Academic Approach to Industry-Relevant Microdevices

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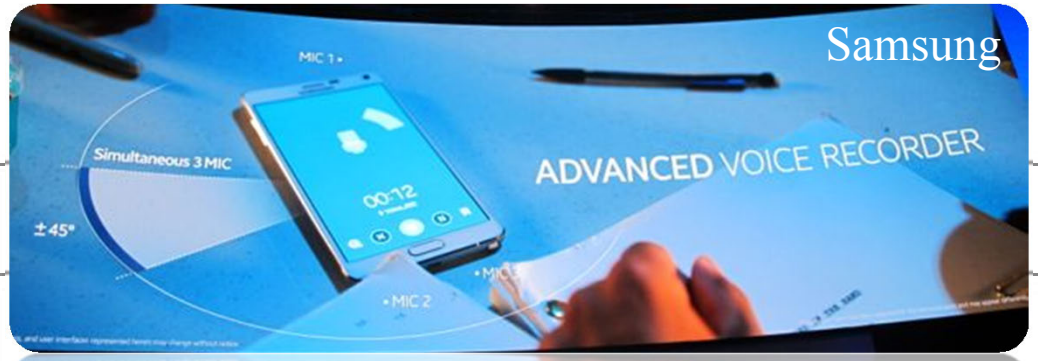
mems tohoku 検索

MEMS Microphone Market Growth

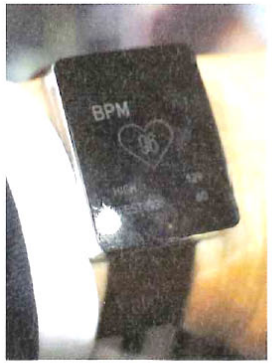


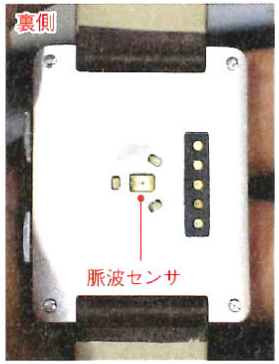
Yole Development, 2013

2.4 billion devices sold in 2013, ~90% for consumer applications
Knowles (USA) holds about 60% market share.
Knowles' microphones are produced in Sony Kyushu in Kagoshima.

Inertia Sensors for Our Health

Watch-type life log terminals (Wellograph)





(JAYBIRD)

Plethysmograph chip (NeuoSky)

Biosensor (Scanadu)

Life log system:
Activity monitoring senor by
MEMS accelerometer
+ Electrocardiograph 心電計,
Plethysmograph 脈波計,
Pulse oximeter,
Thermometer etc.

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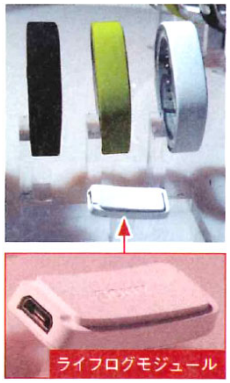
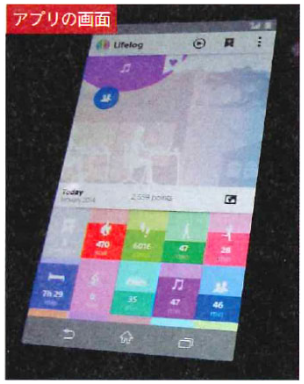
Life log module and software
on smartphone (Sony)





Activity monitors for baby
(Rest Devices)

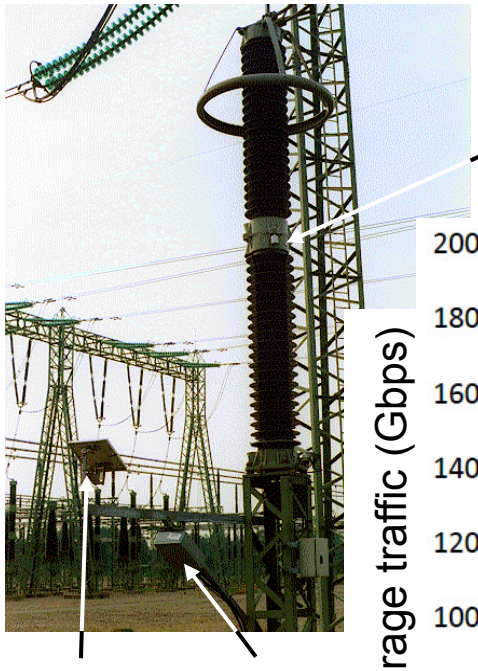
(Sensible Baby)

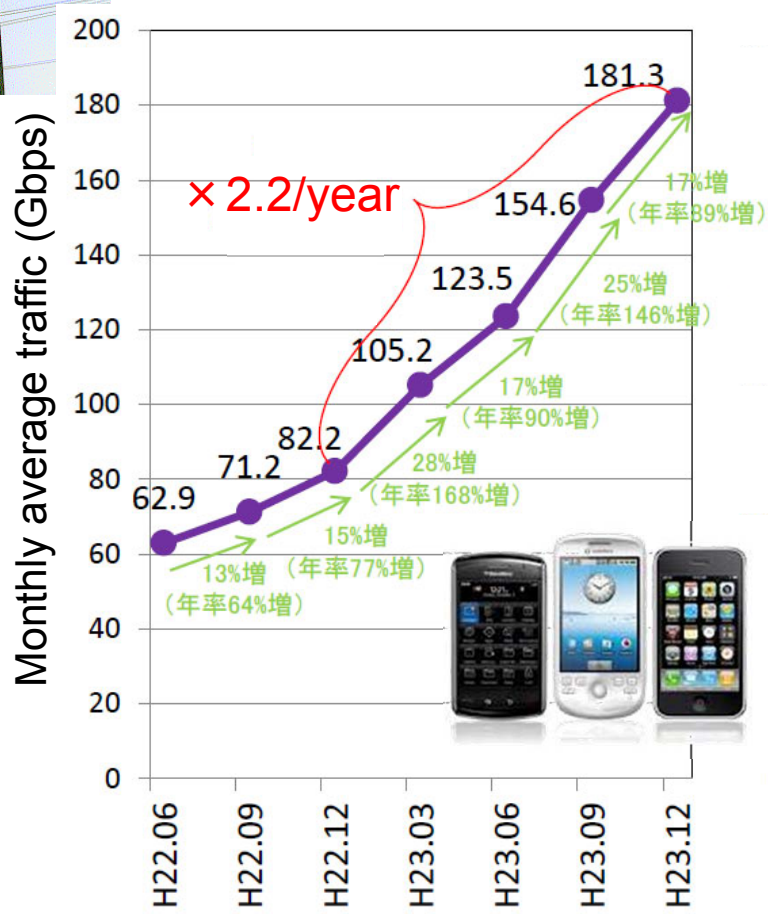
Activity monitor
for pet (FitBark)

Sensor Network for Infrastructure Safety

I-35W Mississippi River bridge (constructed in 1964) suddenly collapsed on August 1, 2007

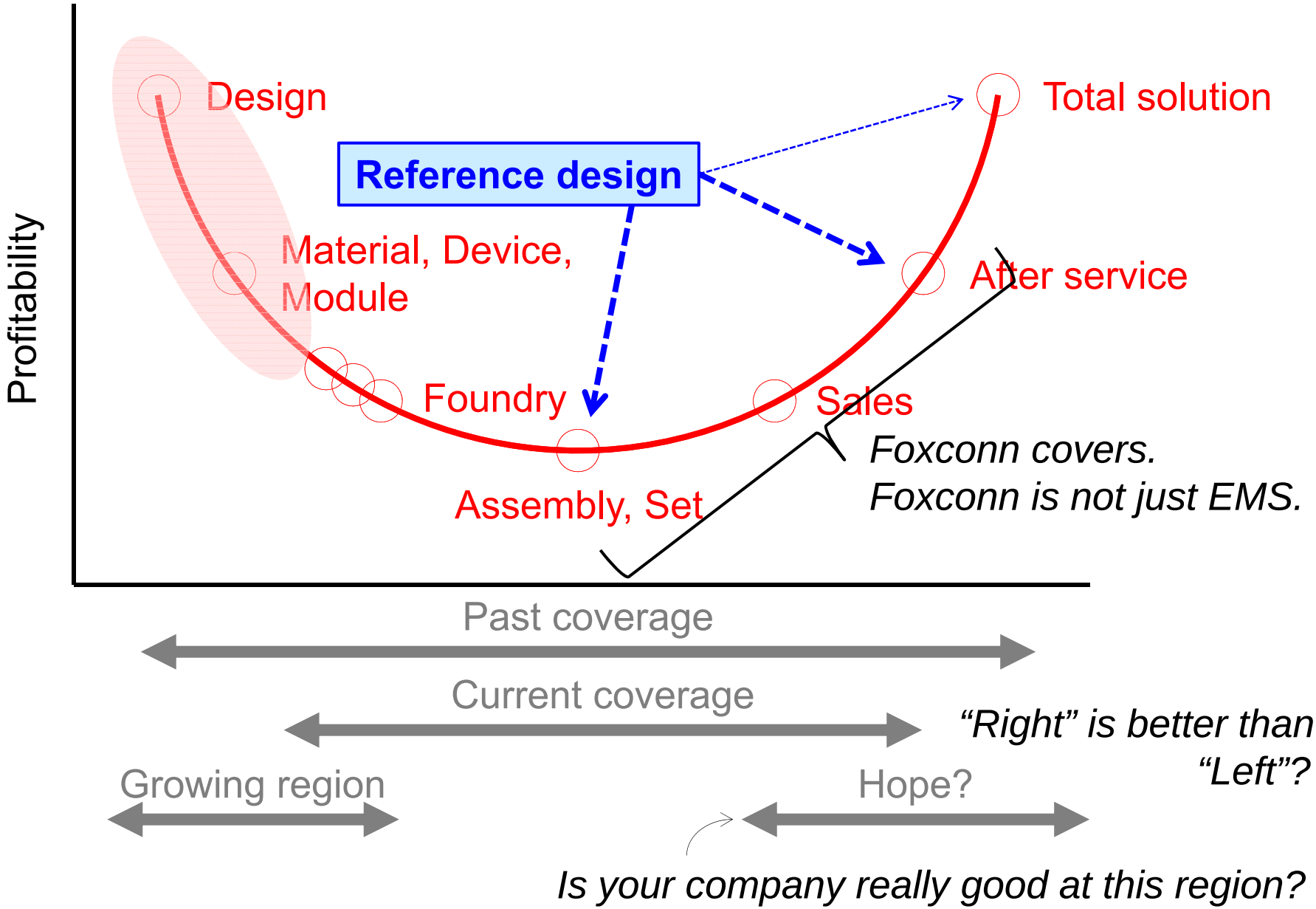
Metropolitan expressway Haneda #1 (constructed in 1963)





Monthly average traffic of mobile communication in Japan

Smile Curve


Profitability
Design
Total solution
Reference design
Material, Device,
Module
After service
Foundry
Sales
Assembly, Set
Foxconn covers.
Foxconn is not just EMS.
Past coverage
Current coverage
"Right" is better than
"Left"?
Growing region
Hope?
Is your company really good at this region?

Messages from Academic

Microdevice industry will develop continuously,
while the research and development of new microdevice is not so easy from technical and economical points of view.

“One device, One process, One package”

In general, an IC can be developed based on the standard process and packaging technology, because CMOS foundries and IC packaging houses are widely available. On the other hand, different MEMS are often made via different fabrication processes using diverse technologies, each of which has its own know-how and history.

Recently, research universities have well-equipped facilities for MEMS, accumulating technology and know-hows.

Collaboration with academic side saves cost and time for companies compared with purely in-house R&D.

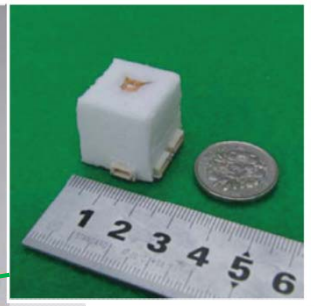
Tactile Sensation on Whole Robot Body

"RIBA", Riken

"Paro", Intelligent Systems

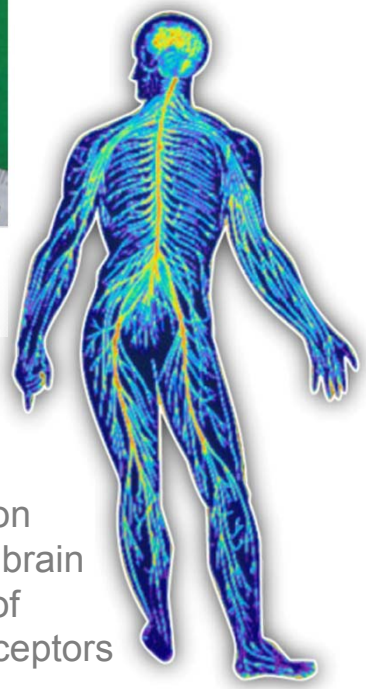
Tactile sensor network for home and medical robots enables:

- Contact detection for collision safety
- Body contact communication



Bus-conencted tactile sensor

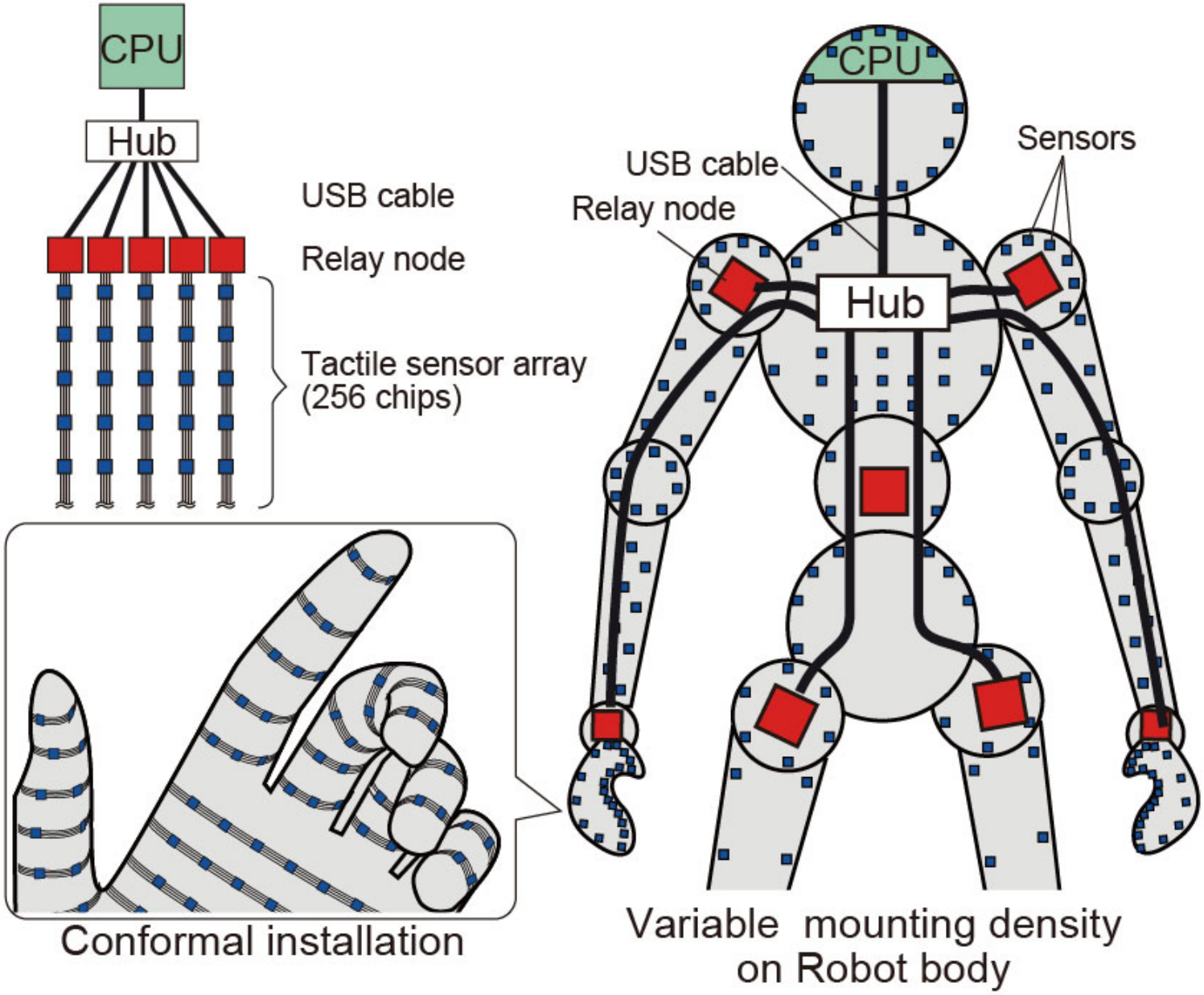
I. Kumagai *et al.*, IEEE/RSJ'12 (2012)



Parallel connection between brain and 10^7 of tactile receptors

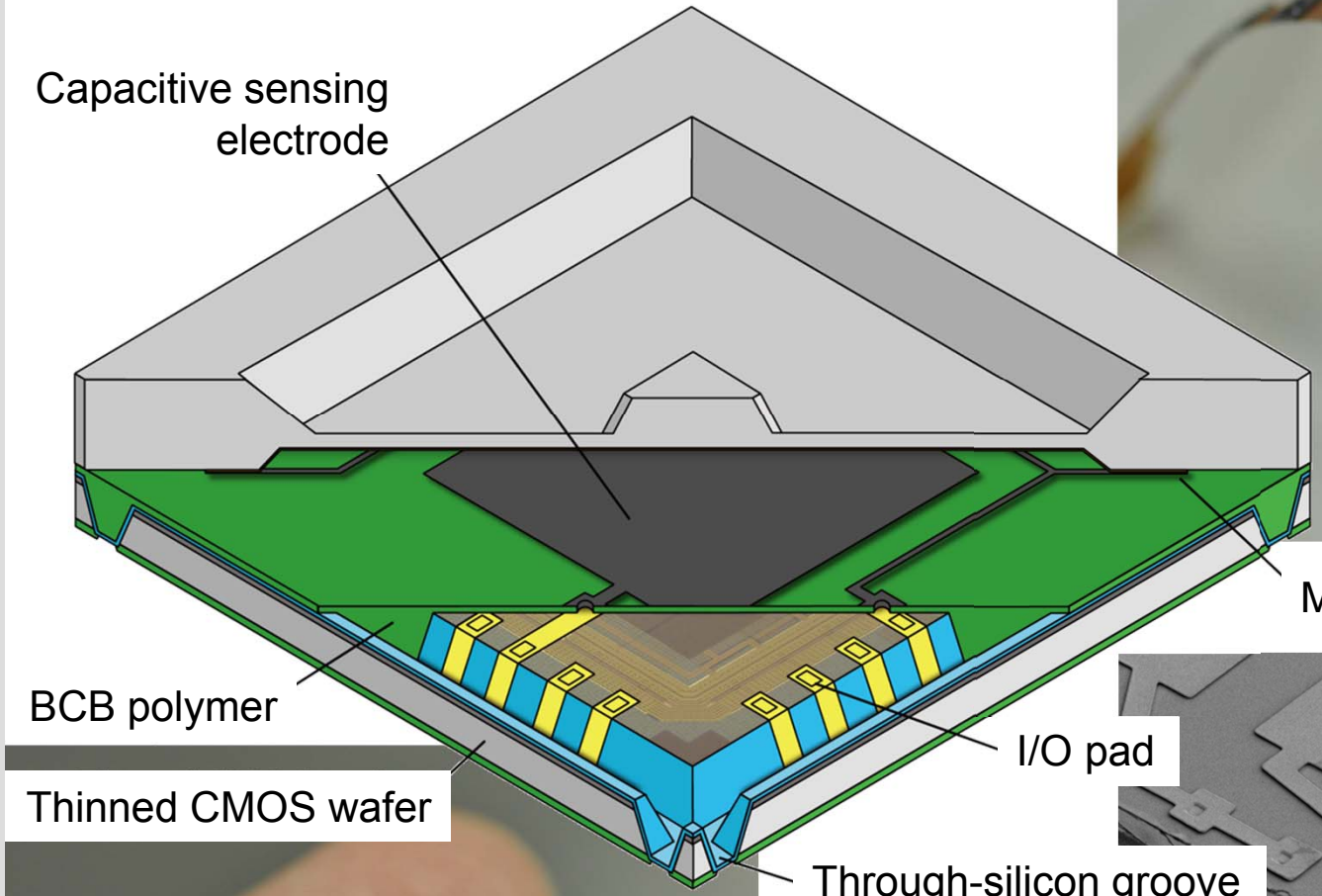
How to imitate or replace nerve network?

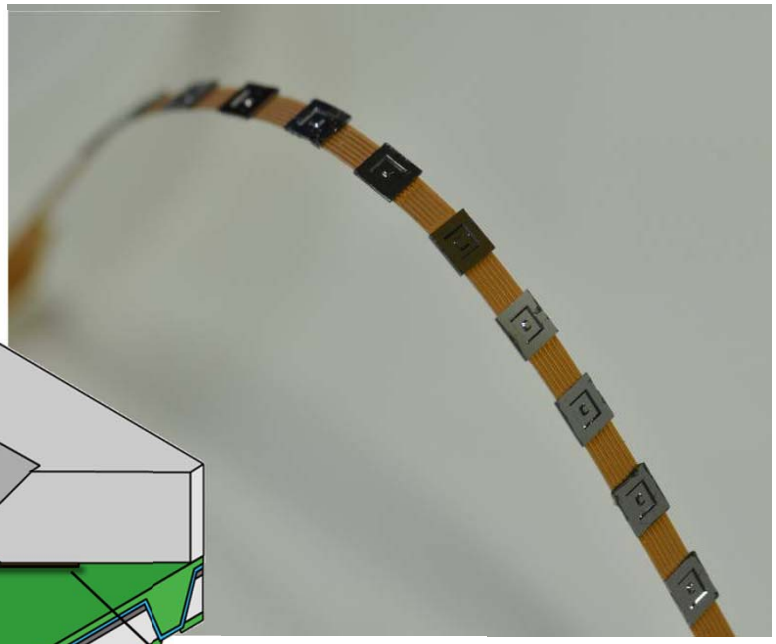
Tactile Sensor Network on Robot

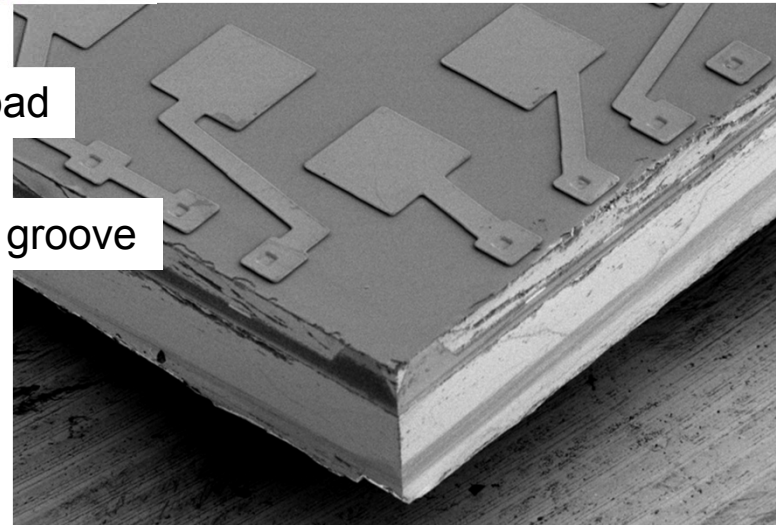


MEMS-on-CMOS Integrated Tactile Sensor

M. Makihata *et al.*, Transducers 2013, pp. 2729-2732

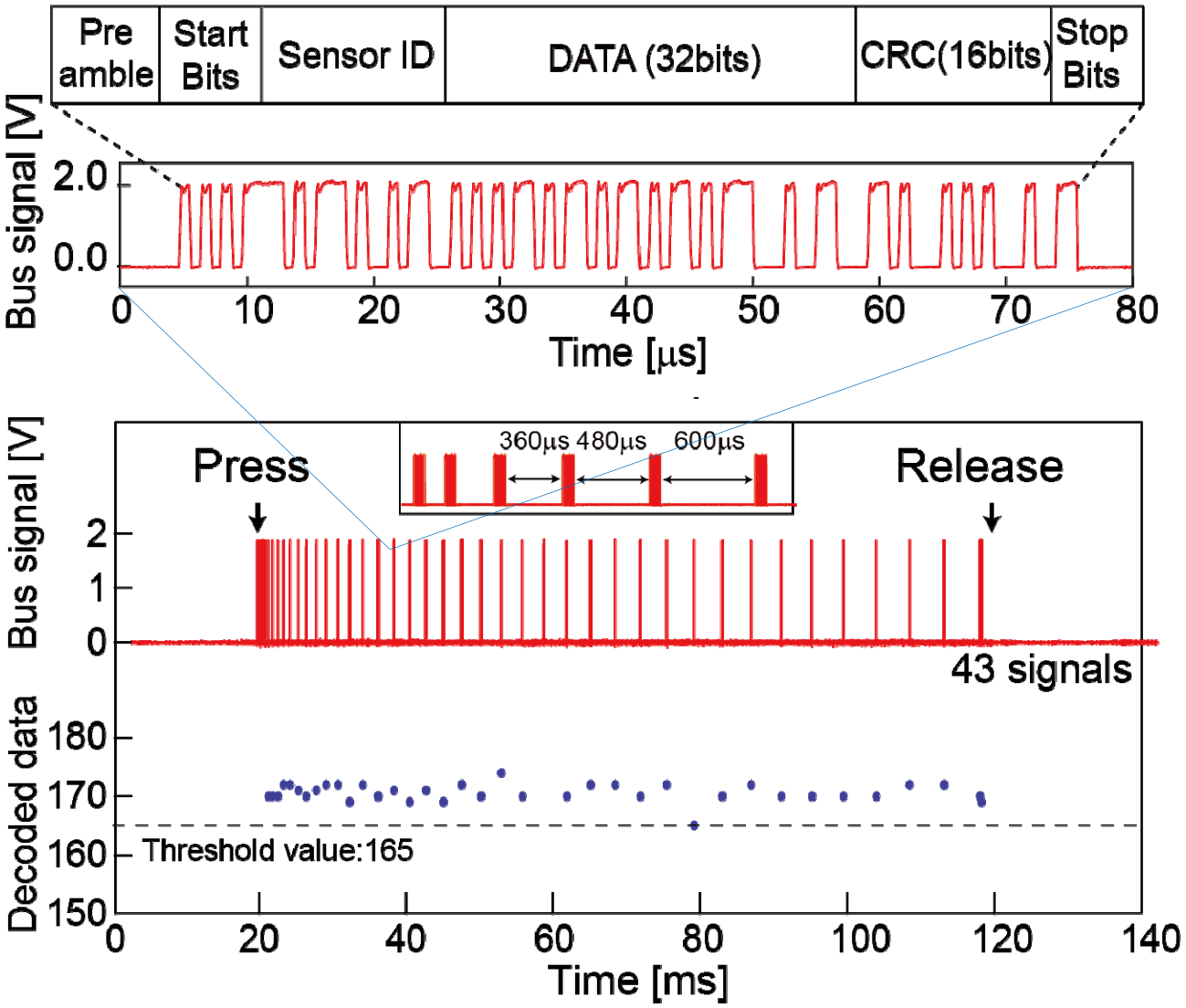


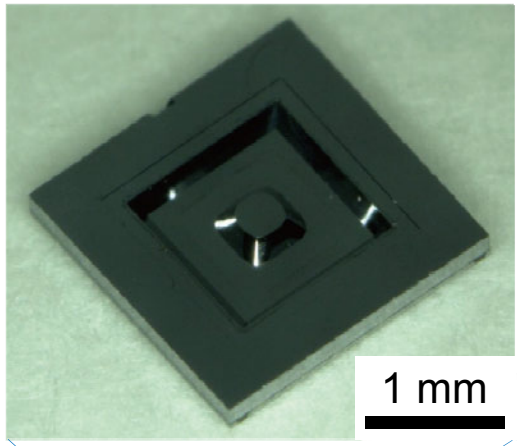


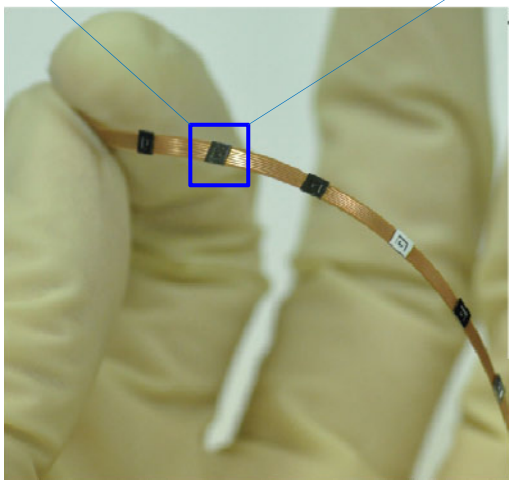


Data from Integrated Tactile Sensor

M. Makihata, M. Muroyama, S. Tanaka *et al.*, 2012 MRS Spring Meeting

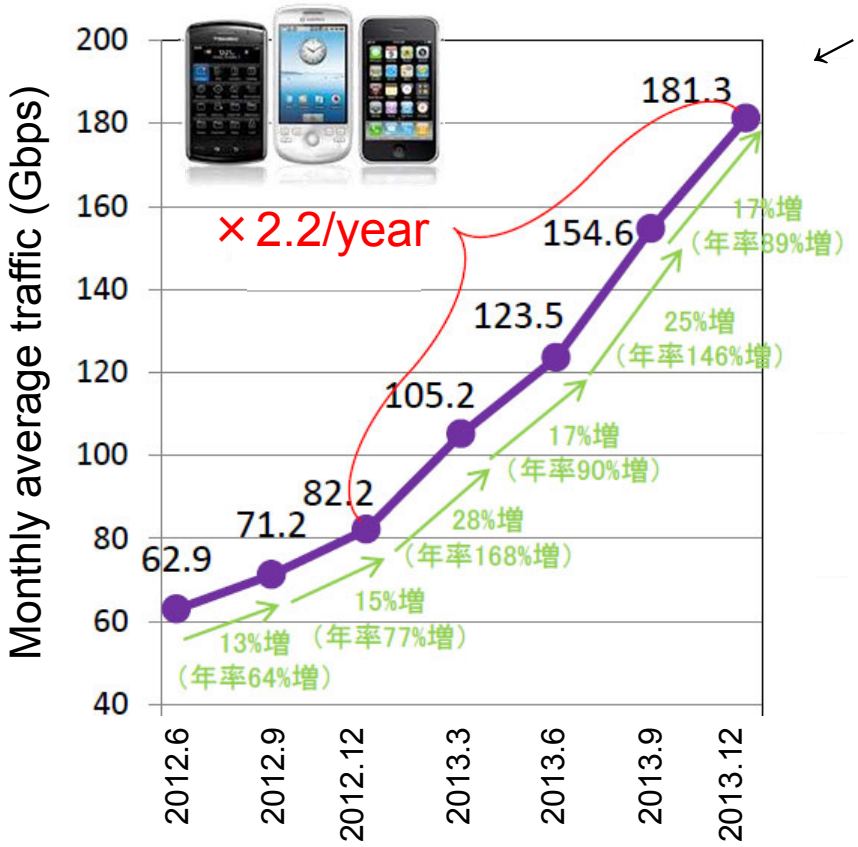




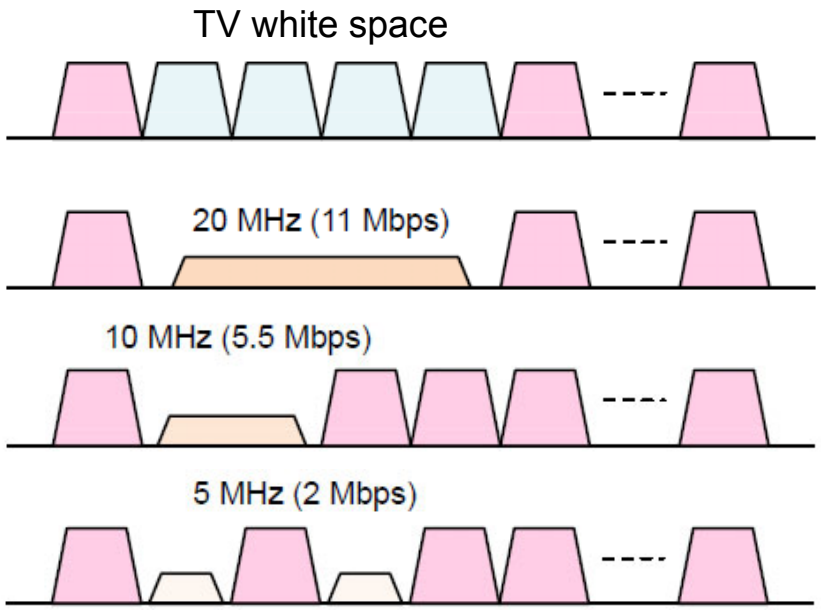


Threshold & Adaption operation

TV White Space Cognitive Radio

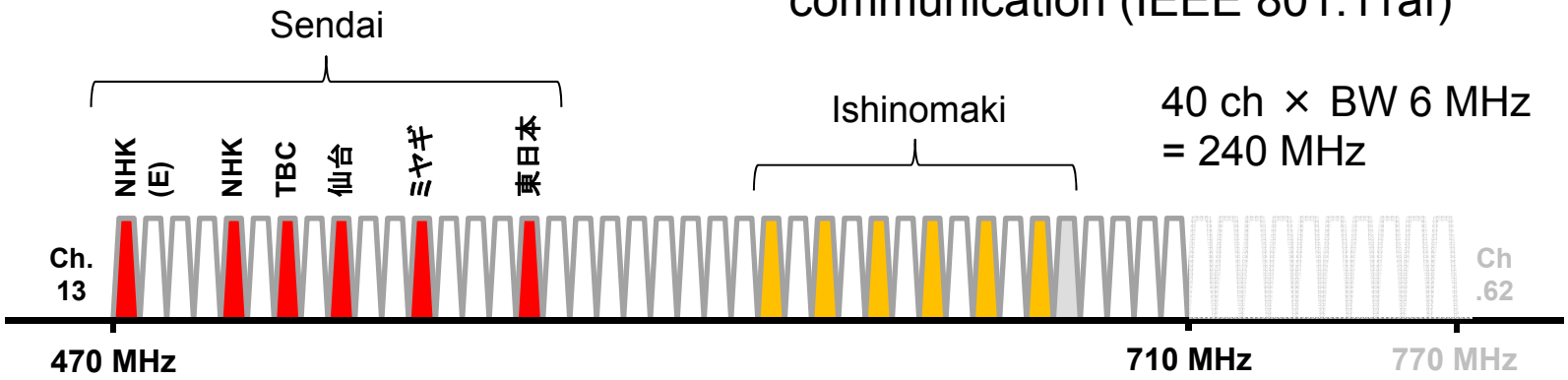


↙ Monthly average traffic of mobile communication in Japan



TV white space cognitive radio communication (IEEE 801.11af)

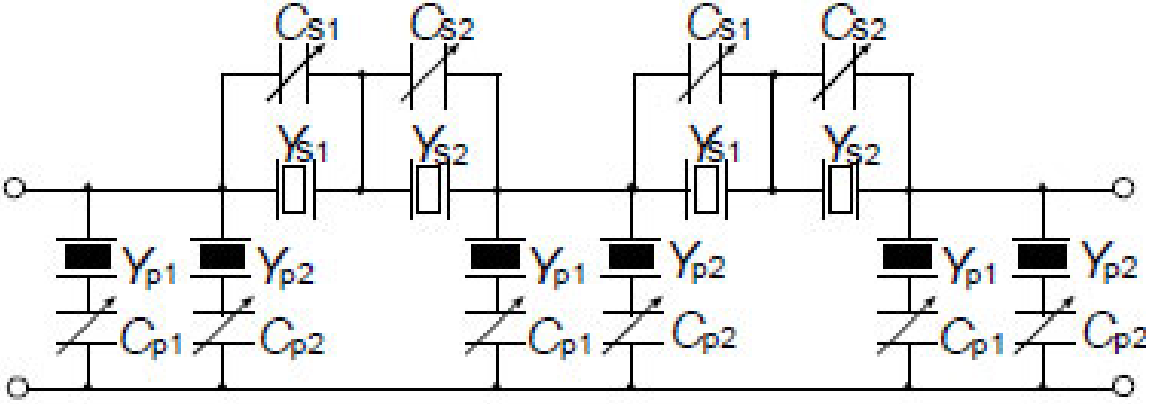
Digital TV band



40 ch × BW 6 MHz = 240 MHz

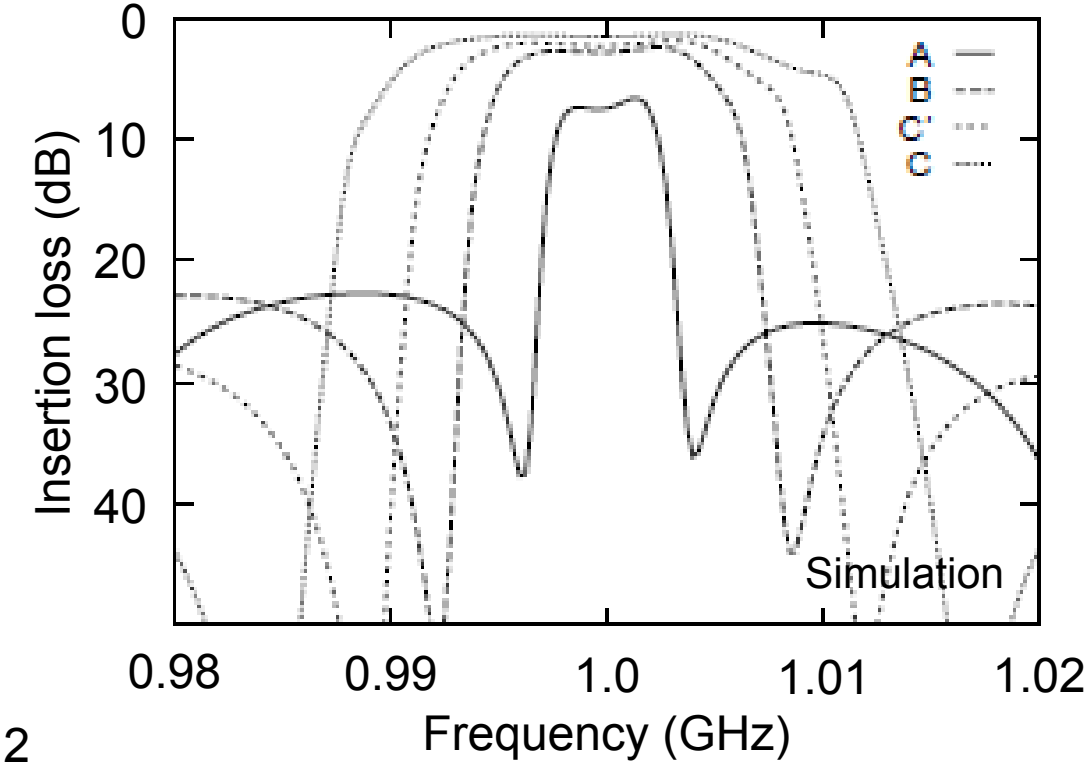
Design of Tunable SAW Filter

M. Inaba, T. Ohmori, K. Hashimoto (Chiba Univ.), Jpn. J. Appl. Phys., 52 (2013) 07HD05



Y: SAW resonator
C: Varactor

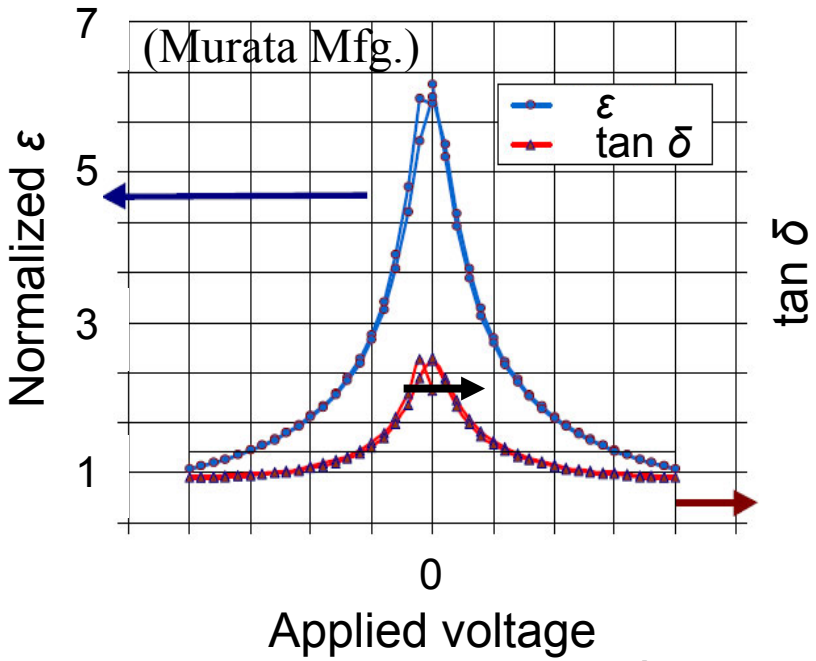
10 SAW resonators and
10 varactors integrated
on 42º Y $LiTaO_3$

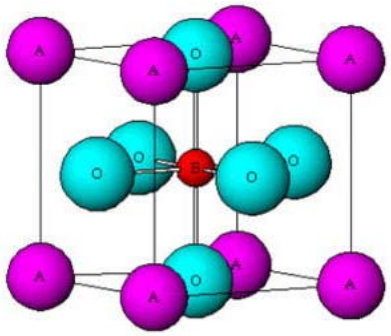


Relationship between capacitance and bandwidth

	A		B		C'	C
C_{p1}	Small	←				Large
C_{p2}	Large	←				Small
C_{s1}	Small	←				Large
C_{s2}	Large	←				Small

Hetero-Integration of BST Varactor

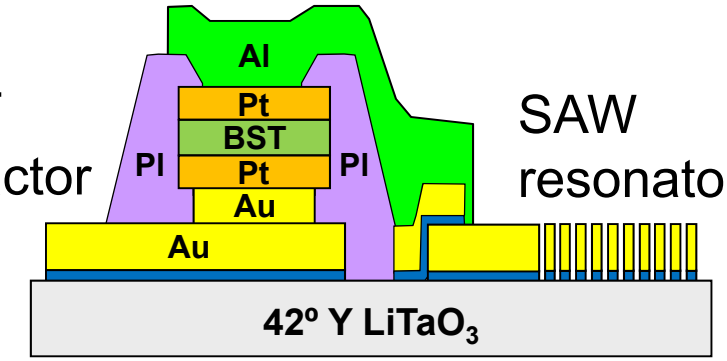




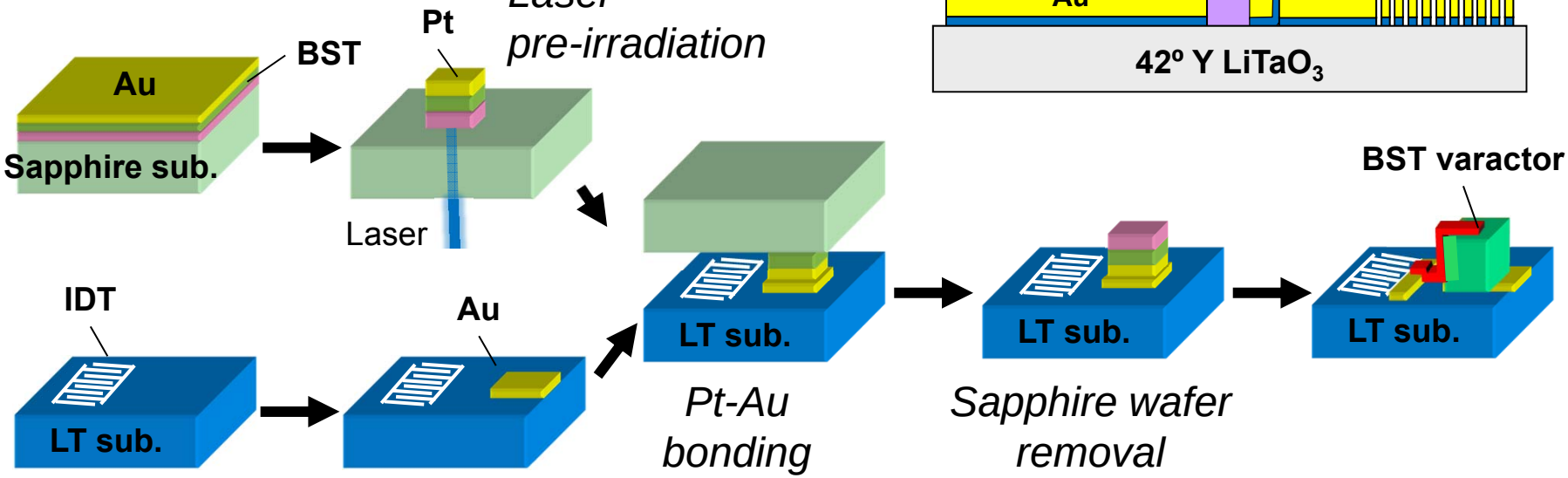
$(Ba_{1-x}Sr_x)TiO_3$

BST is deposited at 600ºC or higher.

BST varactor

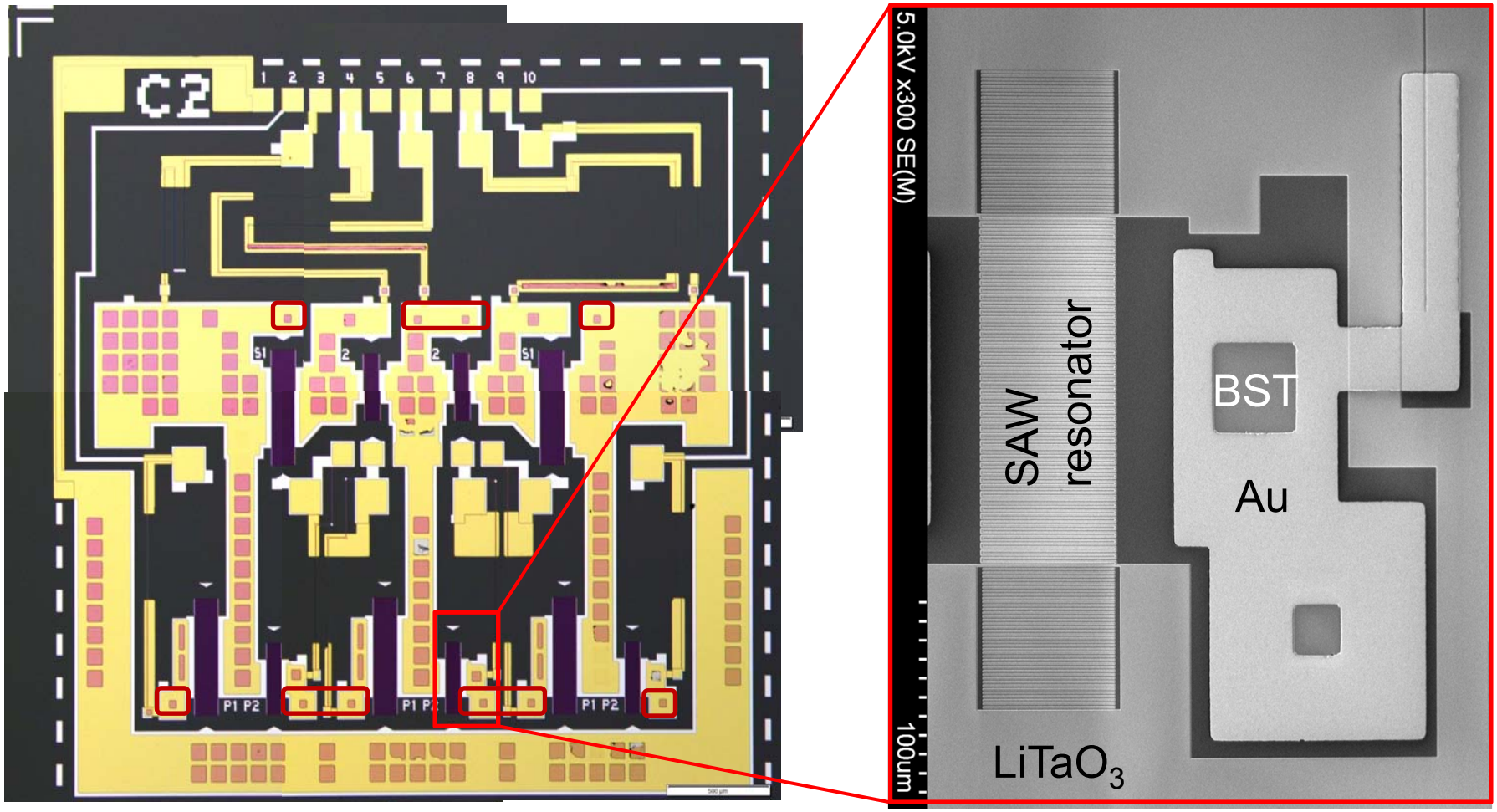


SAW resonator



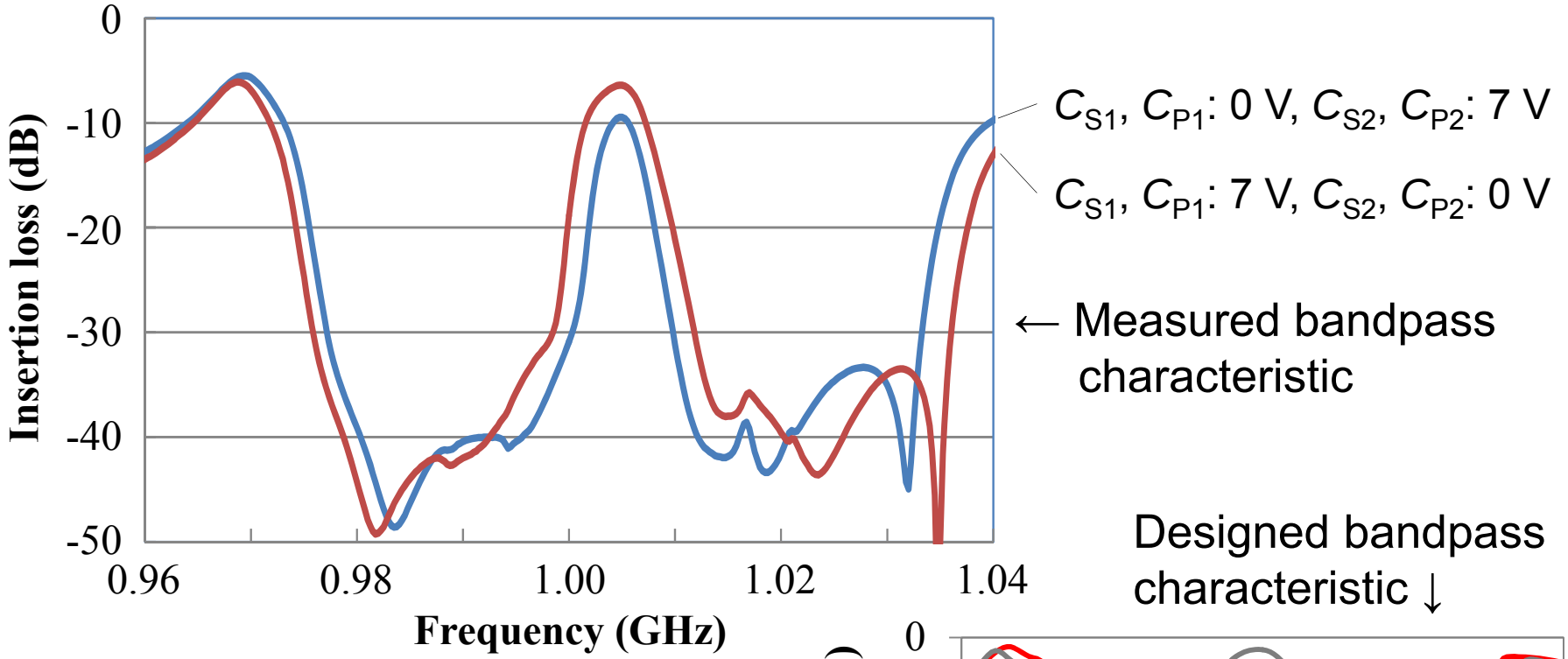
Transferred BST on $LiTaO_3$ SAW Wafer

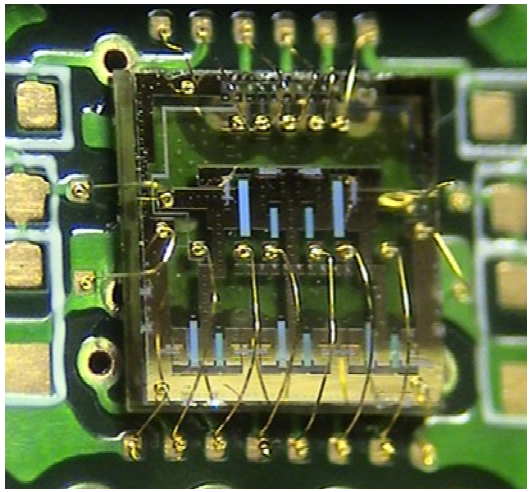
H. Hirano *et al.*, IEEE International Ultrasonics Symposium 2014



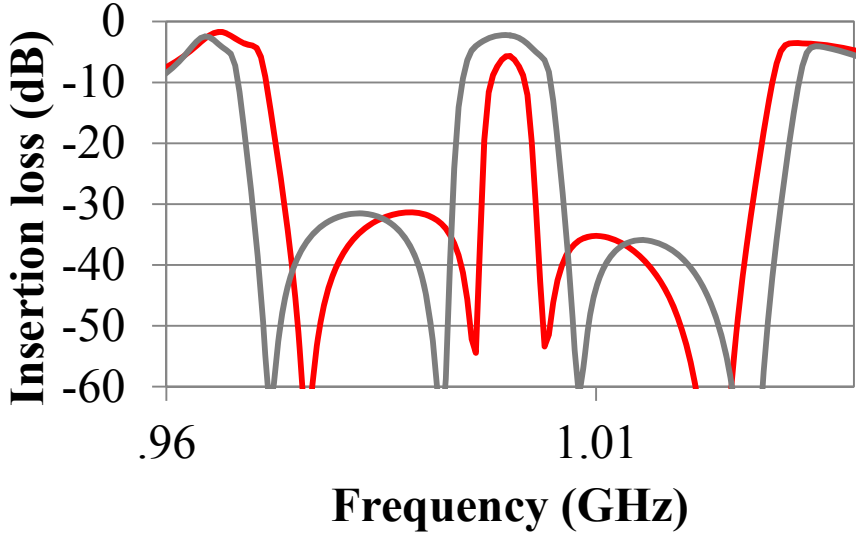
4 mm × 4 mm
(10 SAW resonators and 10 BST varactors)

Bandpass Characteristic of Tunable SAW Filter





Designed bandpass characteristic ↓



Demonstration Using Tunable SAW Filter

Connected using TV band

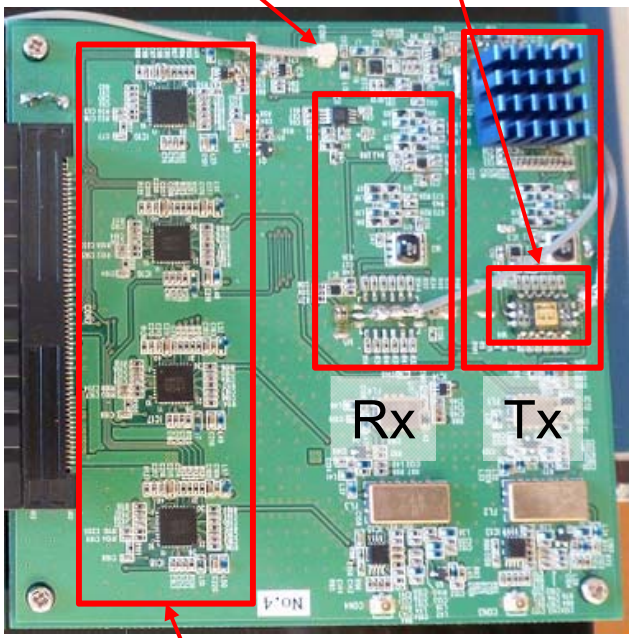
Cognitive wireless system (Terminal)

Cognitive wireless system (Base station)

Tablet PC for interface connected to the terminal cognitive wireless system

Tunable SAW filter

Antenna port

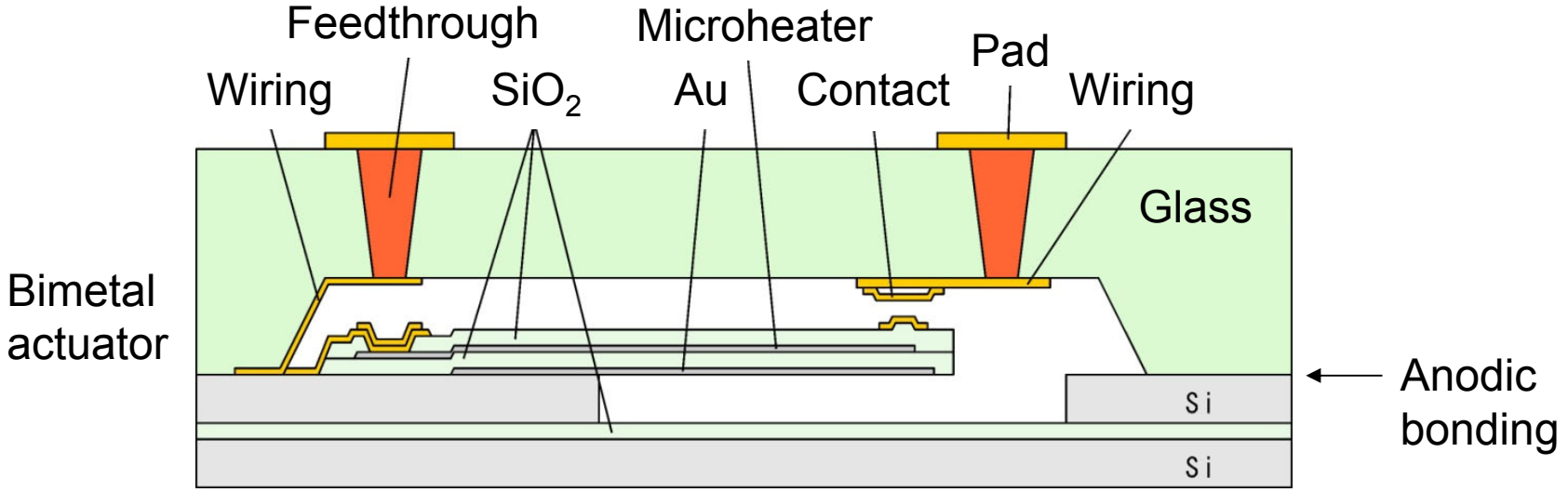


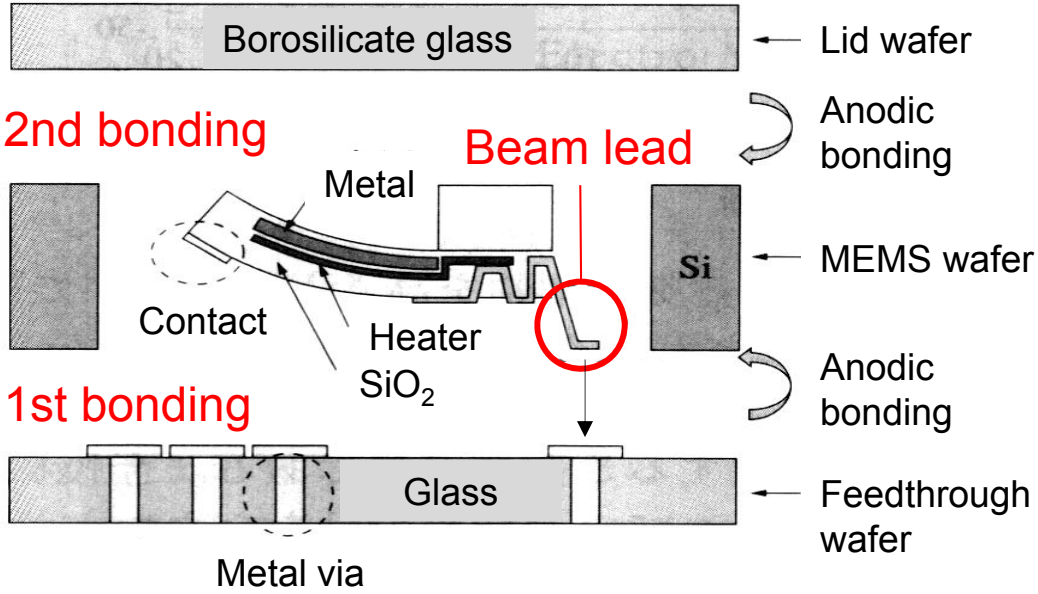
DA converter

The cognitive wireless system was developed by NICT.

RF MEMS Switch with Glass Feedthrough Lid

Y. Liu *et al*. (Tohoku Univ.), IEEE MEMS '01, pp. 220-223

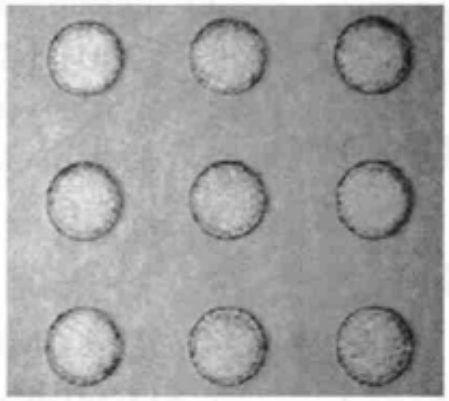


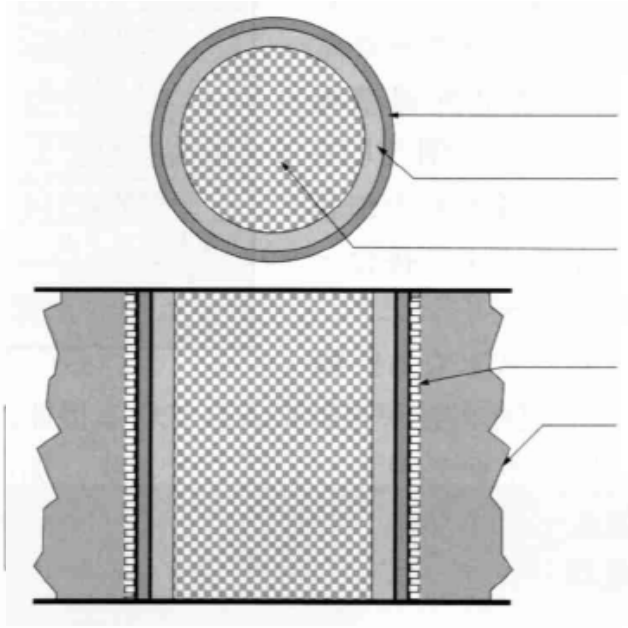


Glass Feedthrough Substrate (Tecnisco)

テクニスコ，2008マイクロマシン／
MEMS技術大全，pp. 684-688

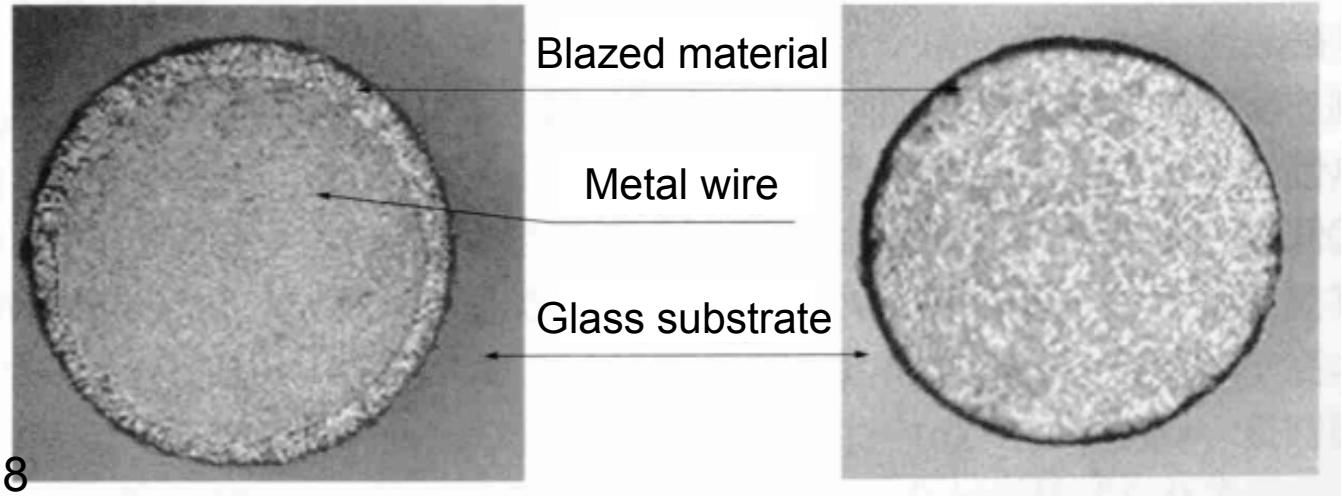
Mechanically-drilled via holes





Metal wire insertion

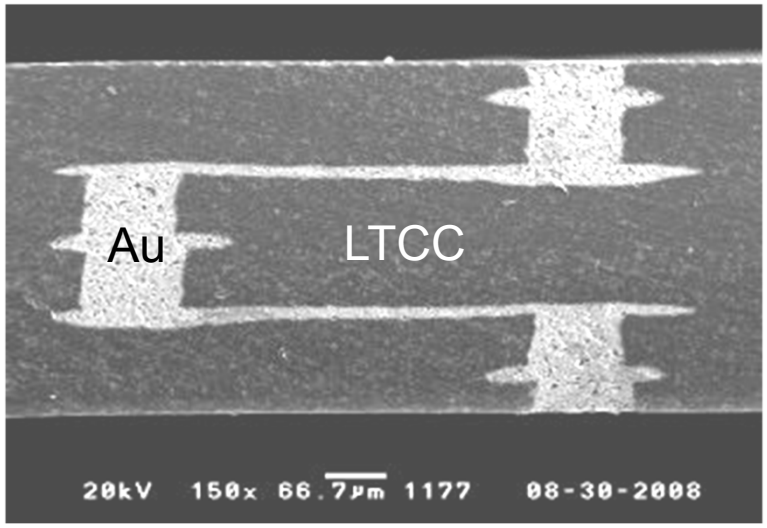
Blazed material filling

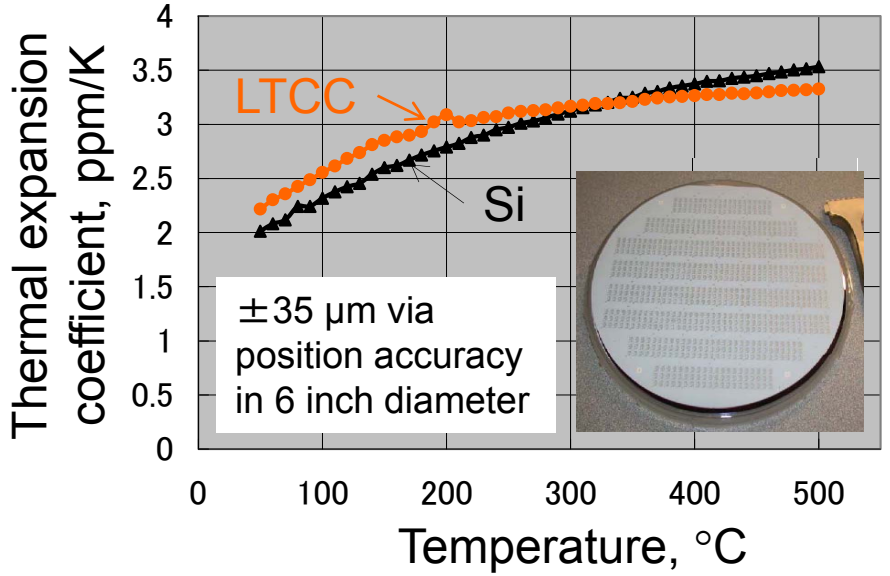


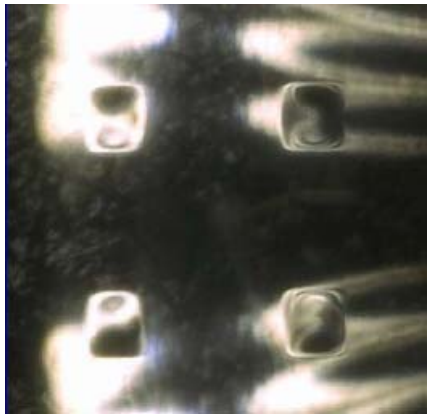
Substrate
thickness: 0.3 mm
Via diameter: 0.3 mm
Via pitch: 0.6 mm

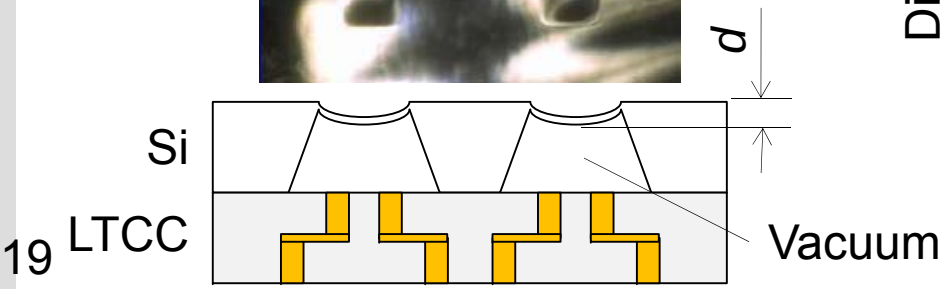
Anodically-Bondable LTCC Wafer

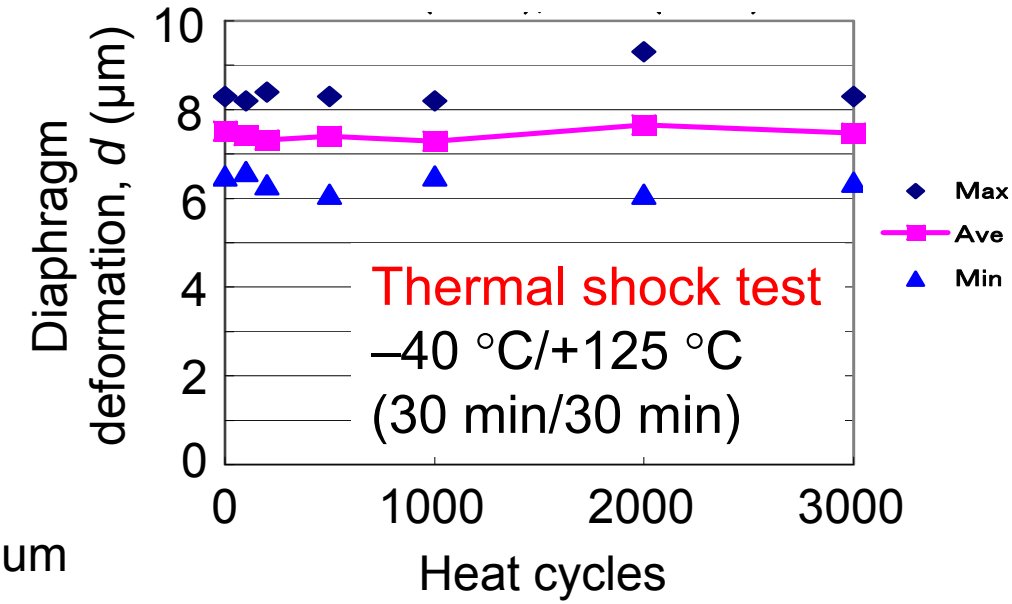
S. Tanaka (Tohoku Univ.), M. Mohri (Nikko) *et al.*, IEEE MEMS 2011, pp. 376-379





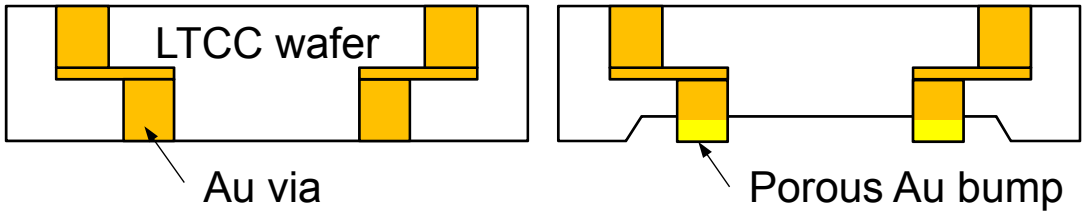






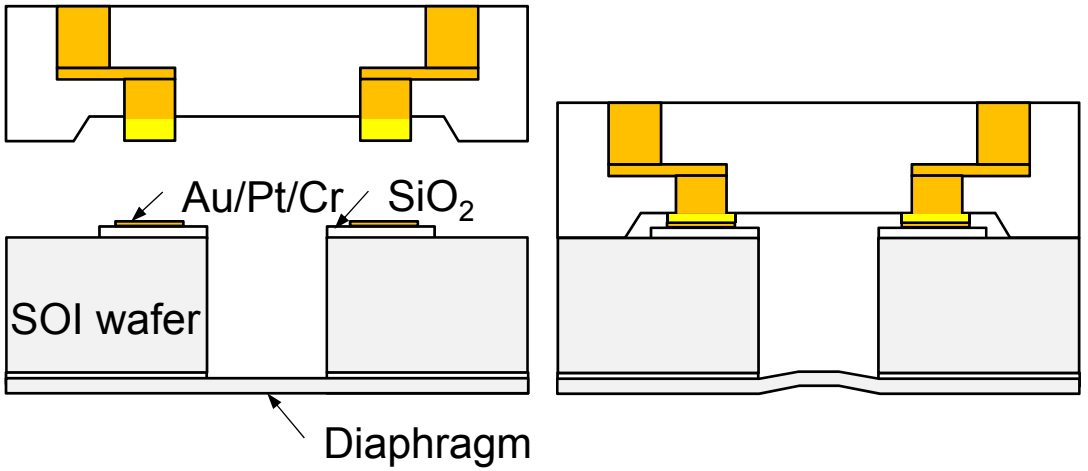
Electrical Connection using Porous Au Bumps

S. Tanaka (Tohoku Univ.), M. Mohri (Nikko) *et al.*, IEEE MEMS 2012, pp. 369-372



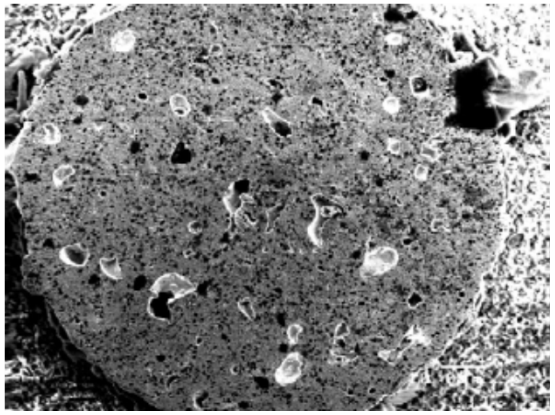
1) Production of LTCC wafer

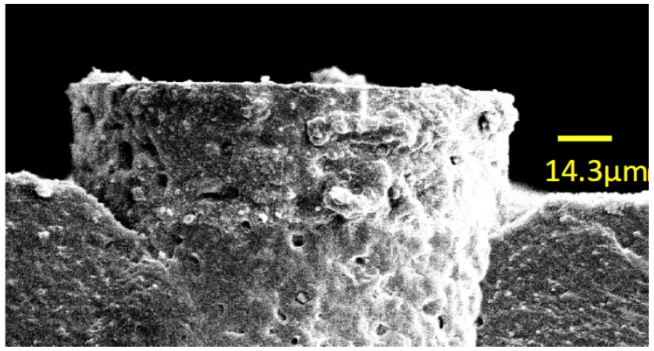
2) Wet etching of LTCC wafer to make cavities



3) Wafer alignment

4) Anodic bonding with electrical connection

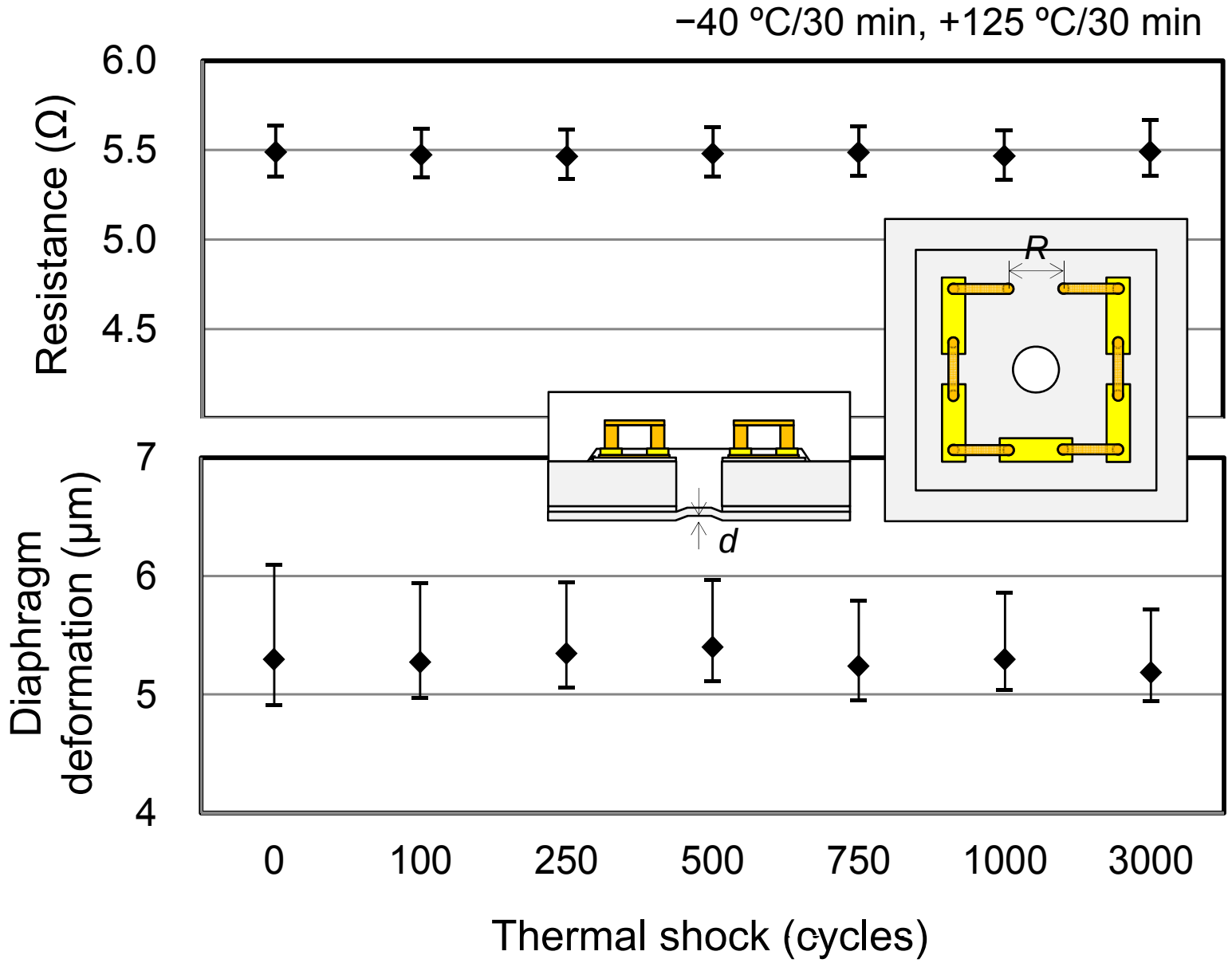




Glass-based filler was dissolved by HF, leaving pores in Au

Porous Au bumps are spontaneously formed after etching the anodically-bondable LTCC wafer to make cavities, where MEMS is sealed.

Reliability of LTCC Anodic Bonding Package



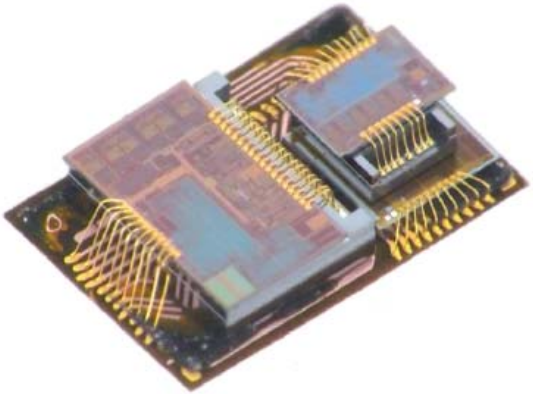
Combo Sensors (2013)

Combo sensor:

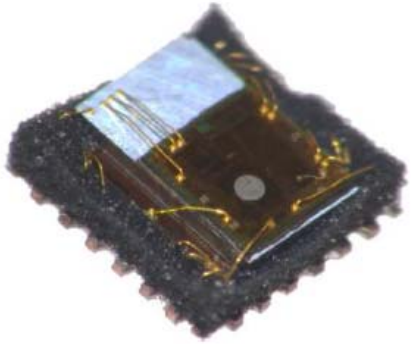
3-axis accelerometer
3-axis gyroscope
3-axis magnetometer (e-compass)

} System in Package (SIP)

STMicroelectronics
LSM9DS0 (4 × 4 mm²)
5 dies
- Accelerometer
- Gyroscope
- Magnetometer
- 2 ASIC



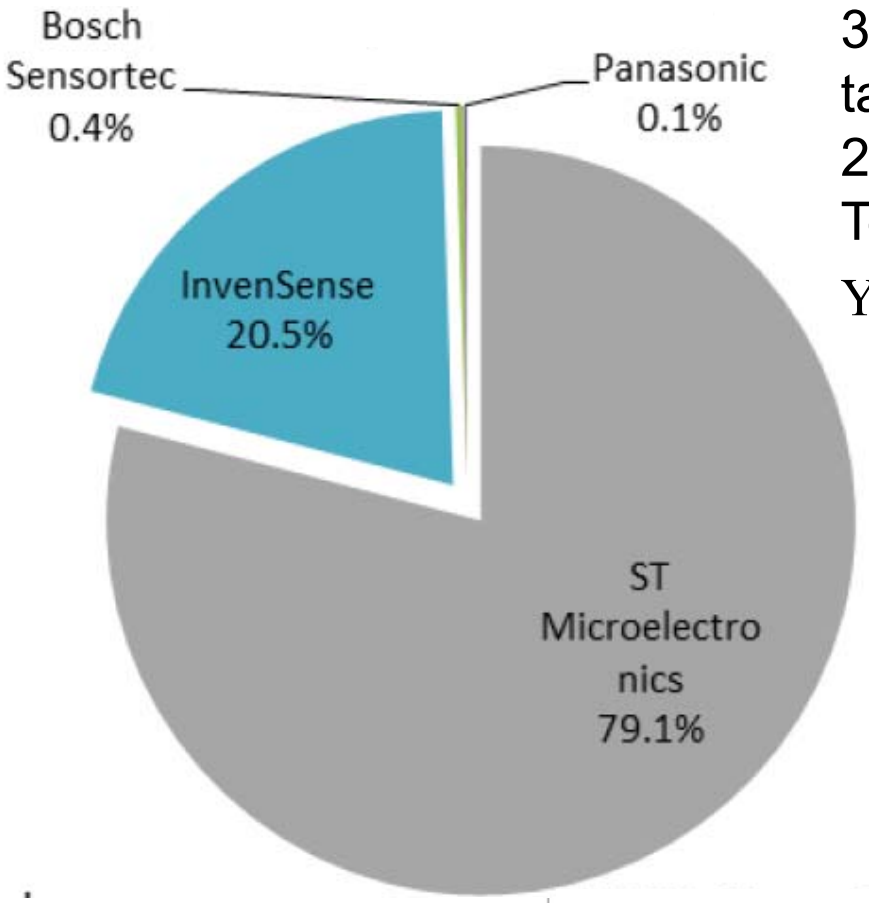
Bosch
BMX055 (3 × 4.5 mm²)
5 dies
- Accelerometer
- Gyroscope
- Magnetometer
- 2 ASIC



InvenSense
MPU-9250 (3 × 3 mm²)
2 dies
- Integrated 6-axis inertia sensor
- Magnetometer

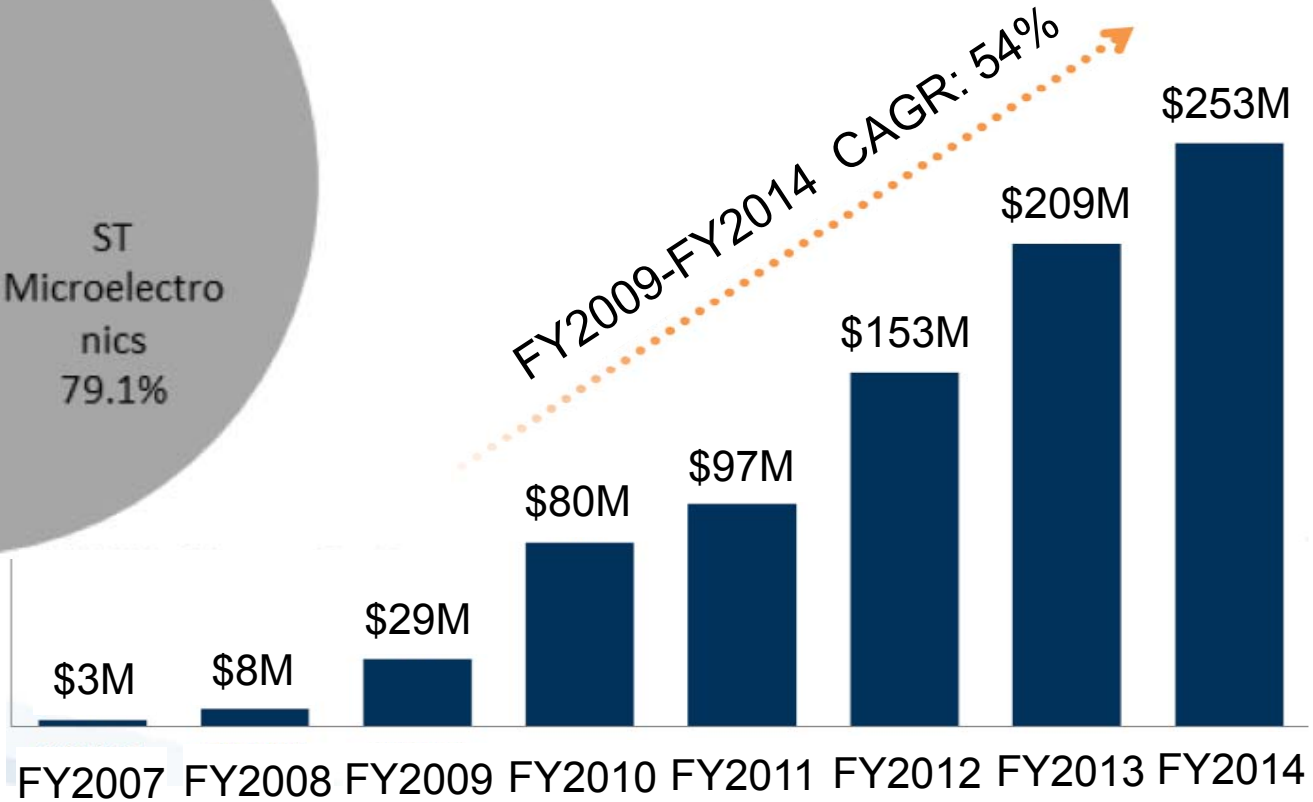
Photographs: Romain Fraux (System Plus Consulting)

InvenSense Realizing American Dream



3-axis gyroscope in mobile phones and tablets (combo sensors not included)
2012 market share
Total: $422.8M

Yole Development, 2013



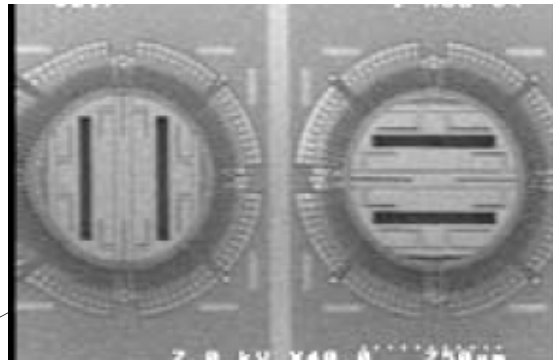
Growth in Revenue of InvenSense

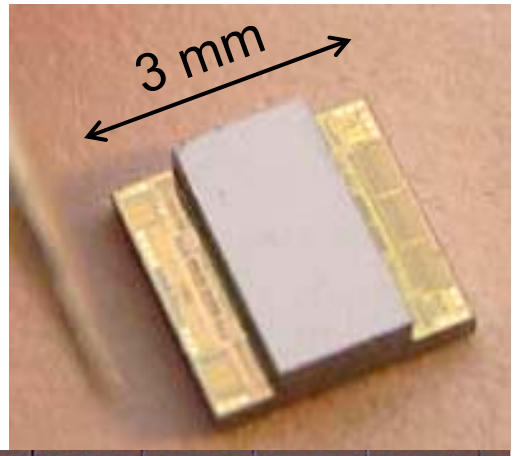
Steve Nasiri,
Founder of InvenSense

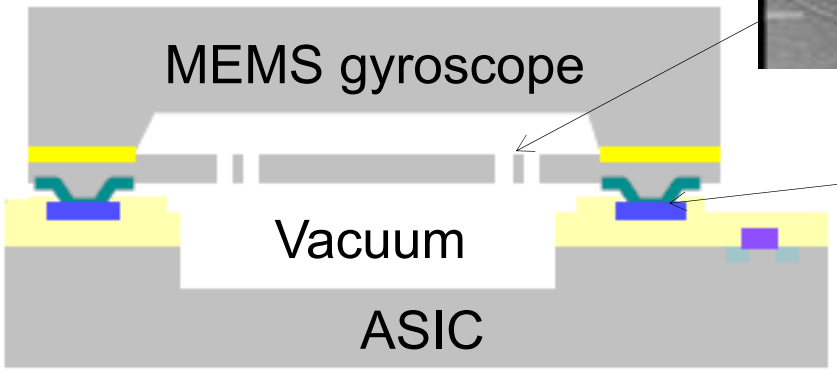
Wafer-Bonding-Based Integration: Problems

Steven Nasiri and Martin Lim,
InvenSense, Inc.

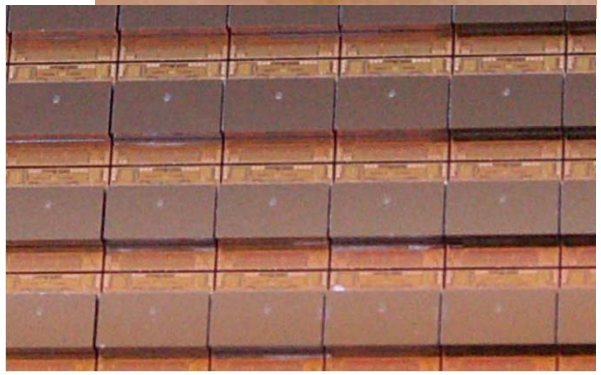
Market share ~20 %
for 3-axis gyros in mobiles (2013)



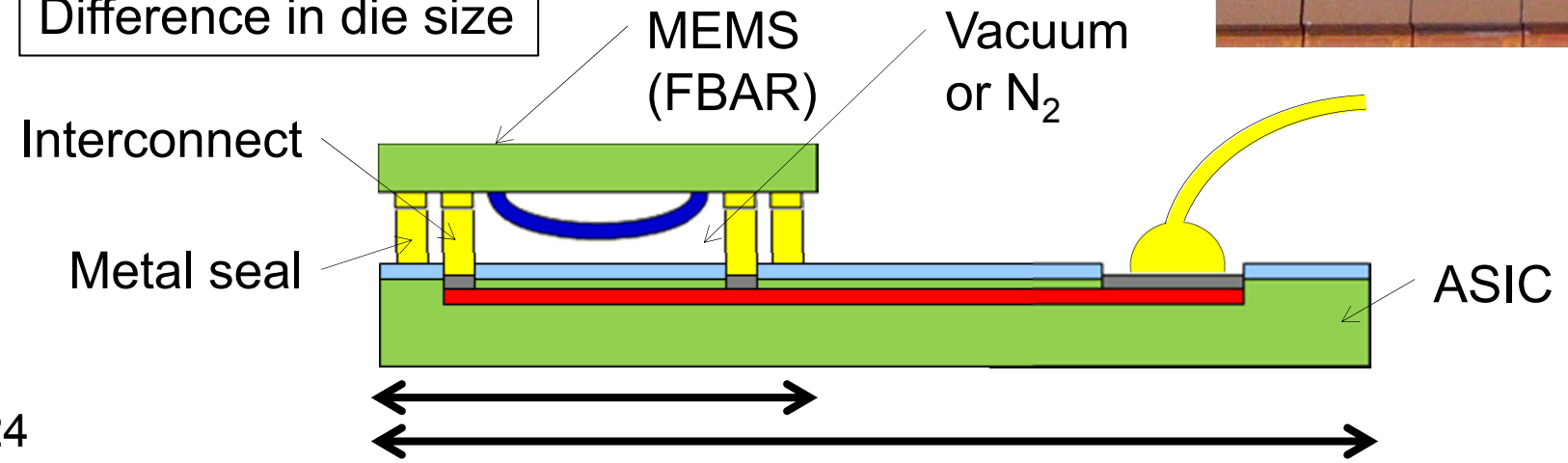




AlGe eutectic boding

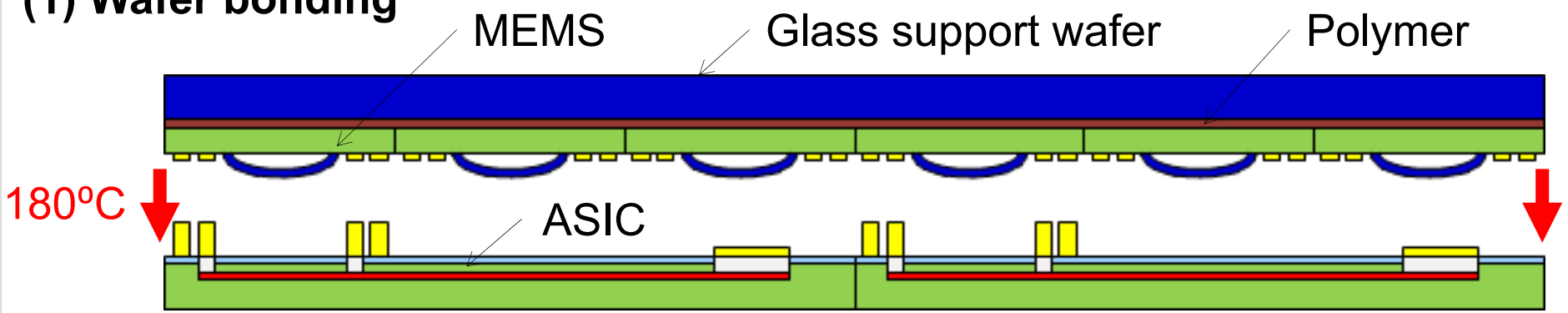


Difference in die size



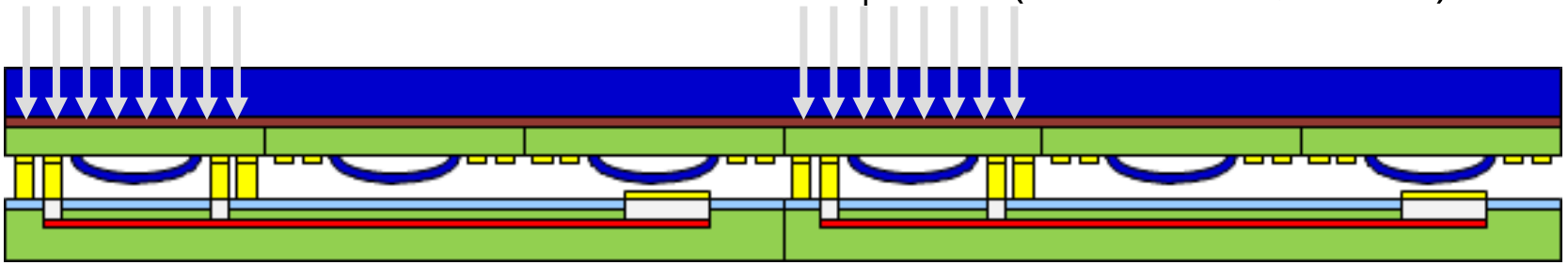
Selective and Multiple Die Transfer

(1) Wafer bonding

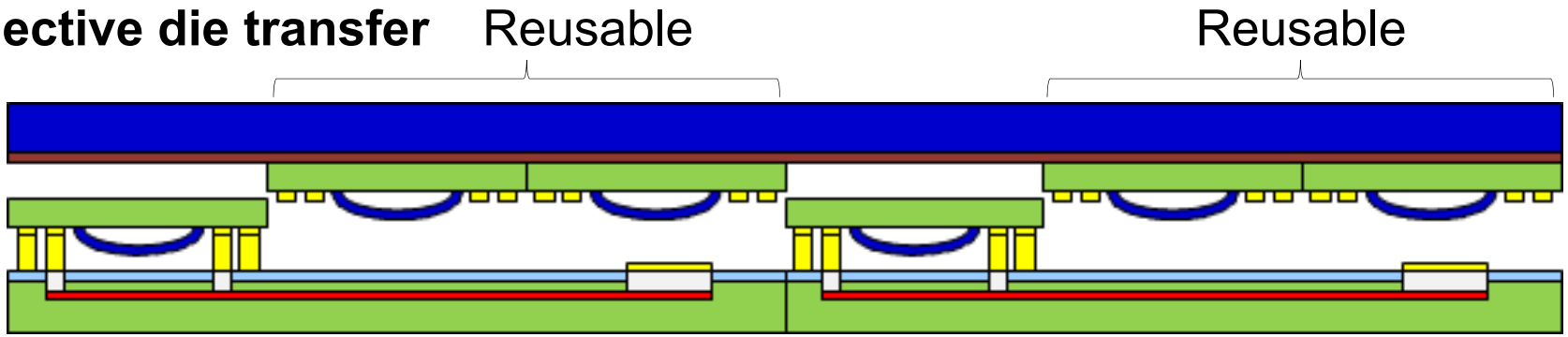


(2) Laser irradiation

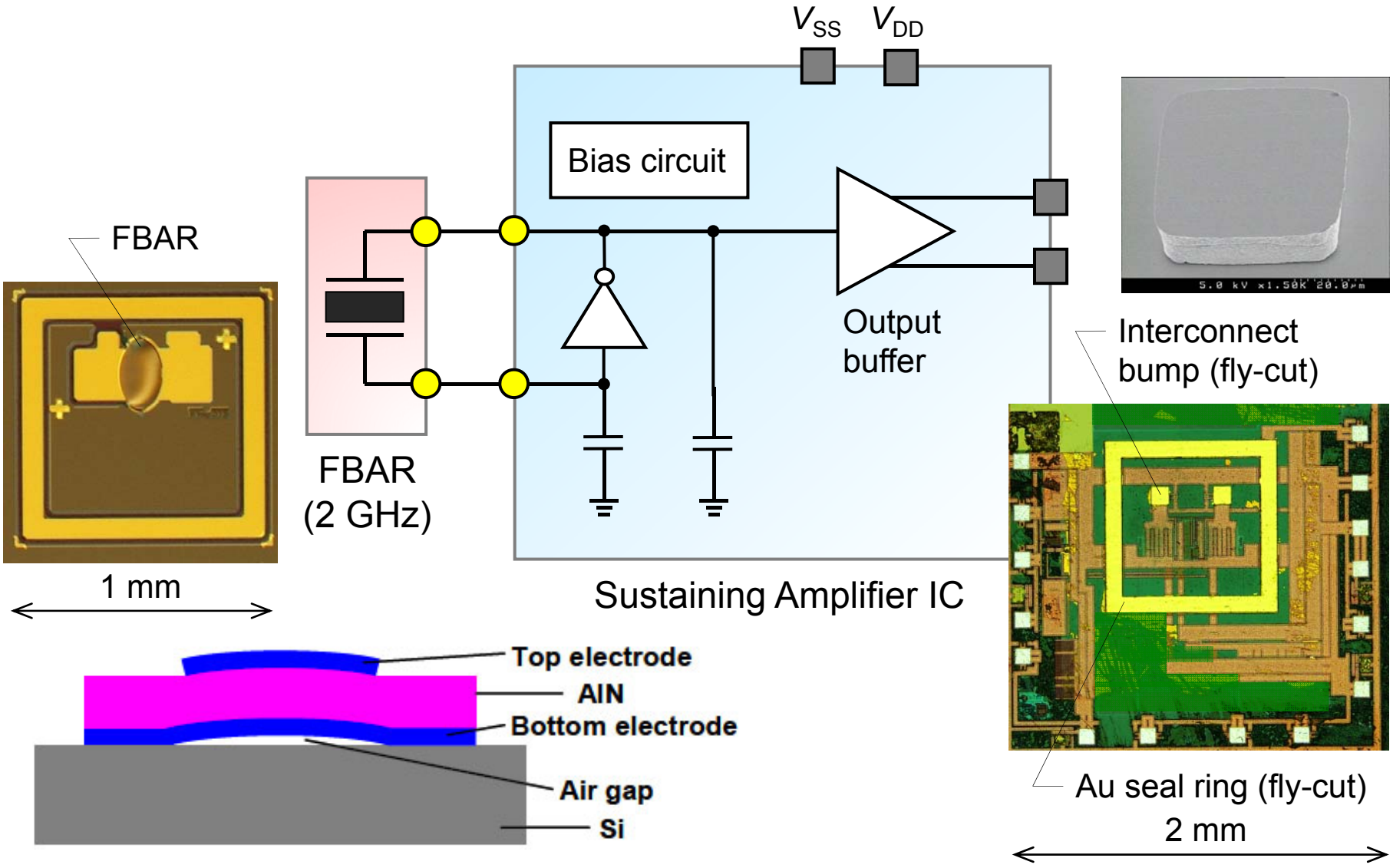
THG Nd:YVO_4 laser (λ = 355 nm, ~ 1 W)



(3) Selective die transfer



FBAR and Sustaining Amplifier IC

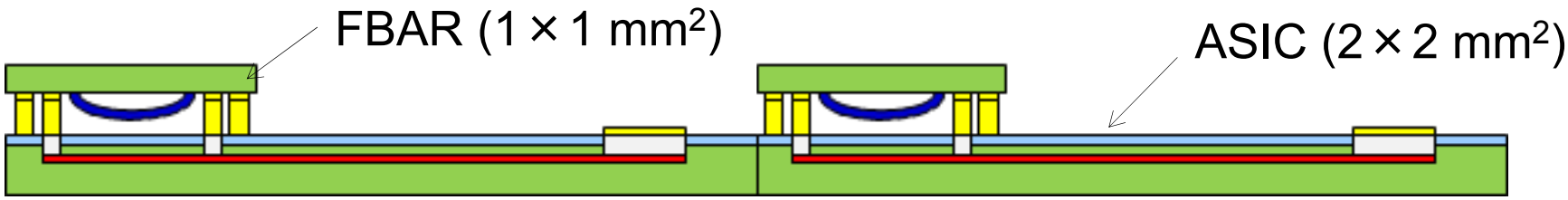


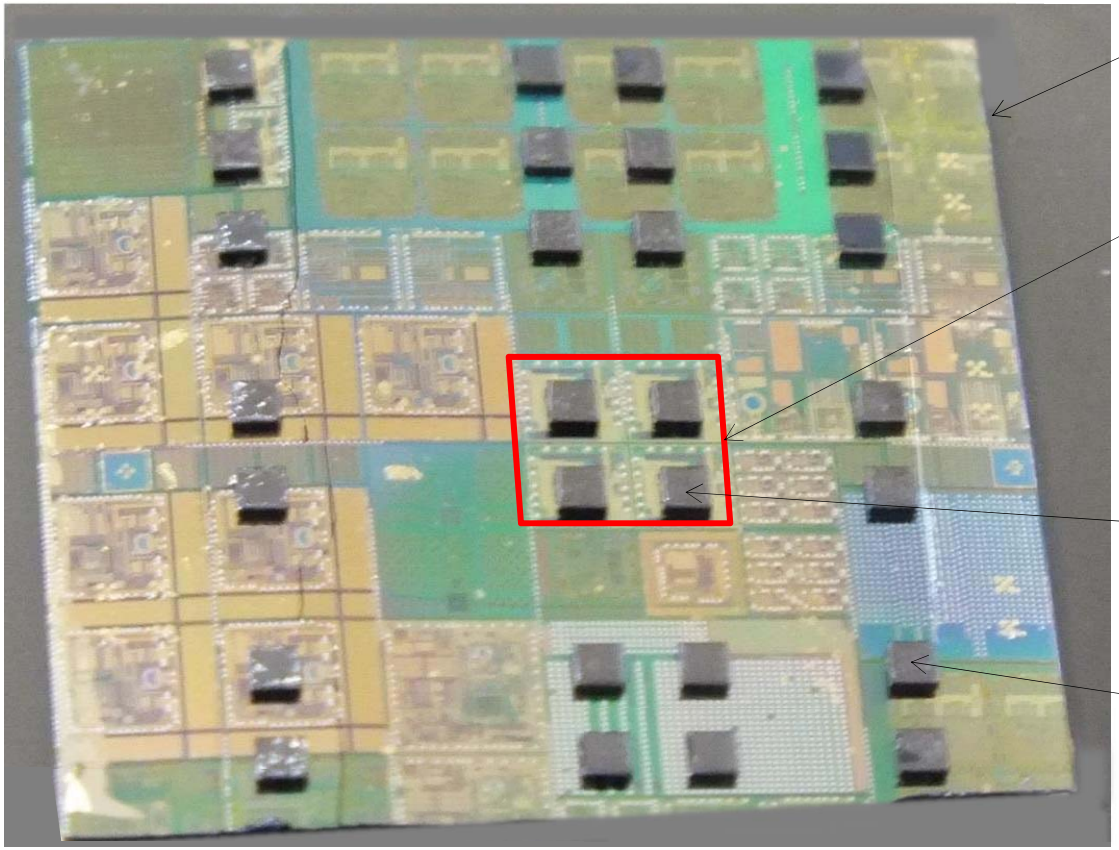
S. Taniguchi *et al.* (Taiyo Yuden), IEEE Ultrasonics Symposium 2007

Designed and fabricated by Asahi Kasei Microelectronics

Selective and Multiple Die Transfer

K. Hikichi *et al.*, IEEE 2014 International Frequency Control Symposium, pp. 246-249





Multi-project LSI wafer
(Shot size 20 × 20 mm²)

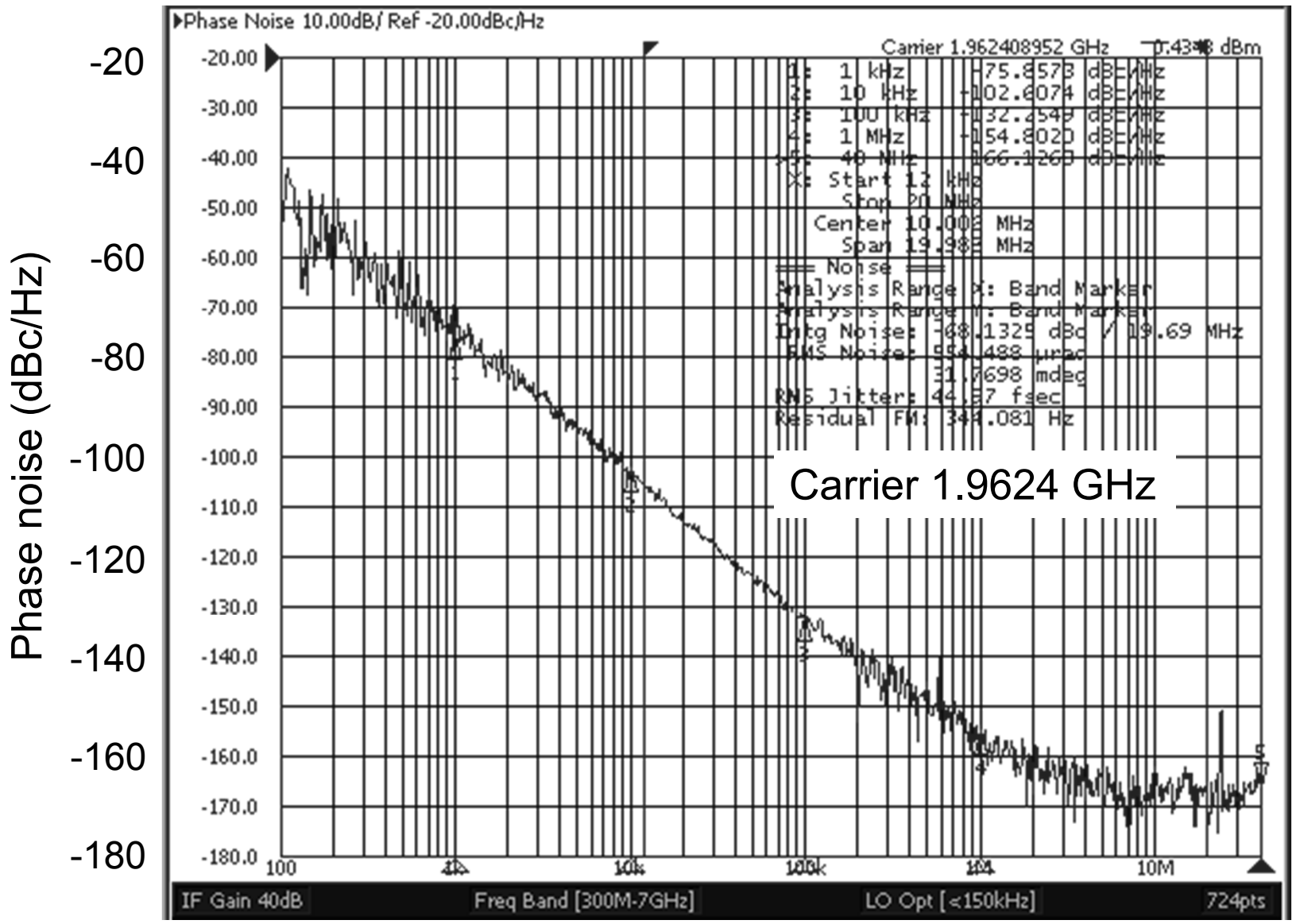
Our ASIC
(2 × 2 mm² × 4 dies)
Asahi Kasei Electronics or Kyushu University

FBAR (1 × 1 mm²)
Taiyo Yuden

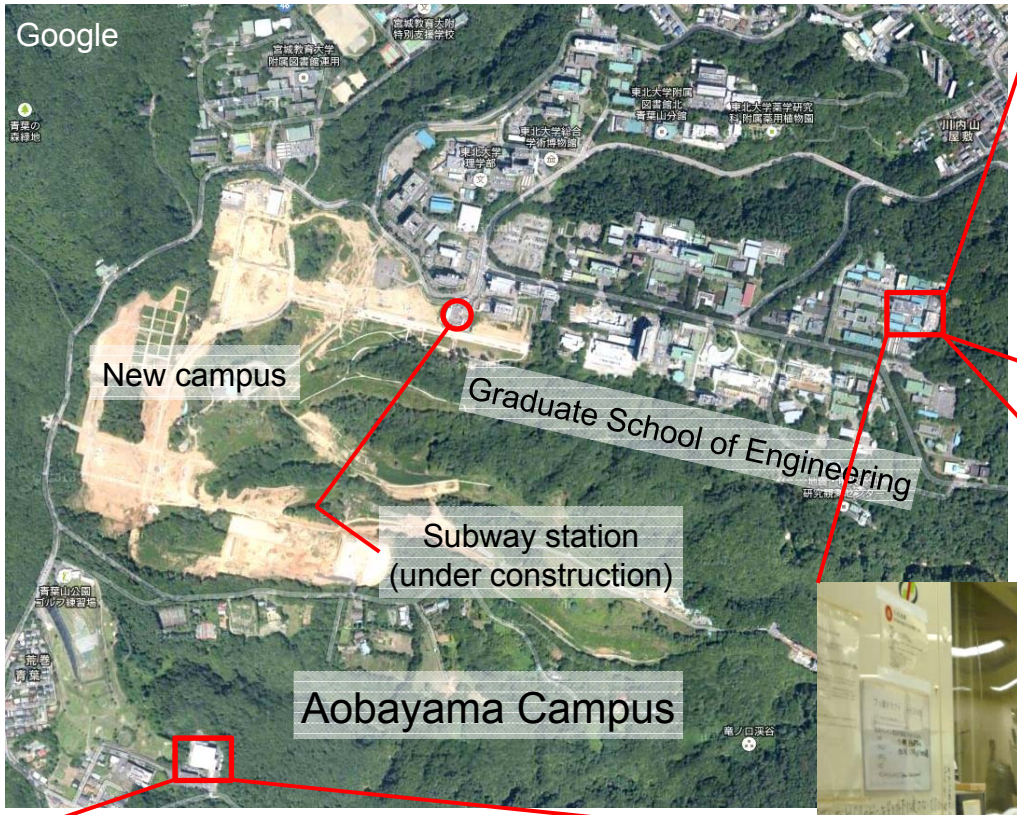
FBAR
(Dummy for bonding)

4 times of die transfer were demonstrated using the same MEMS wafer.

Integrated/Packaged 2 GHz FBAR Oscillator



MEMS Facilities in Aobayama Campus



Micro/Nano-Machining Research and Education Center (MNC)

Microsystem Integration Center

S. Tanaka Laboratory Cleanroom

Epilogue

- From proof-of-concept on small pieces to prototype development on 4 or 6 inch wafers
- Prototyped devices in Microsystem Integration Center can be basically utilized for business, i.e. as commercial samples and provisional products.
- For mass-production in small-to-medium volume, developed technology can be smoothly transferred to our partner foundry, MEMS Core in Sendai, Japan.

S. Tanaka Lab's cleanroom

Micro/Nano-Machining Research & Education Center

Microsystem Integration Center

Small piece

4 inch wafer

6 inch wafer

Please visit S. Tanaka Laboratory website

at http://www.mems.mech.tohoku.ac.jp/index_e.html

Micro Electro Mechanial Systems lab

Tanaka Shuji Laboratory

μSIC

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研究室の技術小史
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Internet Archives
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Password required

Research and Development of Micro-Nanodevices for Healthcare, Safety, Energy Saving, Advanced Communication, Robot Control etc.

Our core competence is MEMS technology!
Students from other universities and foreign countries are welcome.
Please join our laboratory regardless of your experience in MEMS field.

Message to students Message to companies

Information

Questions from companies are being a

mems tohoku

検索

IEEE-NEMS 2016

Matsushima Bay and Sendai MEMS City

The 11th Annual IEEE
International Conference on Nano/Micro Engineered and Molecular Systems

17-20 April 2016

Hotel Matsushima Taikanso & L-Park Sendai, Miyagi, Japan

Sponsored by Microsystem Integration Center, Tohoku University, MEMS Park Consortium and IEEE Nanotechnology Council

General Chair: Shuji Tanaka, Tohoku University

Technical Program Committee Chair: Takahito Ono, Tohoku University