

MEMS Engineer Forum 2015
April 21, 2015

Ultraflexible Organic Devices for Biomedical Applications

Takao Someya

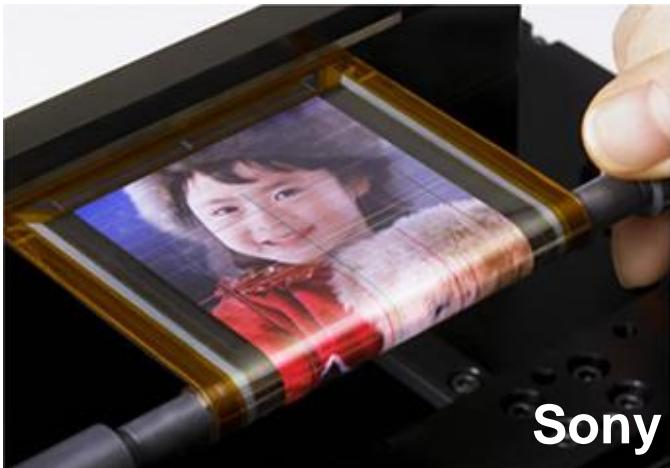
The University of Tokyo, Tokyo, Japan.

Outline

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

Flexible Organic Electronics

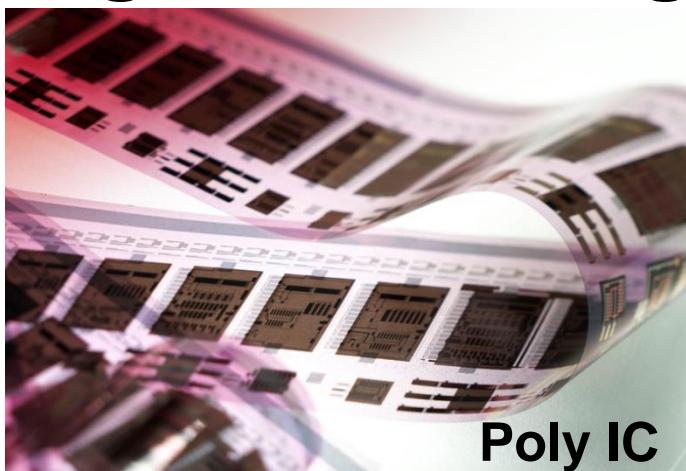
OLED display



OLED lighting



Organic RFID tag



Poly IC

Organic Photovoltaic



Heliatek

Robotic E-skin



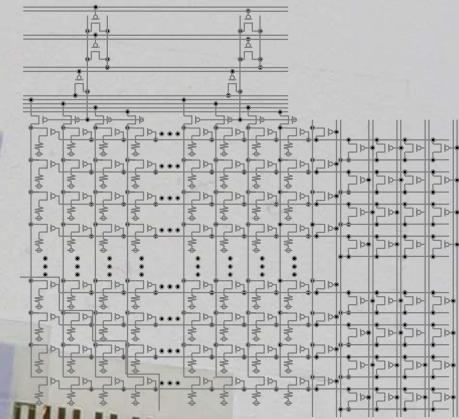
- T. Someya, et al., IEDM #8.4, 203 (2003).
- T. Someya, et al., PNAS 101, 9966 (2004).
- T. Someya, et al., PNAS 102, 12321 (2005).
- T. Sekitani, et al., Nature Mat. 6, 413 (2007).
- T. Sekitani, et al., PNAS 105, 4976 (2008).
- T. Sekitani, et al., Science 321, 1468 (2008).

In 2003

E-skin System

Pressure sensitive
rubbery sheet

Column selectors



Significant reduction of the number of wirings

$$1,000,000 = 1,000 \times 1,000 \text{ (active matrix)}$$

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

$$1,000,000 \text{ wirings} \rightarrow \sim 10+10$$

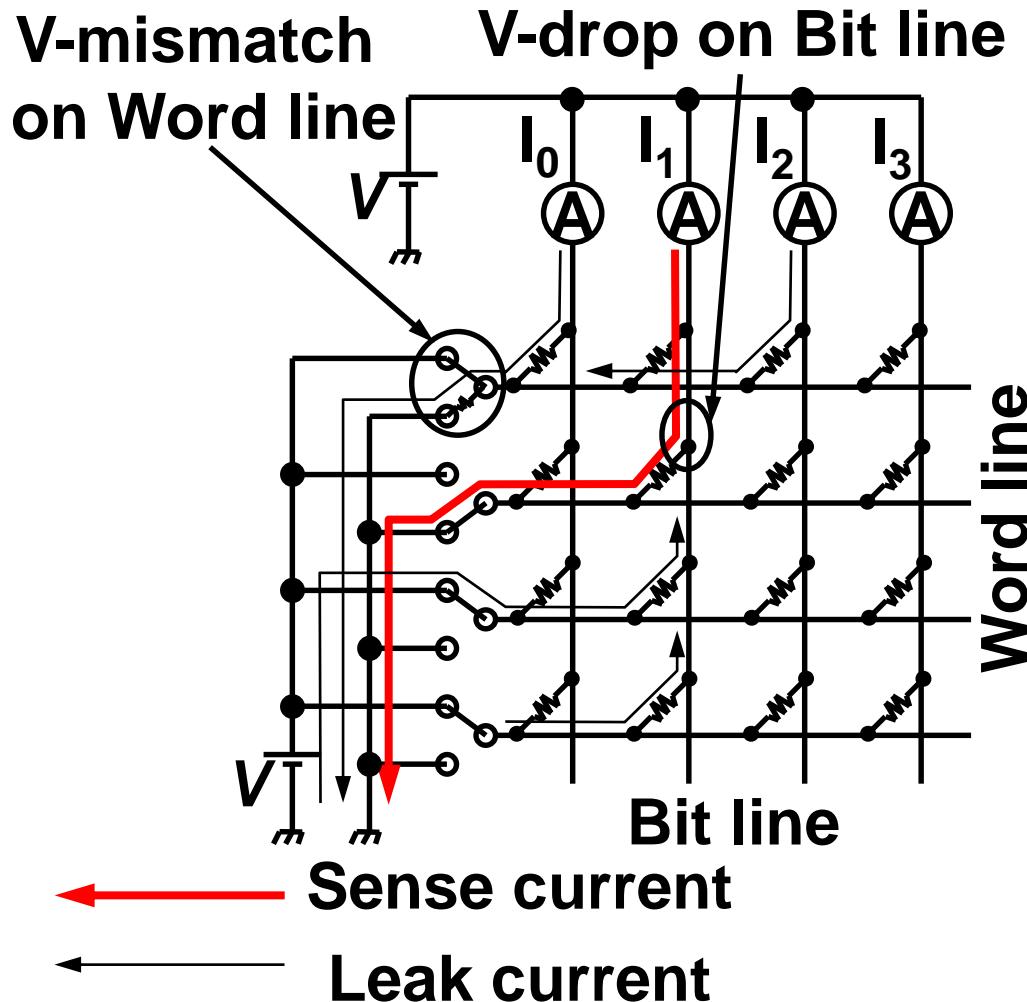
Top electrode

16 x 16 FET matrix

Row decoders

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.

NOVEMBER 21, 2005
TORTURE CASE • BEST & WORST GOVERNORS • CLOONEY'S NEW FLICK
TIME
www.time.com AD: KENNETH TAMBURINI

The Most Amazing Inventions
THIN SKINS

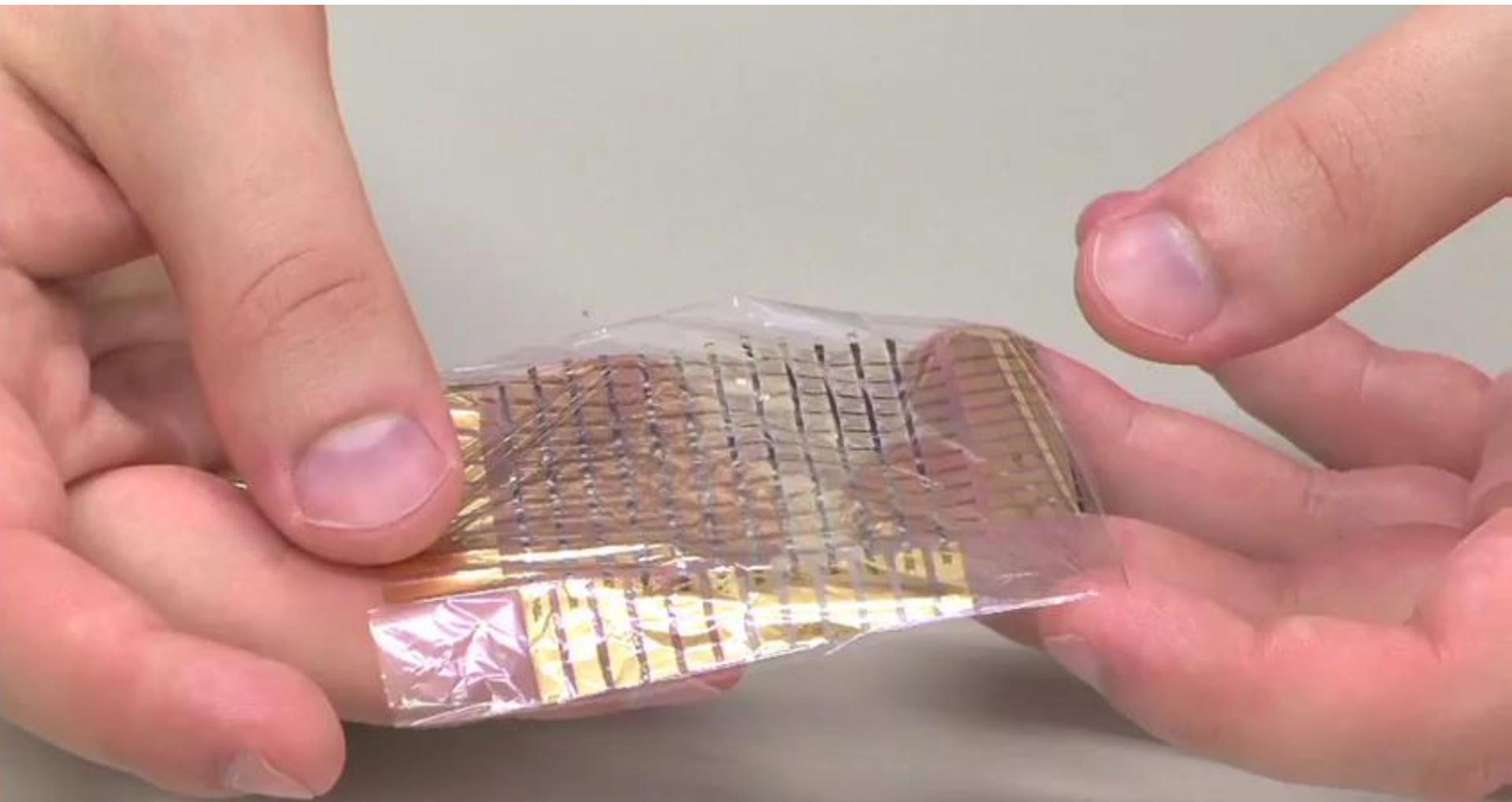
● GOIN' COCONUTS
CocoSkin is a unique carbon-fiber cycling wear. It's cut from a new kind of cloth made by weaving coconut shells into fibers. How does it feel? Carbon from coconuts. The fibers are extremely strong and flexible, yet light and airy. They're also waterproof and sweat-wicking, so when air filters in through tiny pores that make up the patterned arrangement of the carbon particles, heat is relieved by a patented process called "breathable." The fabric's ready smells and harmful rays and makes cycling more comfortable. A 10-second self-adjusting cycle refreshes the fabric for more easy riding.
INFO: www.coco-skin.com
AVAILABILITY: January 2006, shorts and shirts, \$150 each
TO LEARN MORE: time.com/timeinventions

● THE RIGHT TOUCH
The key to making artificially intelligent robots less threatening to us is to make them more aware of what's around them. That's where "skins" come in. Researchers at the University of California, Berkeley, have created an electronic film made up of bendable, stretchable sensors that can detect pressure and temperature. The sheet, which is only one-tenth of a millimeter thick, is small enough to cover small objects and could give robots the ability to "feel" their surroundings without causing damage. It could also be used to cover car seats or furniture upholstery that can become dirty or damaged.

10

Ultraflexible organic devices

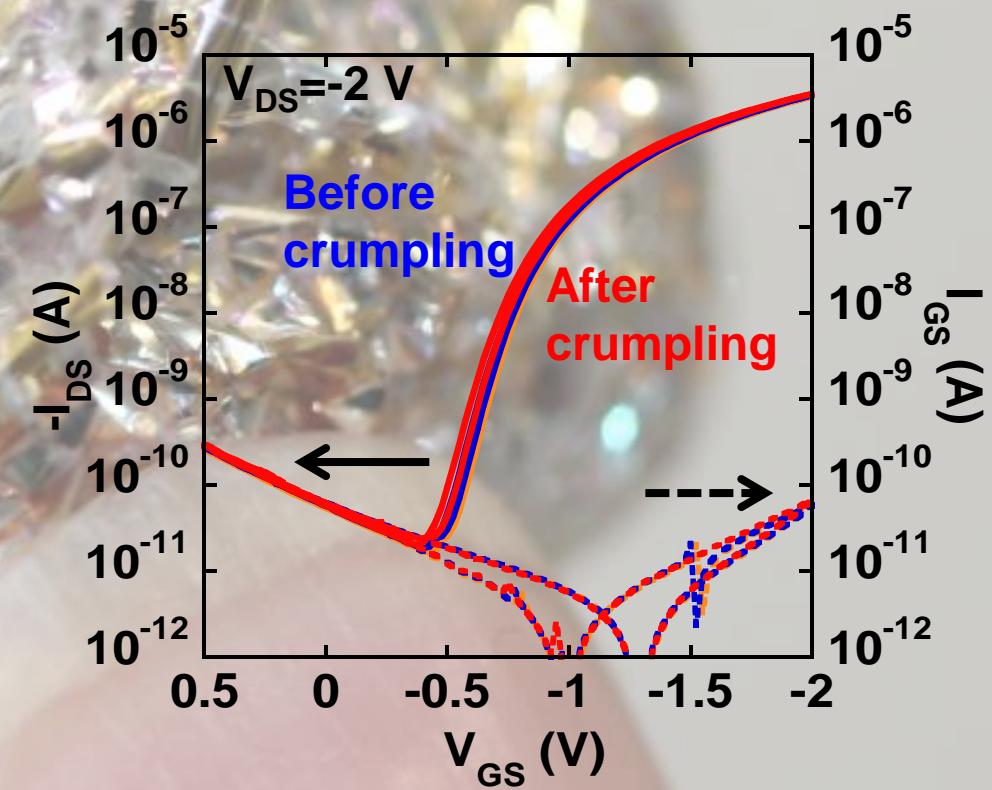
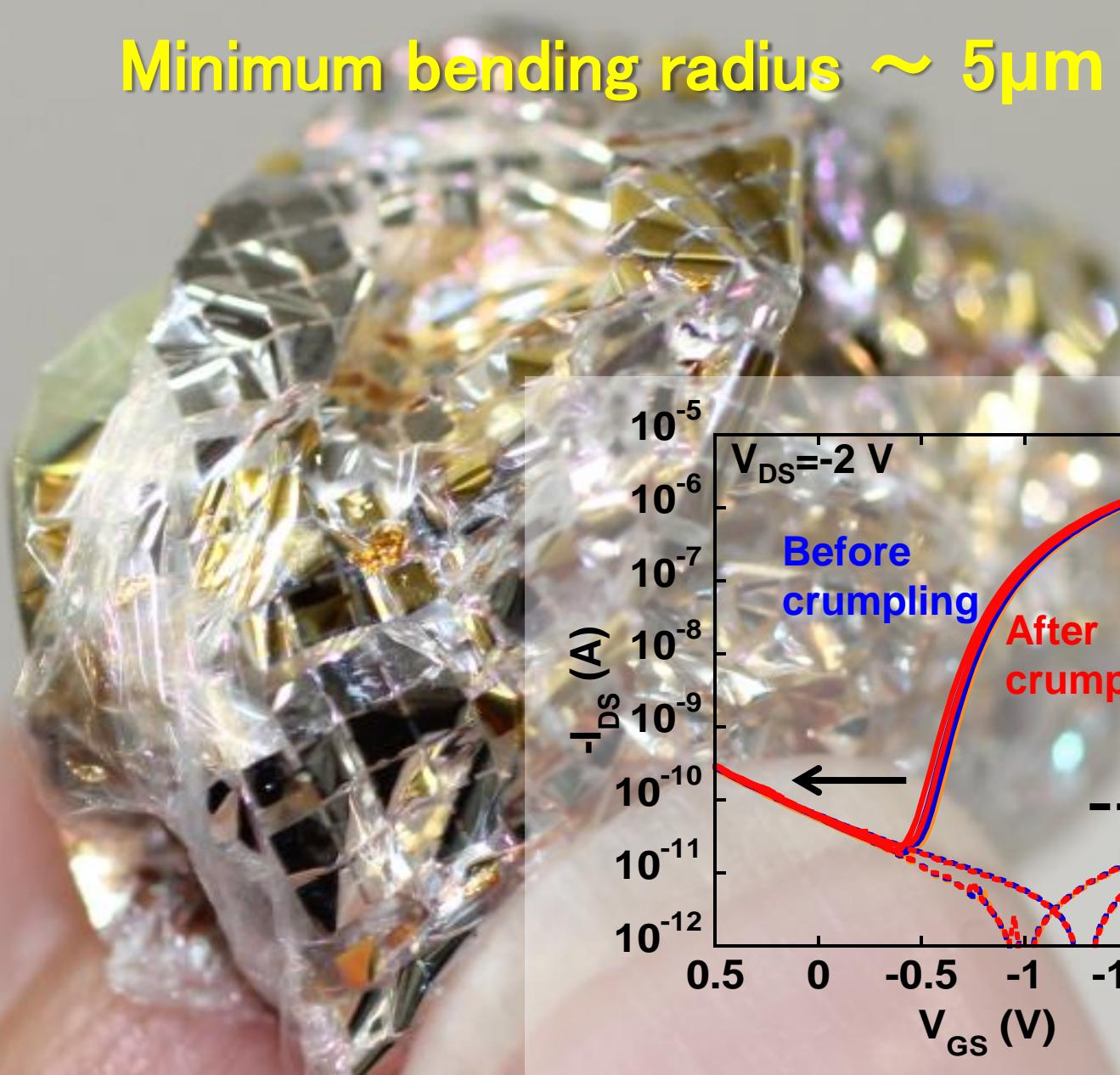
World's thinnest and lightest OTFT (3g/m²)



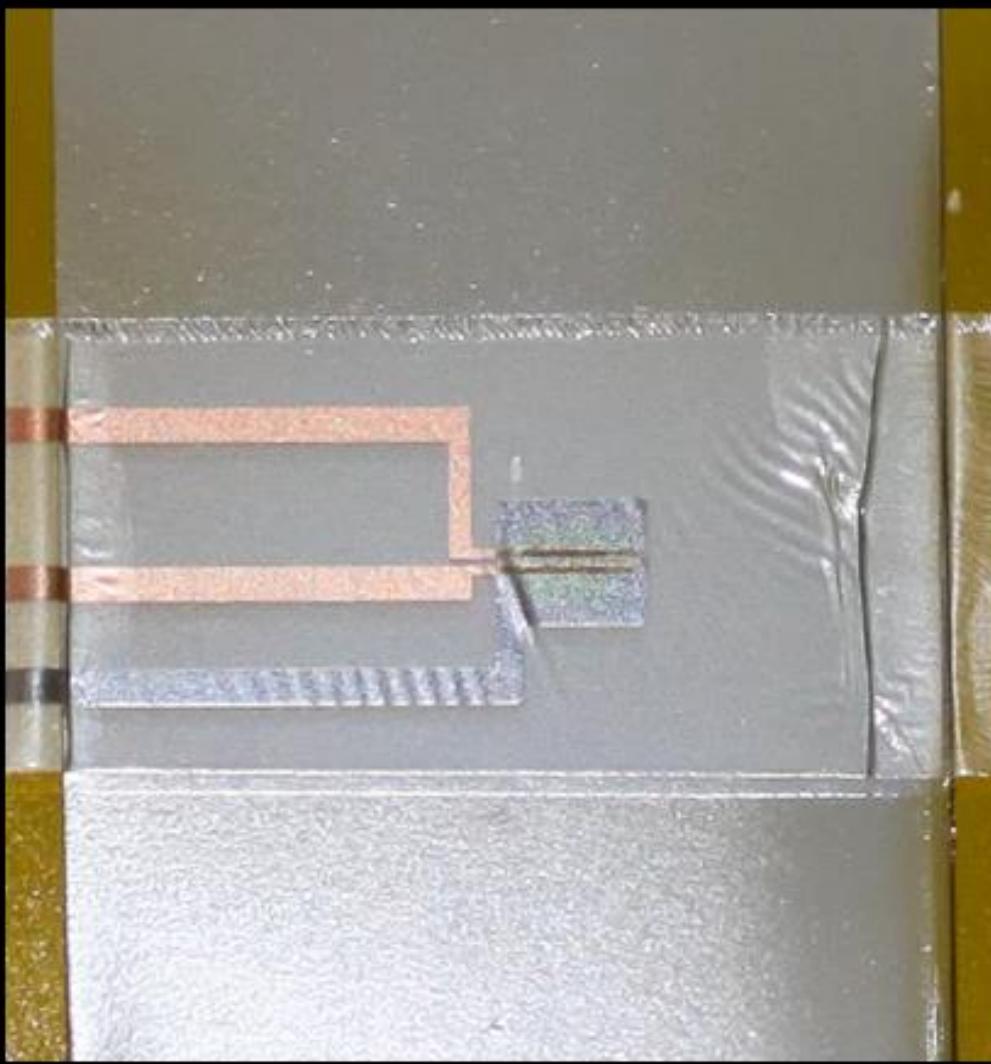
Martin Kaltenbrunner, et al., Nature 499, 458–463 (25 July 2013).

Amazing robustness: Crumpling

Minimum bending radius $\sim 5\mu\text{m}$



Stretchable organic transistors



Crumpled organic integrated circuits

Bending radius

$R=15 \mu\text{m}$



$R=20 \mu\text{m}$

$R=18 \mu\text{m}$



$R=<10 \mu\text{m}$



$100 \mu\text{m}$

Cross-sectional TEM

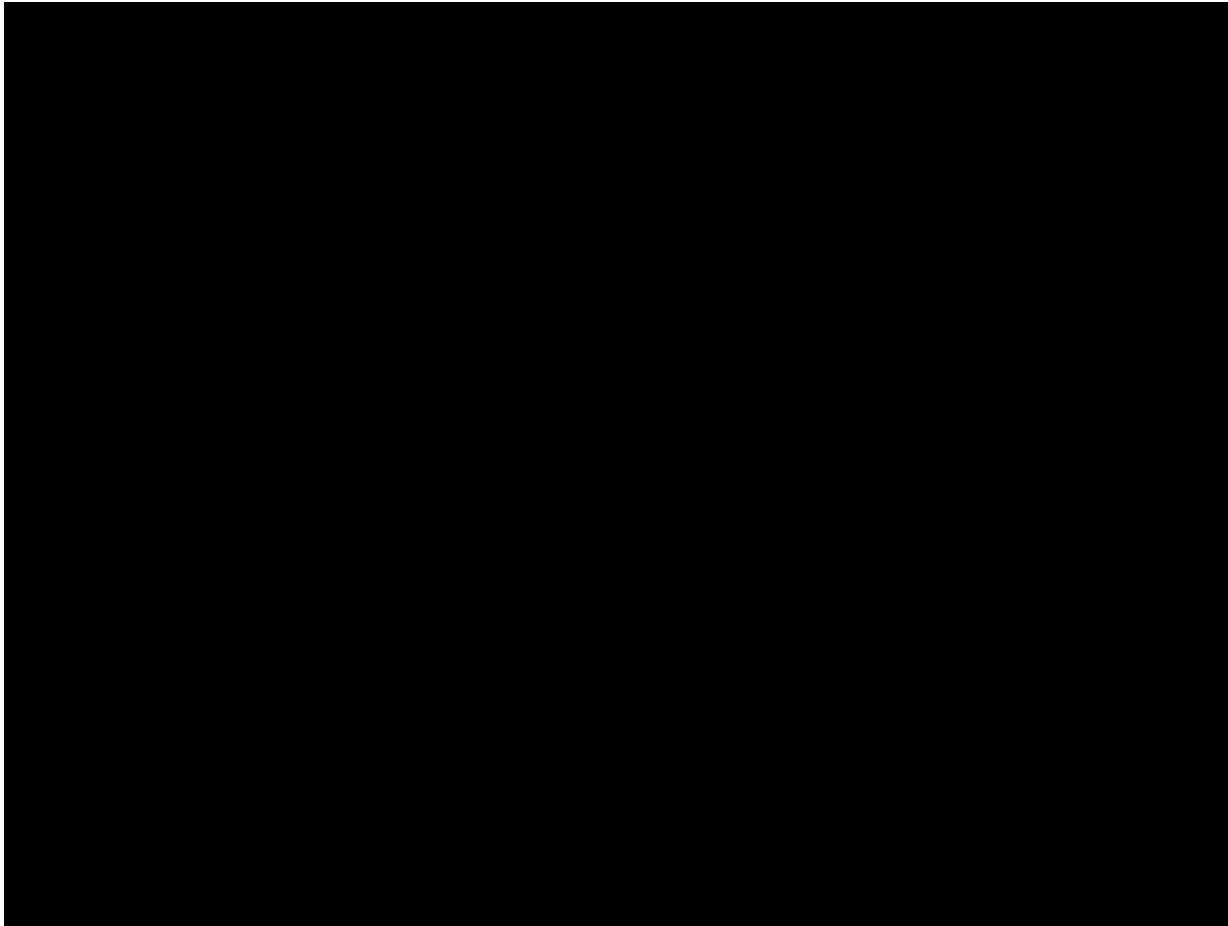
World's thinnest and lightest OPV

TV program on December, 2012
"Chikyu Astech - Sollar Cell on Thin Film"



Stretchable OLED

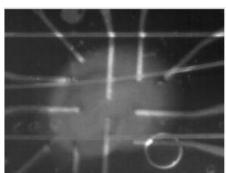
Brightness: 100 cd/m² Stretching >100%!



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

Flexible Electronics for Biomedical Applications

In-vitro neural interface



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

Neural Stem Cells

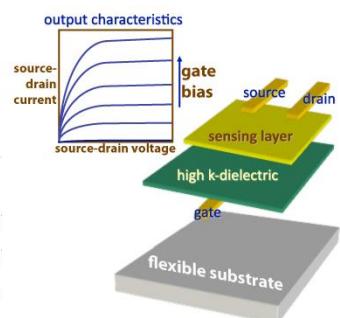
M. Berggren, et al.,
PLoS ONE, 6, e18624 (2011).

High-sensitive electronic skin

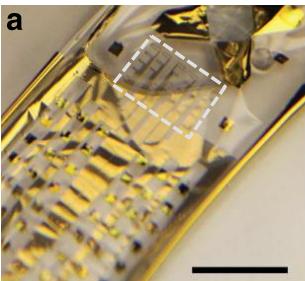


Z. Bao Nature Materials (2010).
Z. Bao, Nature Nanotech (2011). <http://www.holstcentre.com/>

Chemical sensors

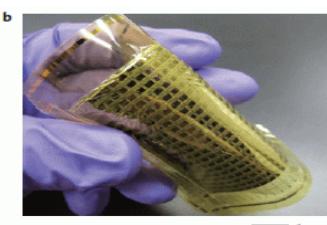


L. Torsi and A. Dodabalapur, Analytical Chemistry 70, 381A (2005).
Neural interfaces



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

Artificial skin

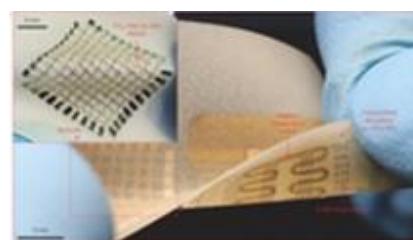


K. Takei, J. Ali
Nature Materials (2010).

Wearable electronics

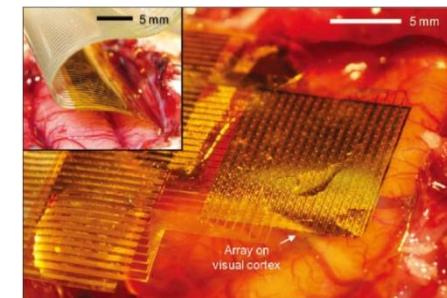


Holst Centre



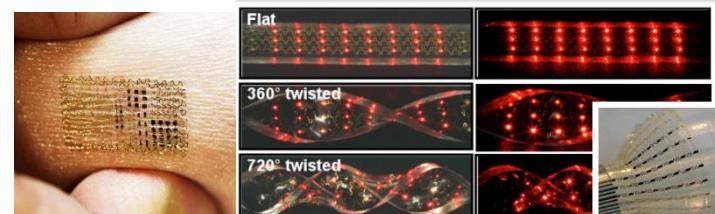
Dae-Hyeong Kim,
Nature Nanotech
9, 397 (2014).

Neural interfaces



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

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

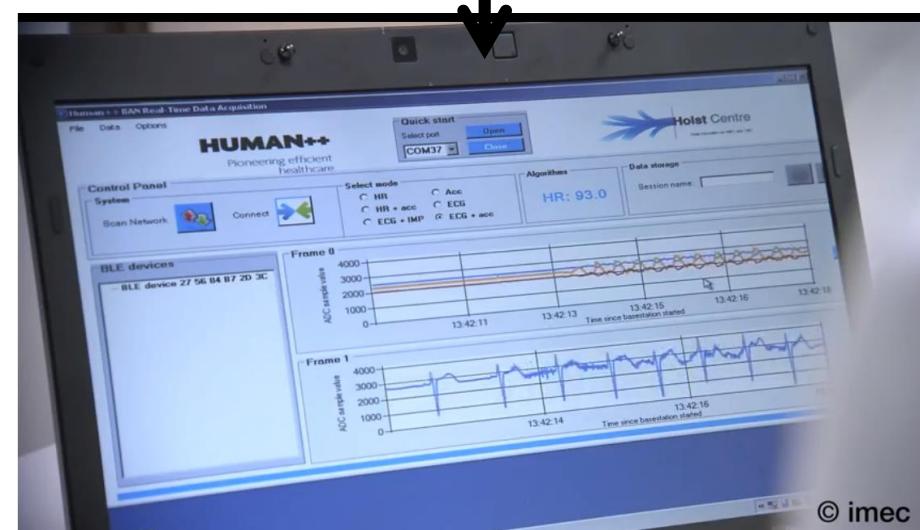
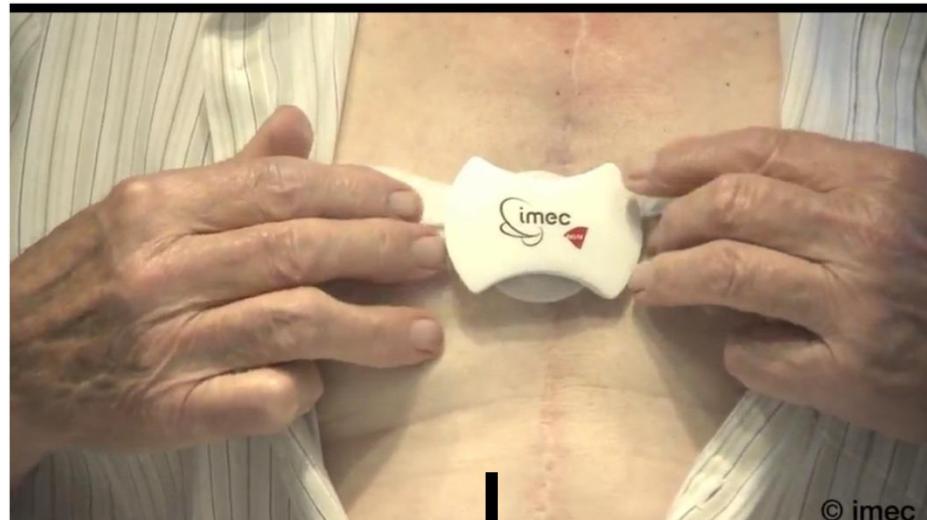
Proceedings of the 2nd Conference on Wireless Health, 15 (2011).



**Bluetooth
System**

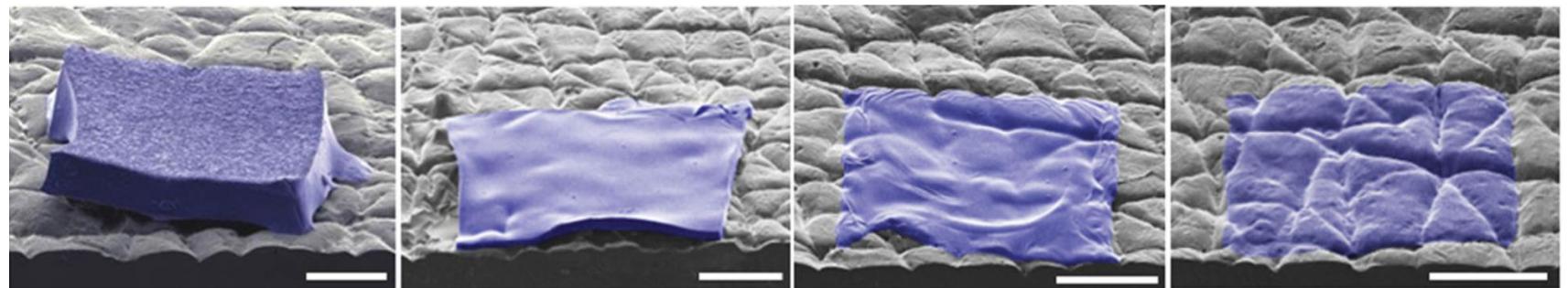
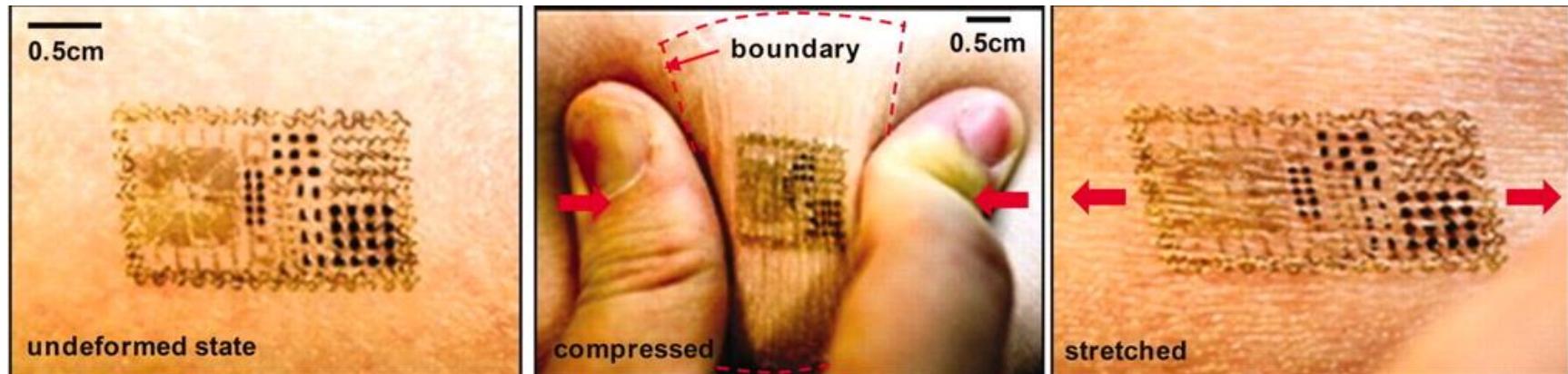
**ECG Measument
System**

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

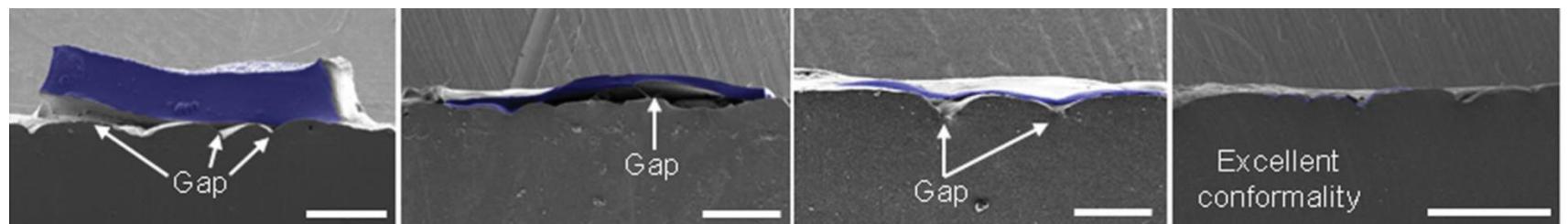


John A Rogers's Flex Devices

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN



500 μ m 100 μ m 36 μ m 5 μ m ← Thickness



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

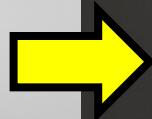
From Robotics to Human

Robotics E-skins
(2003)



$t=1 \sim 2 \text{ mm}$

Thickness : 1/1000



Bionic Skins
(2013)

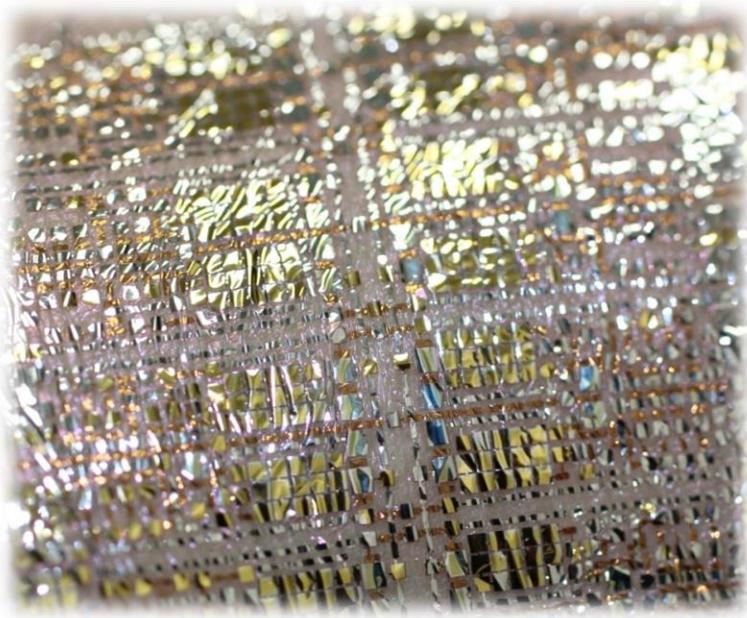


$t=2 \mu\text{m}$

- 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).

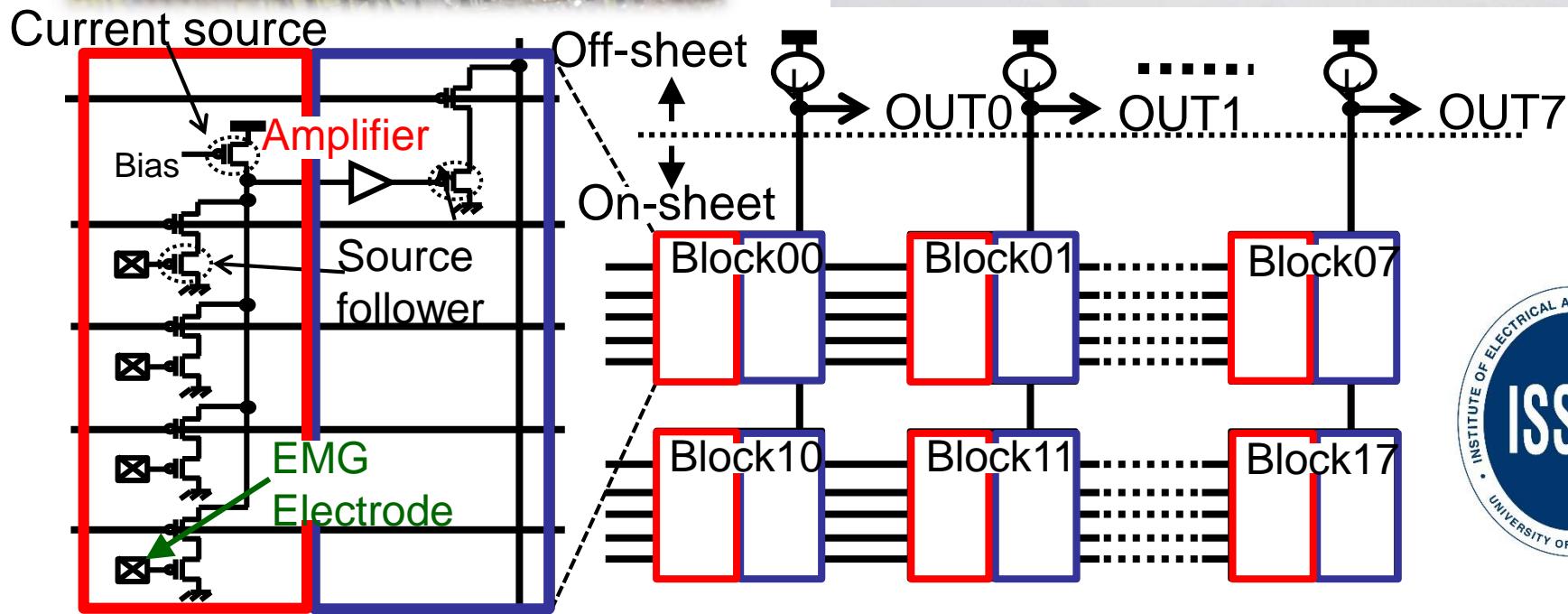
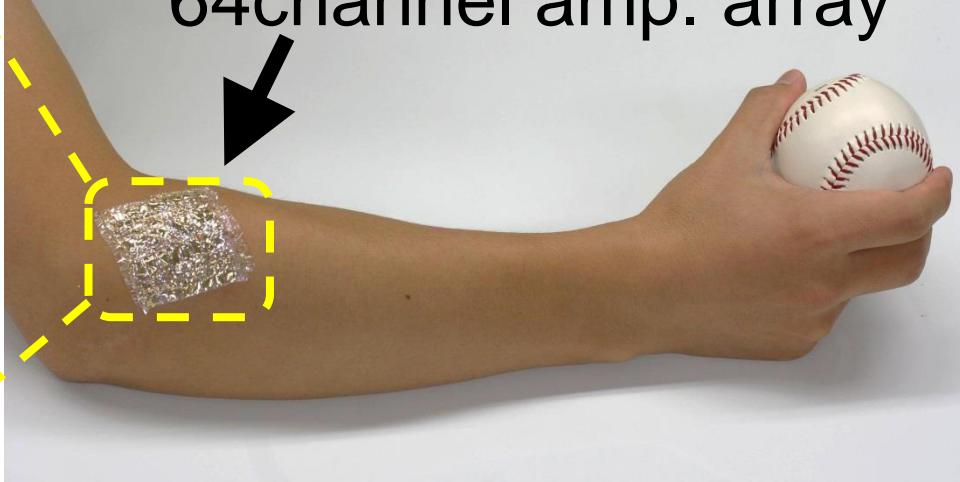
M. Kaltenbrunner, et al., Nature 499, 458 (2013).

Surface electromyogram monitoring



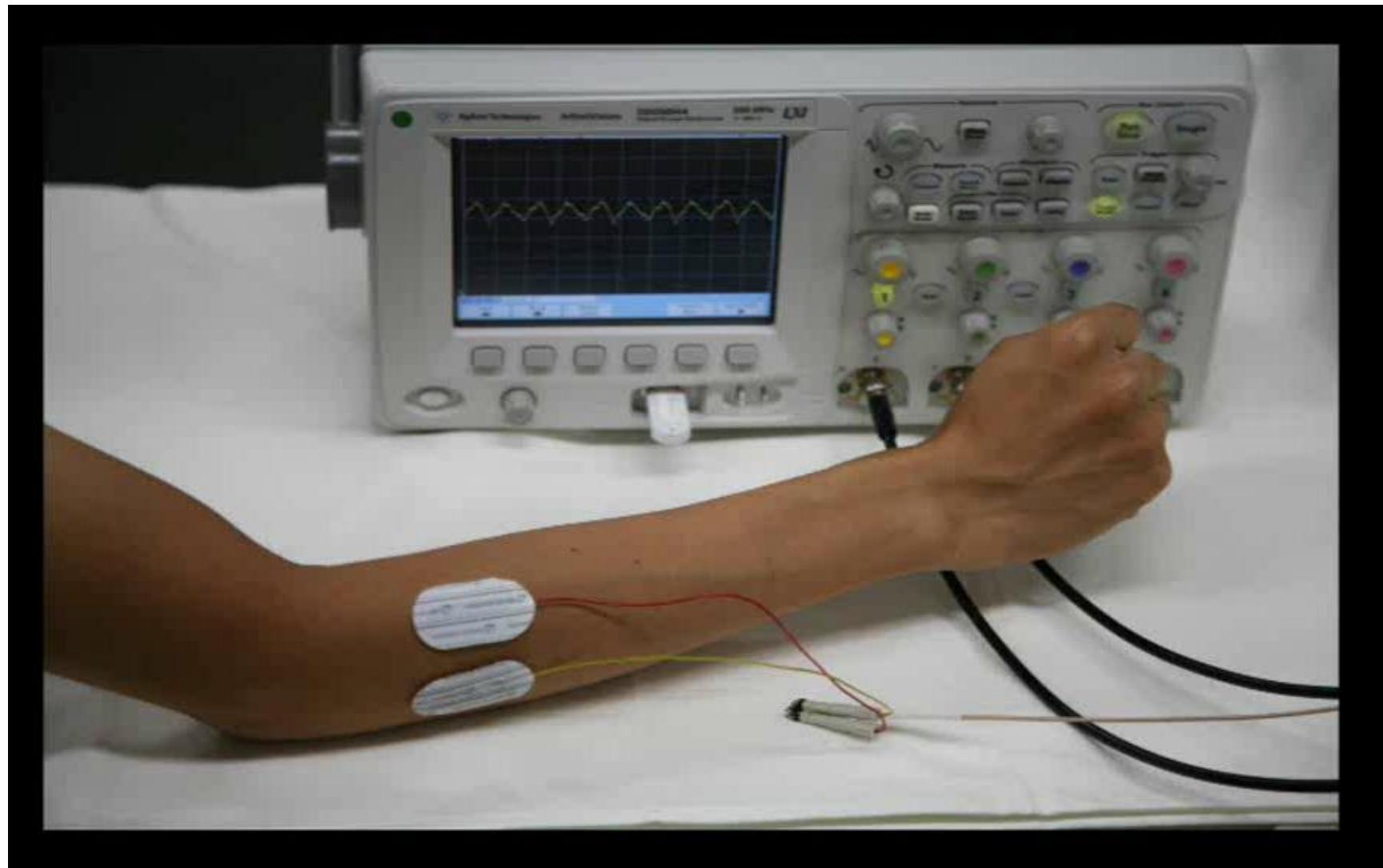
Fuketa, et. al., IEEE/ISSCC2013 #6.4.

64channel amp. array



Electromyogram measurement

For stress-free healthcare-monitoring and welfare IT



Implantable organic amplifier

Flexible: $R < 10 \mu\text{m}$

Weight: $3\text{g}/\text{m}^2$

Total thickness: $2.5 \mu\text{m}$
(w/ encapsulation)

Large-area coverage:
 $50 \times 50 \text{ mm}^2$

Imperceptible electronics

Applications

Medical IT

Welfare IT

Digital Healthcare



What

Electromyogram

Electrocardiogram

Body temperature

Heart rate

Blood pressure

Specifications

The lightest (3 g/m^2)

The thinnest ($2\mu\text{m}$)

Where

Everyday life

During exercise

At hospital

Acknowledgements



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(MPI)



Lynn Loo
(Princeton)



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(JKU)



M. Sekino
(U Tokyo)



T. Isoyama
(U Tokyo)



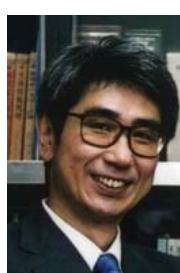
Elastic conductors

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



Emerging applications

Digital Healthcare

Medical IT

Welfare IT