000,000 wirings → ~ 10+10

T. Someya, et al., PNAS 101, 9966 (2004).

Power consumption of active matrix driving

Active matrix configuration shows power consumption much lower than passive matrix



Power consumption

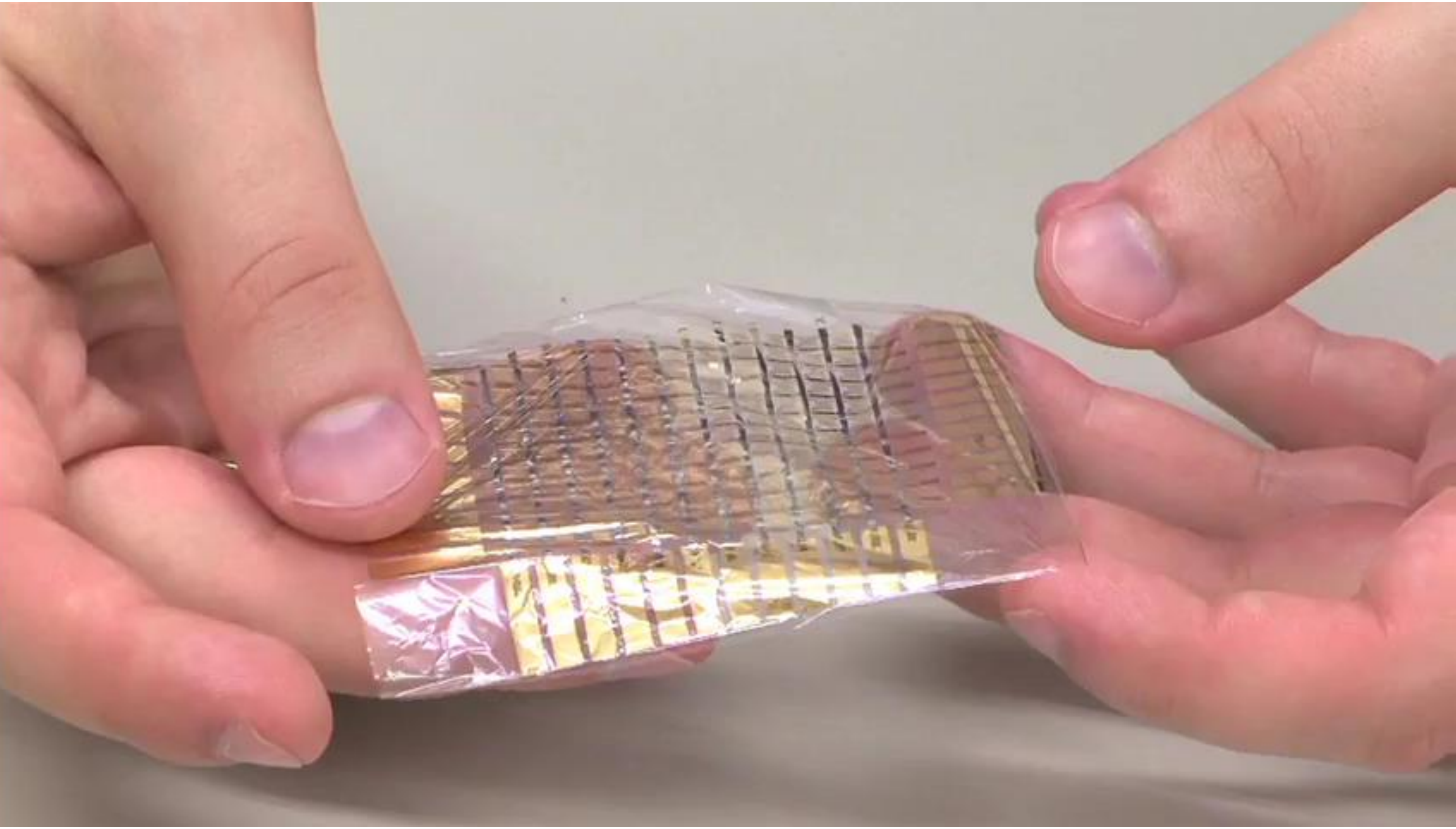
	Passive matrix (w/o TFT)	Active matrix (w/ TFT)
64 x 64	0.6mW	0.1mW
1k x 1k	130mW	1.3mW

Skin-like sensitivity

Robots with sensitive skins will feel and even respond to a person's warmth while shaking hands, consequently letting people feel that robots are warmer.

Ultraflexible organic devices

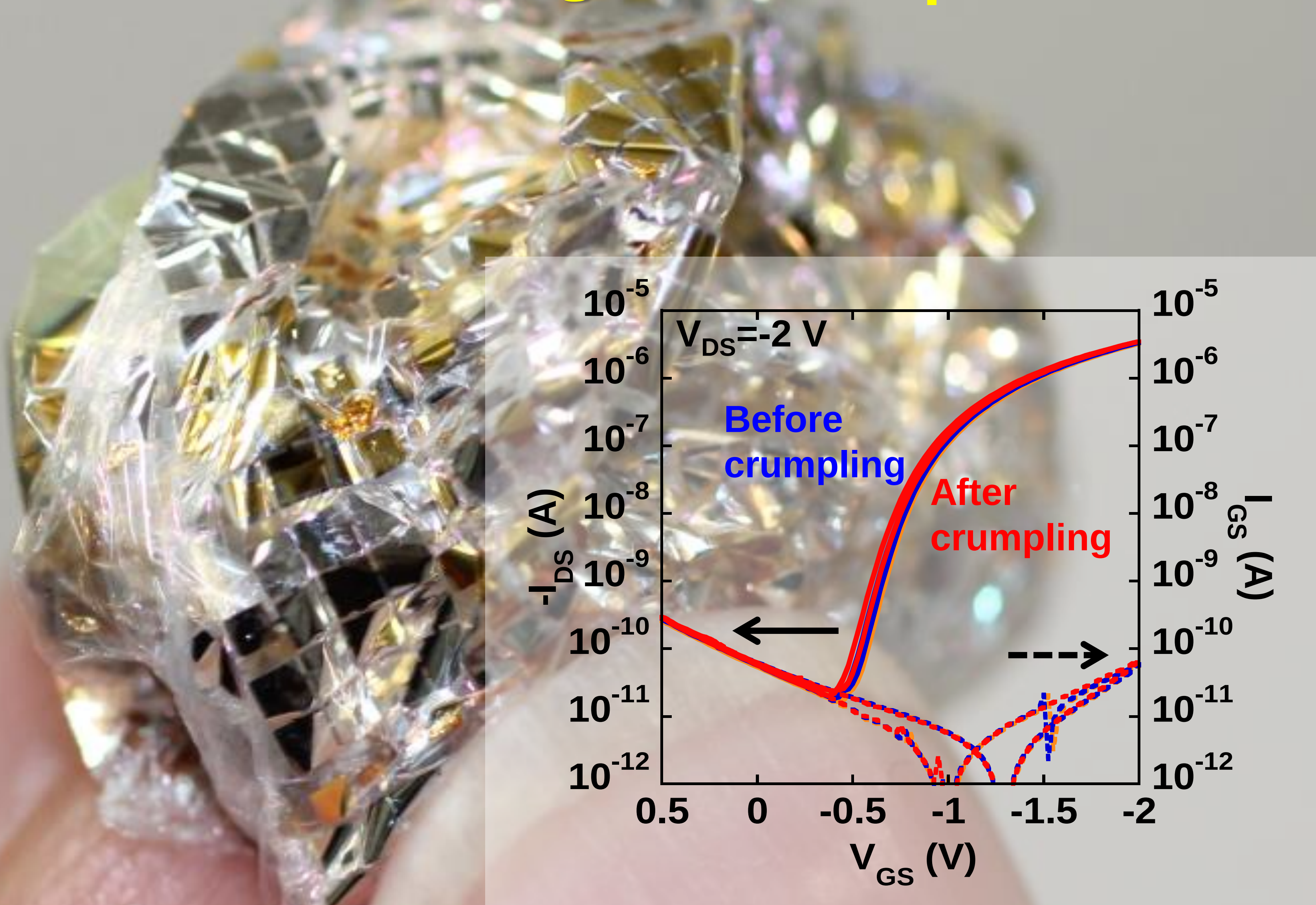
World’s thinnest and lightest OTFT
(3g/m^2)



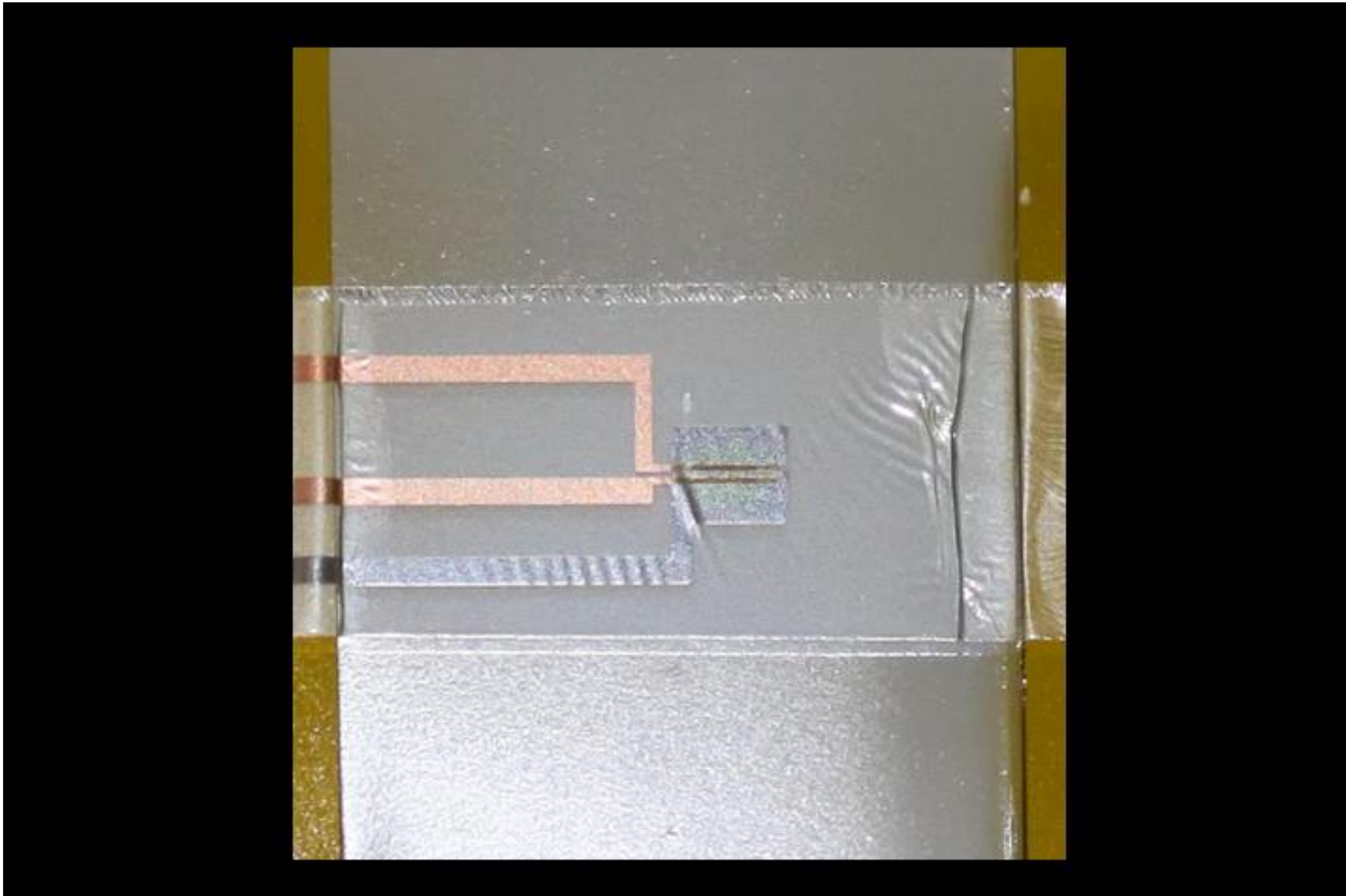
Martin Kaltenbrunner, et al., Nature 499, 458–463 (25 July 2013).

Amazing robustness: Crumpling

Minimum bending radius ~ 5μm

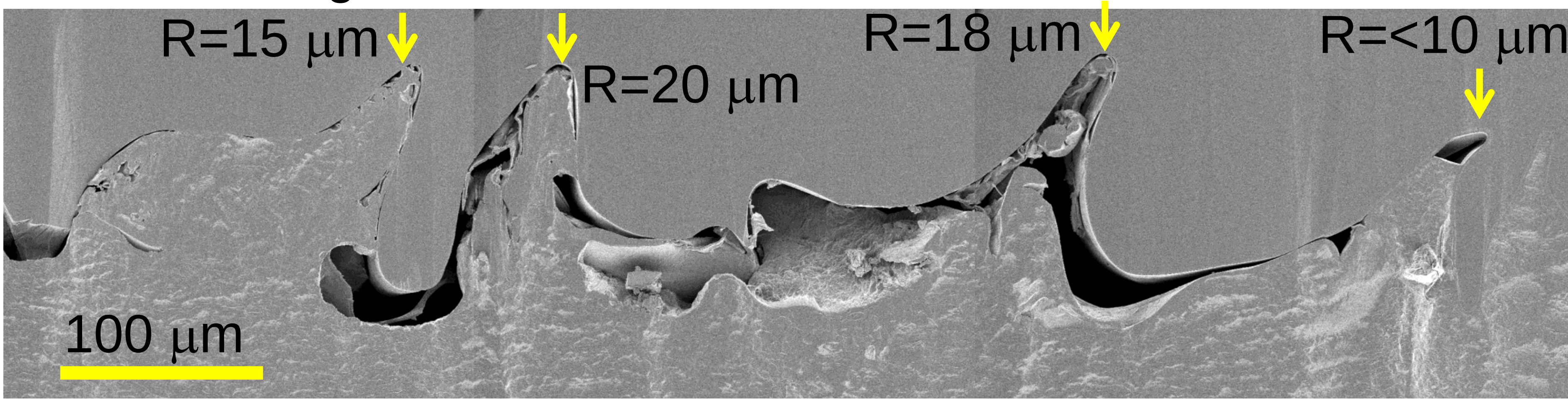


Stretchable organic transistors



Crumpled organic integrated circuits

Bending radius

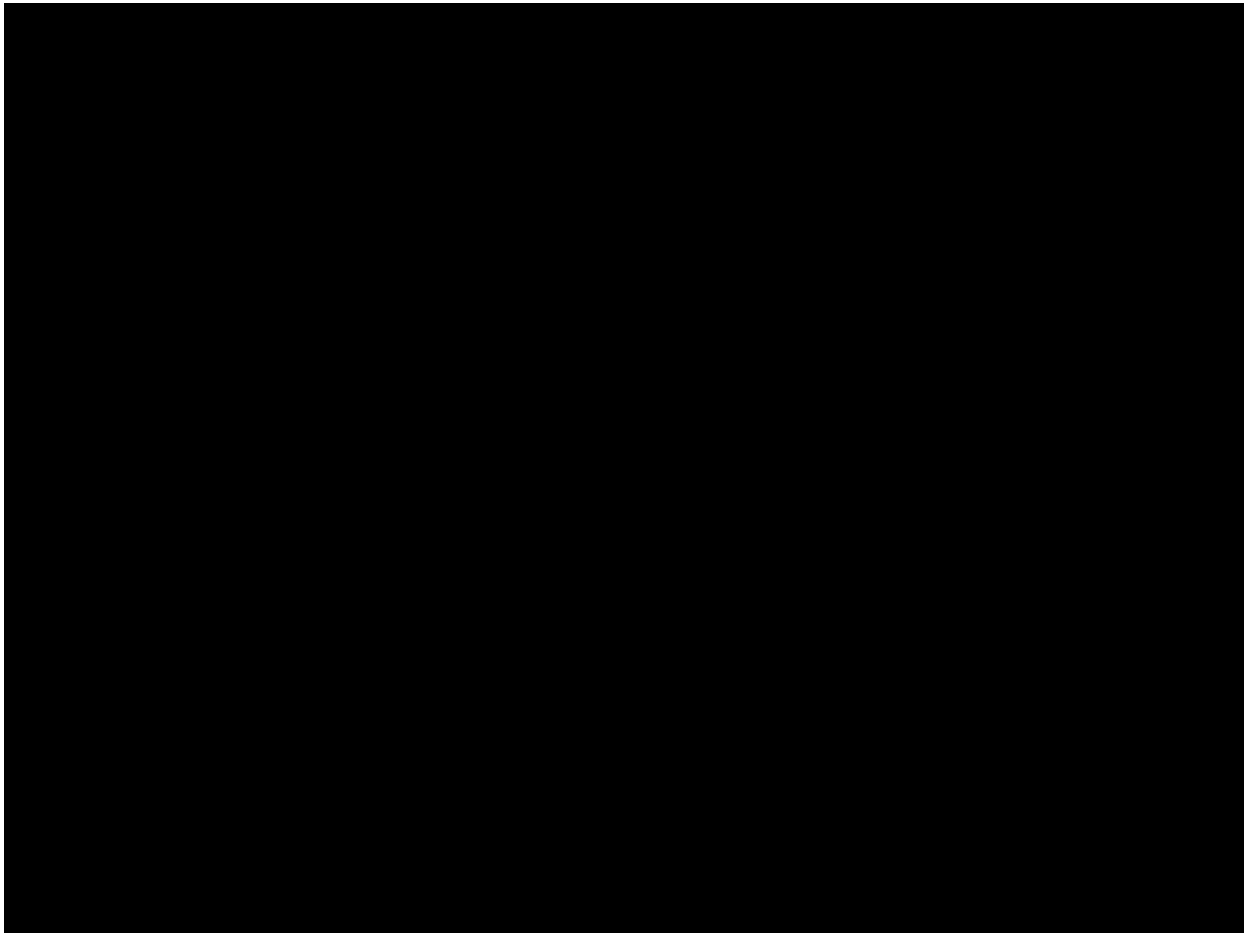


Cross-sectional TEM

World's thinnest and lightest OPV

Stretchable OLED

Brightness: 100 cd/m^2 Stretching >100%!

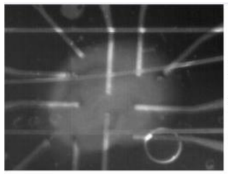


- **Light-emitting device that fits 3D surfaces**
- **Light source health-monitoring sensors**

Nature Photonics 7, 811–816 (2013) doi:10.1038/nphoton.2013.188

Flexible Electronics for Biomedical Applications

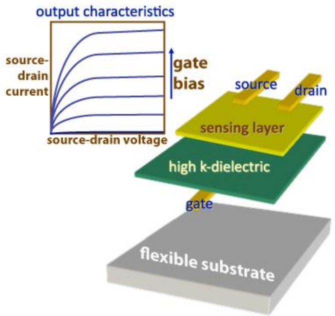
In-vitro neural interface



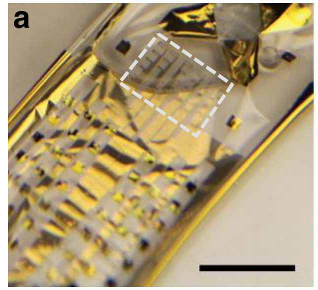
S. Lacour, S. Wagner, Barclay MorrisonIII et al
J.Neurotrauma, 2009, vol. 26, 1135.

Chemical sensors

L. Torsi and A. Dodabalapur, Analytical Chemistry 70, 381A (2005).

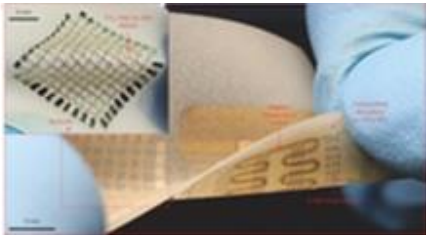


Neural interfaces



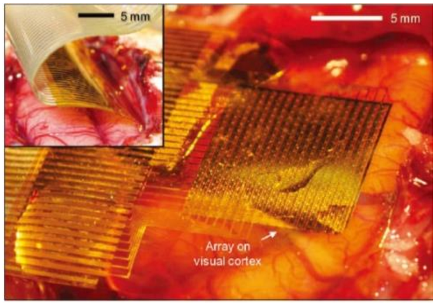
G. Malliaras, et al, Nature Comm., 4:1575 (2013)

Multifunctional wearable devices



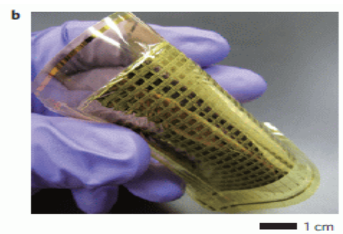
Dae-Hyeong Kim,
Nature Nanotech
9, 397 (2014).

Neural interfaces



J. Viventi, J. A. Rogers et al,
Nature Neuro., 14, 1599 (2011)

Artificial skin

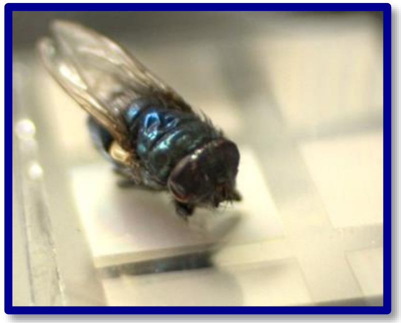


K. Takei, J. Ali
Nature Materials (2010).

Neural Stem Cells

M. Berggren, et al.,
PLoS ONE, 6, e18624 (2011).

High-sensitive electronic skin

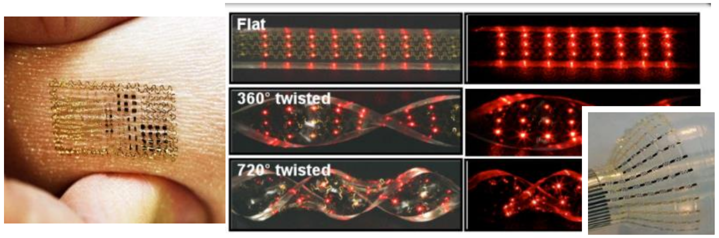


Z. Bao Nature Materials (2010).
Z. Bao, Nature Nanotech (2011).

Wearable electronics

Holst Centre
http://www.holstcentre.com/

Medical sensors & lighting
Intelligent balloon catheter
Epidermal electronic skin



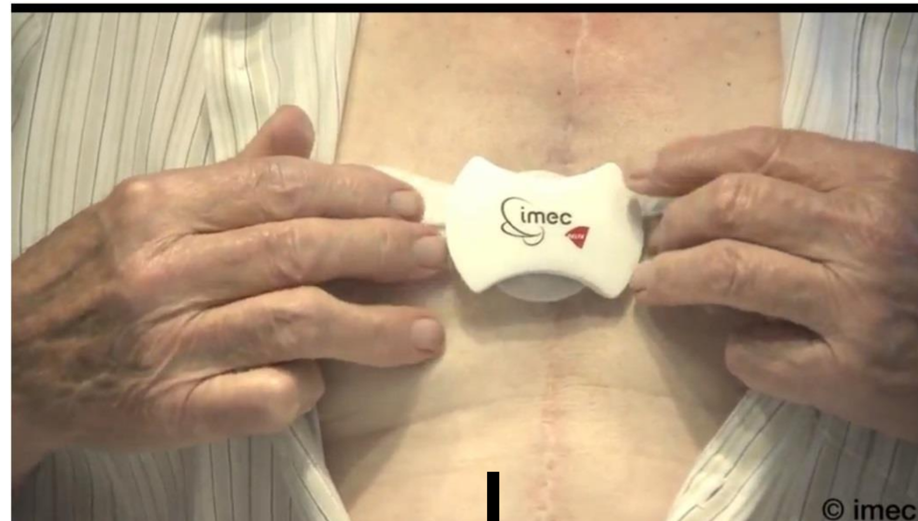
J. A. Rogers, Nature Materials 10, 316 (2011).
J. A. Rogers, Nature Materials 9, 316 (2010).
J. A. Rogers, Science 333, 6044 (2011).
J. A. Rogers, Nature Mater. 12, 6938 (2013).

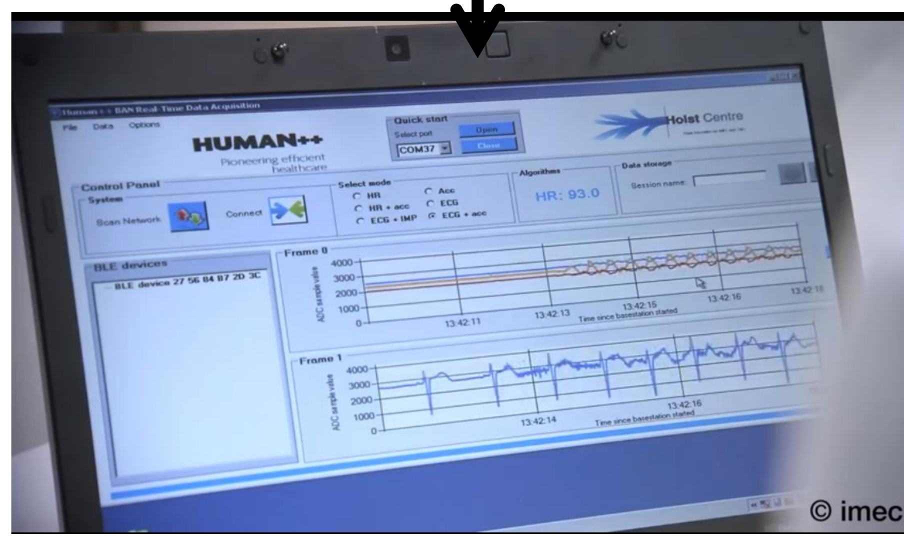
IMEC: ECG patch sensor

Proceedings of the 2nd Conference on Wireless Health, **15** (2011).

Bluetooth System

ECG Measument System



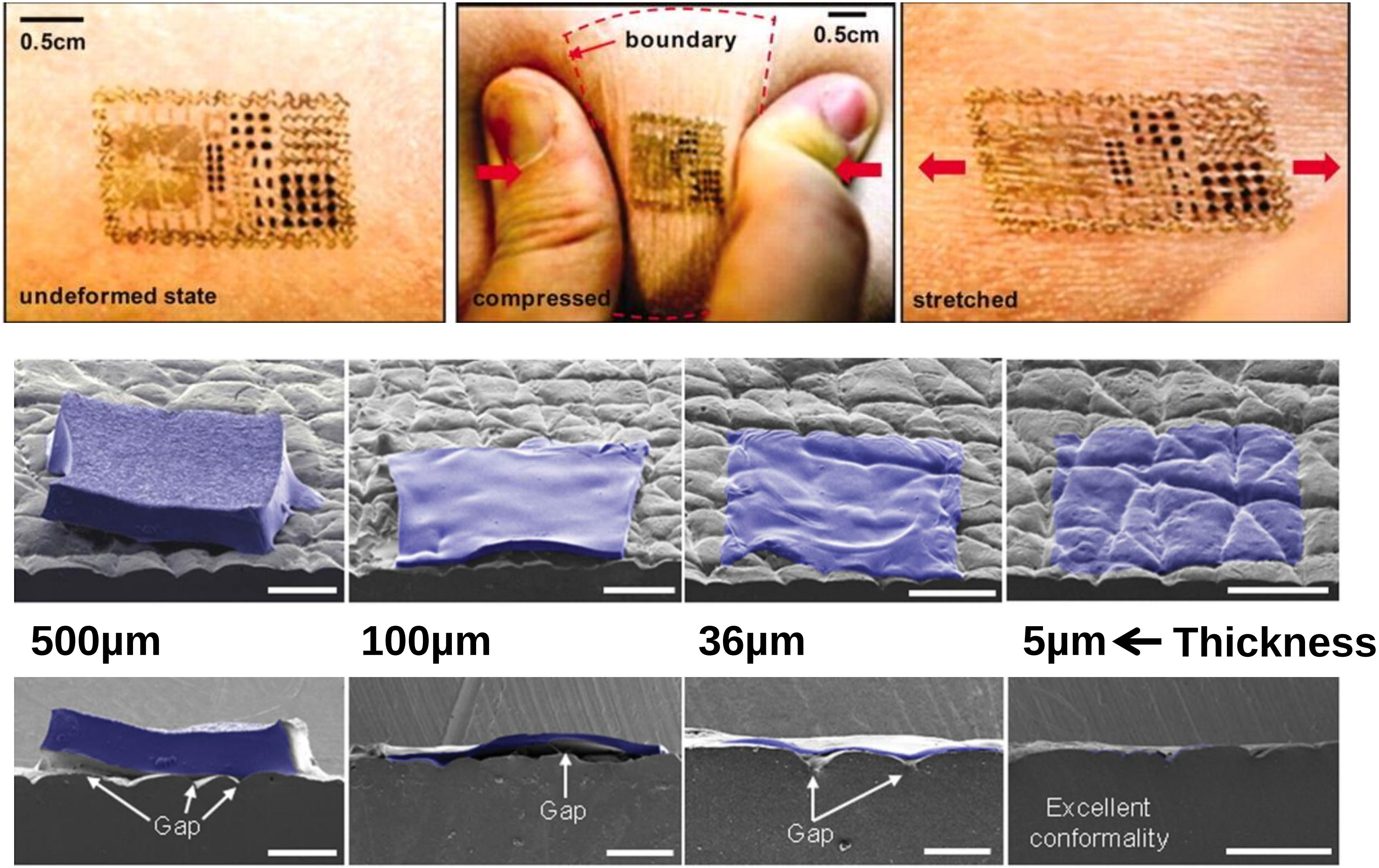


ECG measurement result can be sent to doctors through Bluetooth and Internet.

http://www.youtube.com/watch?v=iv7Wlly_W0Q

John A Rogers's Flex Devices

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN



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

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

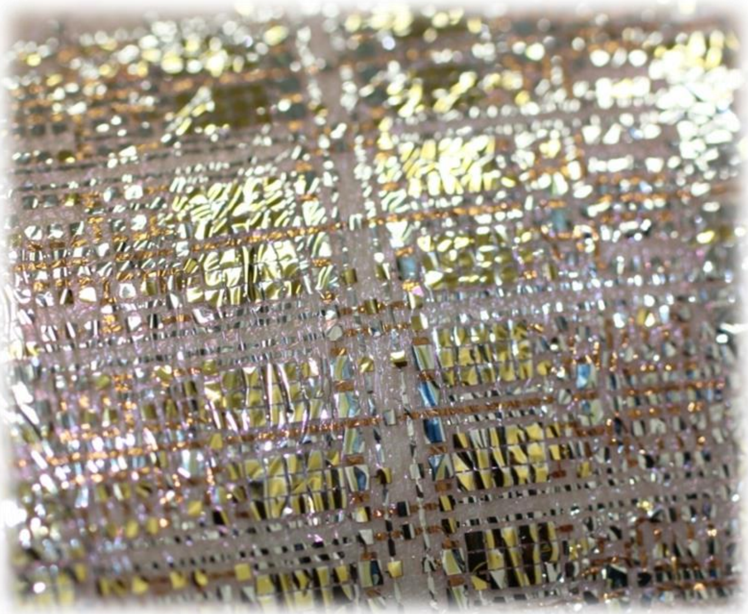
Bionic Skins
（2013）

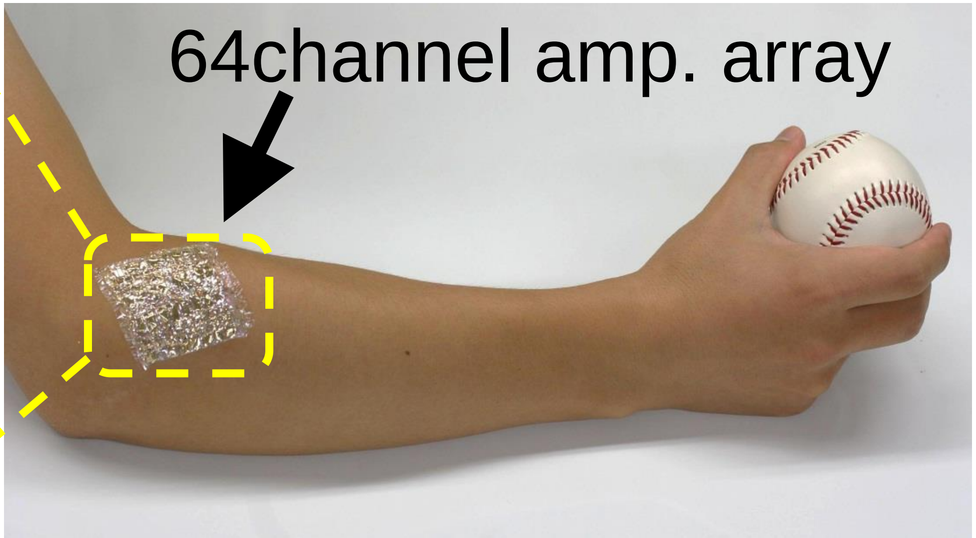
t=2μm

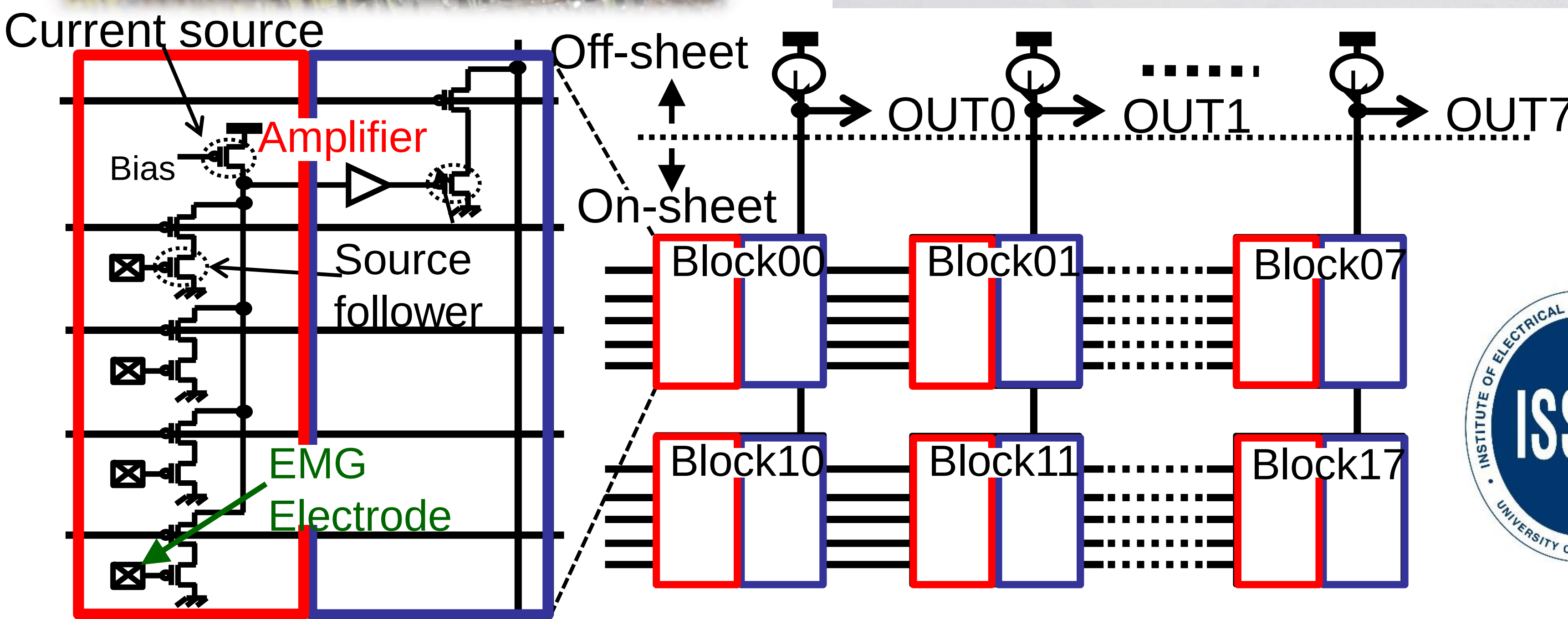
M. Kaltenbrunner, et al., Nature 499, 458 (2013).

Surface electromyogram monitoring

Fuketa, et. al., IEEE/ISSCC2013 #6.4.

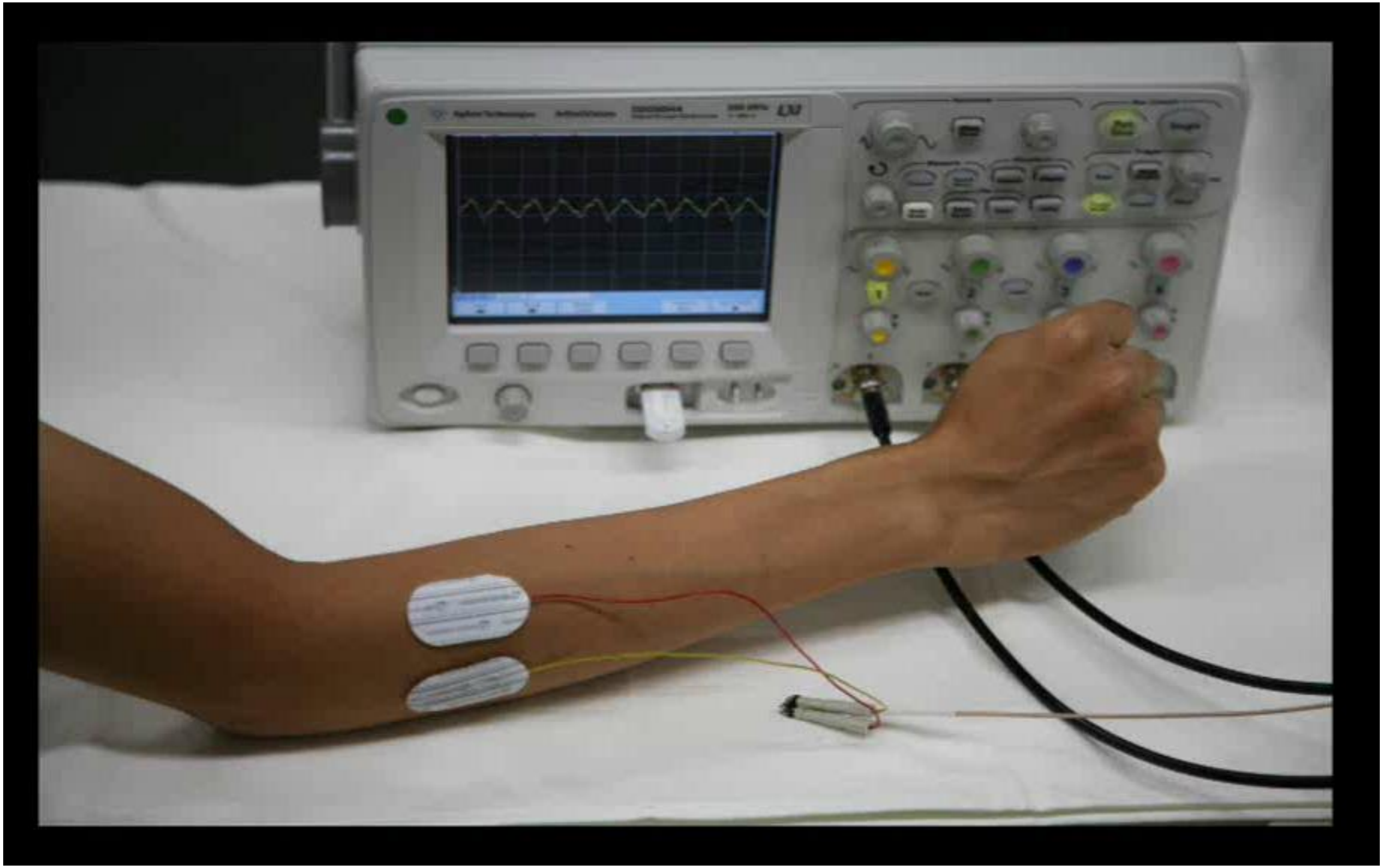




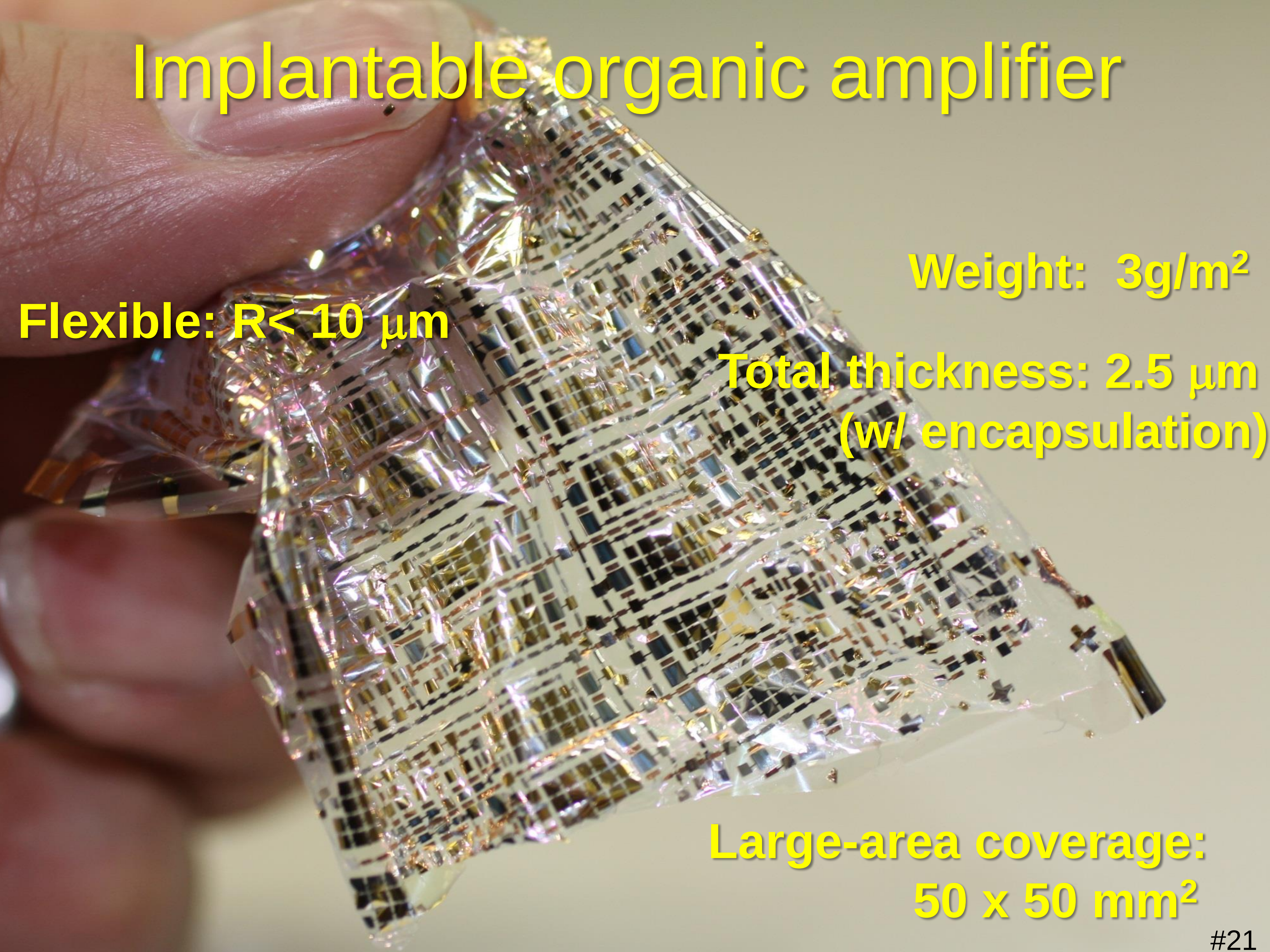


Electromyogram measurement

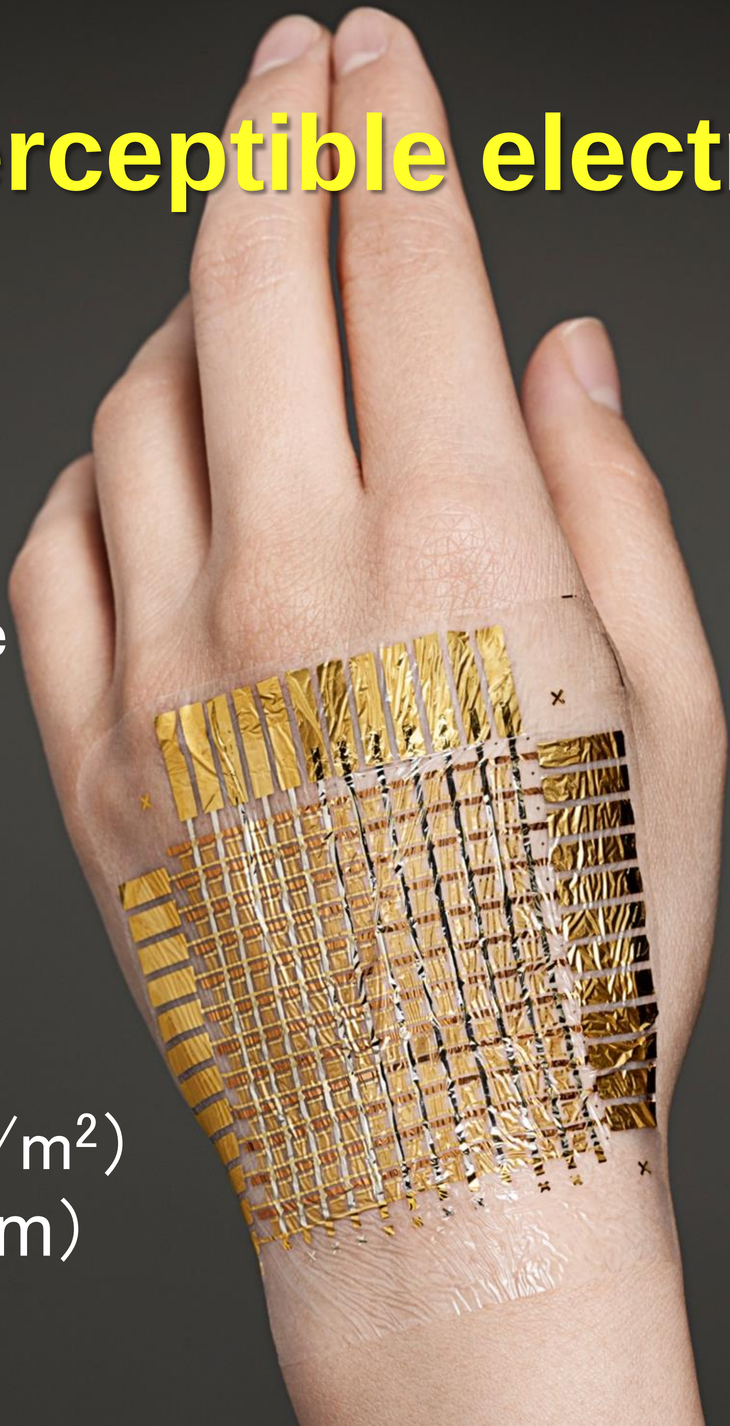
For stress-free healthcare-monitoring and welfare IT



Fuketa, et. al., IEEE/ISSCC2013 #6.4.


Implantable organic amplifier
Weight: 3g/m²
Flexible: R< 10 μm
Total thickness: 2.5 μm
(w/ encapsulation)
Large-area coverage:
50 x 50 mm²

Imperceptible electronics



<u>Applications</u>

Medical IT

Welfare IT

Digital Healthcare

<u>Specifications</u>

The lightest（3 g/m^2）

The thinnest（2μm）

<u>What</u>

Electromyogram

Electrocardiogram

Body temperature

Heart rate

Blood pressure

<u>Where</u>

Everyday life

During exercise

At hospital

Acknowledgements

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JST/CREST
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T. Sakurai (T Tokyo)

M. Takamiya (U Tokyo)

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T. Aida (U Tokyo)

T. Fukushima （TIT）

Elastic conductors

H. Klauk (MPI)

SAM

Lynn Loo （Princeton）

NEXSAFS

S. Bauer (JKU)

Ultrathin

M Sekino (U Tokyo)

Animal

T. Isoyama (U Tokyo)

Artificial heart

M. Hirata, MD
Osaka U, Hospital
Brain surgery
BMI

H. Onodera, MD
University of Tokyo,
Footprint

Y. Abe, MD
U Tokyo, Medicine
Animal Experiment
Artificial Hearts

Summary

The frontier of organic electronics

Today: OLED Display & Lighting
OPV

Tomorrow: Healthcare / Medical

Uniqueness of organic devices

Ultralight, Ultrathin ⇒ Minimum invasiveness

Flexible, Durable ⇒ High reliability & High sensitivity

➡ **Emerging applications**

- Digital Healthcare
- Medical IT
- Welfare IT