【MEMS Engineer Forum 2015】

Trillion Sensors & MEMS

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21 April, 2015

Agenda

- **Trillion Sensors (TSensors™)**
- **Trillion Sensors Summits (TSensors Summit™)**
- **MEMS Development with SPP/SPT Involvement**
- **Summary**

Trillion Sensors (TSensors^{TM})

Genesis of TSensors Summit

- **October 2010, MEMS Technology Summit Conference at Stanford University**
  - **Muenzel Horst (then President, Bosch Akustica) presentation**
    - a vision for 7 trillion "sensory swarms" by 2017.
  - **Janusz Bryzek (then VP Development, Fairchild Semiconductor), one of the Summit organizers**
    - triggered to continue exploring high growth sensor opportunities.
    - discovered multiple pointers to the trillion sensors in coming decade.
    - believed that accelerated growth of sensor market to trillions will not be possible without a focused commercialization effort.

- **BSAC/UC Berkeley presentation**
  - **Vijay Ullal (then President, Fairchild Semiconductor)**
    - calling for creation of "Cooptition", or cooperating competitors,
    - jointly funding development of standard MEMS processes necessary to support accelerated growth of MEMS market from $10B to already visible $300B.

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Genesis of TSensors Summit

Steve Walsh (UNM and MANCEF)

- suggested development of a Trillion Sensor Roadmap reusing MANCEF's past Roadmaps experience, to provide early visibility of emerging sensor applications.

Evolving concepts of the Roadmap

- presented at several 2012 meetings(IMAPS, iNEMI, SensorsCon, MEPTEC, MEMS Business Forum, COMS, MEMS in Motion, MIG Congress)

Brainstorming the ideas with

Steve Walsh, Robert Haak (Insight InterAsia, MANCEF), Robert Giasolli (Intactvascular, MANCEF), Bette Cooper (MEPTEC), Mike Pinelis (MEMS Journal), Karen Lightman (MIG), Michael McLaughlin (Yole), Job Elders (Xsens), Al Pisano (UC Berkeley), Roger Howe (Stanford University) and others

The concept of TSensors Summit Conference

chaired by Janusz Bryzek was born.

Genesis of TSensors Summit

Late 2012

- Bryzek read book Abundance1, which gave him an additional motivation to drive TSensors Summit.

March 8, 2013, UC Berkeley

- Al Pisano, learning from Bryzek about TSensors initiative, decided to help, developing a conference
  "The Trillion Sensor Universe: Manufacturing Challenges"

TSensors Summit

- discovery of a trillion sensor applications and sensor types

TSensor Systems chaired by Steve Walsh

- development of the Roadmap for 2023 infrastructure

Abundance book outlined a vision for the utopian world

with no hunger,

with medical care to all,

with no pollution and energy to all coming in about 20 years.

Abundance being made possible mainly
by eight exponential technologies

Sensors are one of them

Estimated need for sensors

- 45 trillion in late 2020s
  (up from 10 billion in 2014 and 1 billion in 2007)

Average historical development cycle for new sensors

- 30 years,
  longer than the expected arrival of Abundance

TSensors Initiative aims to significantly reduce this cycle

Abundance、楽観主義者の未来予測

『Abundance』: http://www.abundancethebook.com/
『楽観主義者の未来予測』: 熊谷玲美訳 早川書房

Sensors for the Next Decade in Support of Abundance

Early visibility of

emerging ultrahigh volume applications supporting Abundance

outlined by visionaries at TSensors Summits

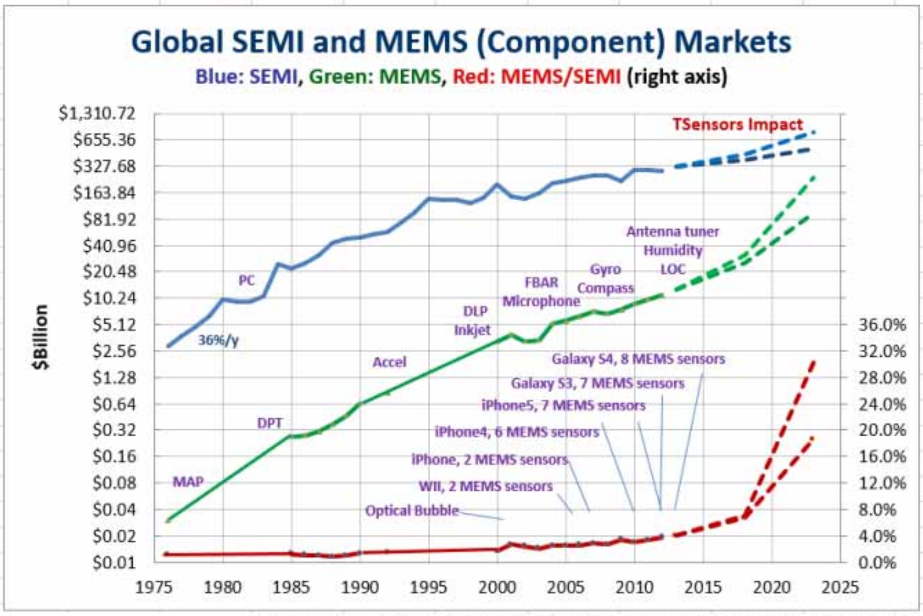
expected to be a significant contributor to reduction of the new sensors development cycle time.

- *TSensors Summits*
  - visionaries invited to talk about emerging ultrahigh volume sensor based applications over the next decade
  - Objective: provide advanced visibility to sensors developers, to enable early development focus which should significantly reduce the historical average 30 year new sensor development cycle.

- *TSensors Roadmaps*
  - summarizing the findings and enabling easy access for sensor developers at academic, government and industrial entities, to help them sort through emerging opportunities supporting Abundance
- *TSensors Supply Chain*
  - Start proactive commercialization acceleration of selected sensors providing the biggest benefit for Abundance

MEMS Migration into Mainstream

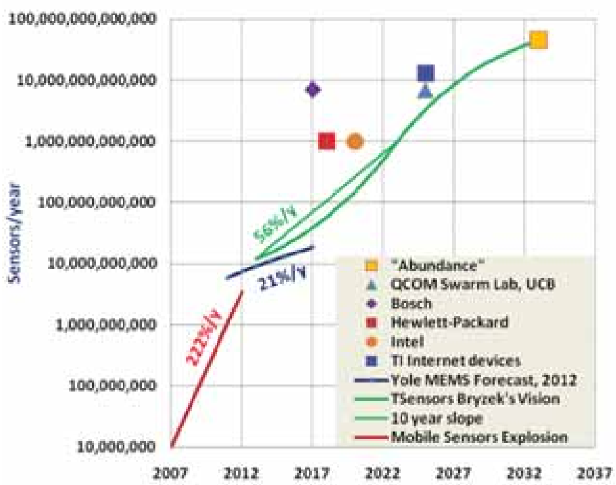
MEMS Migration into Mainstream



Concept of the slide developed by Dr. Kurt Petersen; implementation by Dr. Janusz Bryzek

TSensors Summit
Supporting Abundance with Trillion Sensor Roadmap

Trillion Sensor Visions



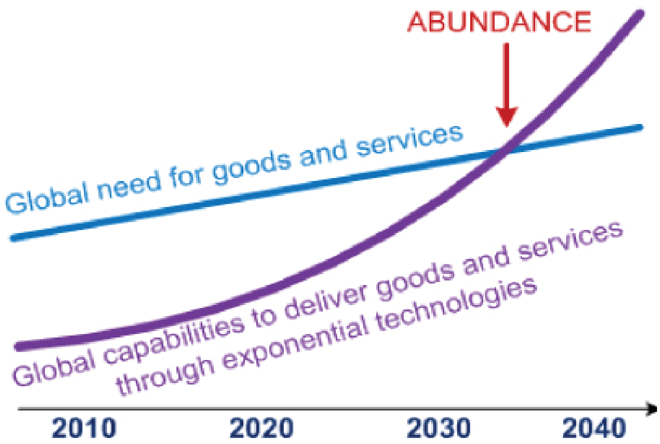
Mobile sensor market for volumes not envisioned by leading market research organizations in 2007, grew exponentially over 200%/y between 2007 and 2012.

Several organizations presented their visions for a continued growth to trillion(s). Market research companies don't yet see this growth (see Yole's forecast). So the explosion to trillion(s) is likely to be driven by applications not yet envisioned by leading market research organization.

As sensor development has been historically much longer than pure semiconductor technologies, TSensors Roadmap development is being launched to improve visibility of needed sensors to enable their accelerated development.

(Courtesy of Dr. Janusz Bryzek, "Need for a Trillion Sensors Roadmap")

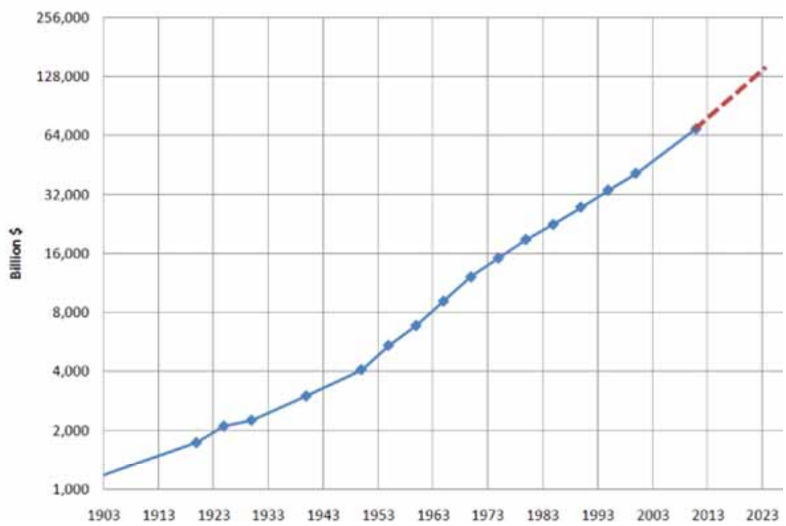
Abundance



Exponential technologies promise growth of goods and services to match global demand for them within one generation, enabling Abundance.

(Courtesy of Dr. Janusz Bryzek, "Need for a Trillion Sensors Roadmap")

Global GDP



Global GDP is likely to reach $130 trillion by 2030. This forces smart sensor prices to challenging $0.10 level.
(Historical Data (blue) from Wikipedia. Extrapolation (red) by J. Bryzek.)

(Courtesy of Dr. Janusz Bryzek, "Need for a Trillion Sensors Roadmap")

Trillion Sensors Summits
(TSensors Summit^{TM})

Trillion Sensors Summits

March 2013: **"Trillion Sensors Universe" workshop at University of California, Berkeley**

October 2013: **"Trillion Sensors Summit 2013" at Stanford University**

February 2014: **"Trillion Sensors Summit Japan 2014"**

Trillion Sensors Summits

September 2014: "Trillion Sensors Summit Munich"

November 2014: "Trillion Sensors Summit San Diego"

December 2014: "Trillion Sensors Summit Tokyo"

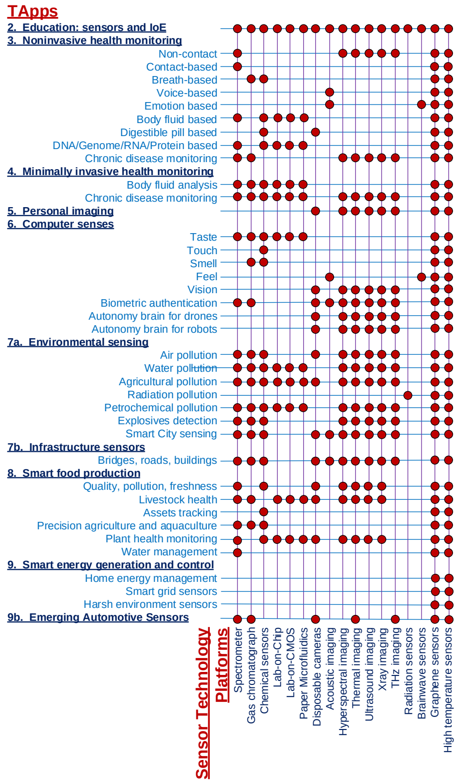
TSensors Summits

Location	Date	My Co-Chairs	Logistics by	Number of Speakers	Attendees
Stanford University	Oct 2010	Roger Howe, Kurt Petersen, Joe Mallon, Roger Grace	Mepcom/Bette Cooper	28	250
UC Berkeley	Mar 2013	Al Pisano, UC San Diego	UC Berkeley	8	140
Stanford University	Oct 2013	Roger Howe, Stanford University	Mepcom/Bette Cooper	47	250
Tokyo	Feb 2014	Susumu Kaminaga, SPP Technologies	Nikkei BP/Tsuneyuki Miyake	17	200
Munich	Sep 2014	Christoph Kutter, Fraunhoffer Institute	Fraunhoffer Institute	36	150
San Diego	Oct 2014	Al Pisano, UC San Diego	Mepcom/Bette Cooper	36	200
Tokyo	Dec 2014	Susumu Kaminaga, SPP Technologies	Nikkei BP/Tsuneyuki Miyake	41	200
Total				**213**	**1390**

(Courtesy of Dr. Janusz Bryzek, "Analysis of the First Six TSensors Summits and Findings")

TSensors Summit at Stanford University

- Presentations at first TSensors Summits implied the following direction for Working Groups:
  - ➢ Education
    - ✓ Preparation of workforce for massive global retraining resulting from development of exponential technologies.
  - ➢ 9 TApps™ cross-referenced with 20 sensor technology platforms.
    - ✓ Highlighting the biggest economic impact areas.
  - ➢ 6 infrastructure technologies enabling TSensors.
    - ✓ 3D printed electronics and sensors
    - ✓ Energy harvesting
    - ✓ Ultralow power wireless communication
    - ✓ Network infrastructure for Internet of Everything
    - ✓ Analytics
    - ✓ Security



(Courtesy of Dr. Janusz Bryzek)

Note: numbering relates to Chapters of TSensors Roadmap

TSensors Summits

TSensors Theme	Stanford 2000	UC Berkeley	Stanford 2013	Tokyo Feb/14	Munich	San Diego	Tokyo Dec/14	Total
TSensors Roadmap								
Introduction to TSensors, IoT, eHealth					2			2
Healthcare Abundance: Sensors, Imagers and FDA	2	2	10	4	4	11	9	42
Feeding the New World						2	2	4
Energy Generation and Harvesting			6			1		7
Sensor Technologies, including 3D printing	1	4	20	7	15	11	6	65
Environmental Sensing: Home, City and World			2	2			2	6
Automotive Energy Consumption and Pollution	1		1		6	4	2	14
TSensors Systems (Infrastructure) Roadmap								
Emerging Network Infrastructure			1	3	2	3	7	16
Emerging 3D printed ICs								
Education: Sensors, IoT and eHealth			1			1	1	3
Sensor Analytics and Big Data			1		1		7	9
Ultralow power wirelss communication			3	1		1	1	6
Security-Privacy					6	1		7
Total	4	6	45	17	36	35	37	181
Total speakers	28	8	47	17	36	36	41	213
% Speakers focused on TSensors	14.3%	75.0%	95.7%	100.0%	100.0%	97.2%	90.2%	85.0%

(Courtesy of Dr. Janusz Bryzek, "Analysis of the First Six TSensors Summits and Findings")

TSensors Summits

Dr. Bryzek recruited 2013 TSensors presentations and had about 1400 attendees.

In addition to dedicated events, Dr. Bryzek delivered about 40 TSensors presentations across the world, all receiving enthusiastic receptions.

Susumu Kaminaga delivered about 20 presentations, primarily in Japan, receiving a similar response.

The combined audience was over 10,000 attendees.

Presentations in Japan in 2014-2015

- MEMS Engineer Forum 2014
- Micromachine Center (マイクロマシンセンター)
- Japan Techno-Economics Society (科学技術と経済の会)
- Japan Society of Next Generation Sensor Technology (次世代センサ協議会)
- Science Council of Japan (日本学術会議)
- MEMS Seminar (MEMS集中講義)
- Japan Science and Technology Agency (科学技術振興機構)
- The Japan Society of Mechanical Engineers (日本機械学会)
- Japan Electronics and Information Technologies Industries Association (電子情報技術産業協会)
- The Institute of Electrical Engineers of Japan (電気学会)
- Technology Research Association for Inertial Sensors and their Application (慣性センサ応用技術研究協会)
- The Institute of Systems, Control and Information Engineers (システム制御情報学会)
- The Japan Institute of Electronics Packaging (エレクトロニクス実装学会)

TSensors Initiative

TSensors initiative was split into two activities:

- TSensors focused on emerging ultrahigh volume sensors and
- TSensor Systems focused on require infrastructure for deployment of trillion sensors.

The most interesting finding from TSensors Summits:

- Abundance enabled by 8 exponential technologies was the trigger for TSensors Initiative, which lead to
- Finding that TSensors is also an enabler for IoT and eHealth, the biggest economic tides in history of humans, which
- Are expected to create the incredible $18 trillion opportunity for businesses by 2020, which
- Will dramatically restructure global workforce, eliminating perhaps more than 60% of existing jobs in one decade, and
- Creating more than that of high tech jobs, which
- Will require a massive global retraining to avoid massive unrests.

TSensors Summit Florida

Date:	**December 7-9, 2015**
Location:	**Orlando, Florida**
URL:	**http://www.tsensorssummit.org/ (To come)**

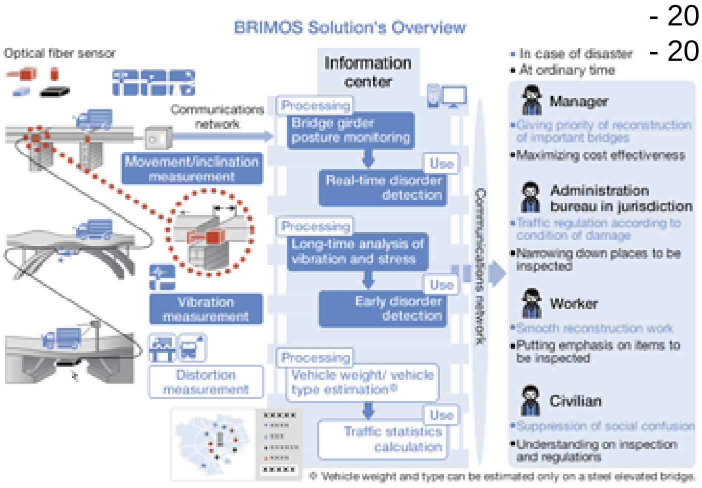
Future Potential

Current Status - Infrastructure

Monitoring System at Tokyo Gate Bridge, 2012

Key Project Experiences

- 2010: Chiangsu Interchange Bridge (China) (Pilot project)
- 2012: Tokyo Gate Bridge (Japan)
- 2012: Can Tho Bridge (Vietnam)



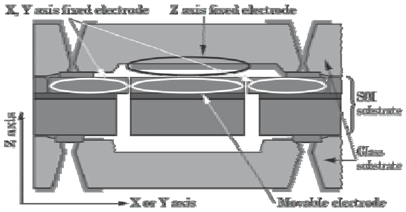
Tokyo Gate Bridge

NTT DATA

(http://www.nttdata.com/global/en/services/bds/case/casestudy-01.html)

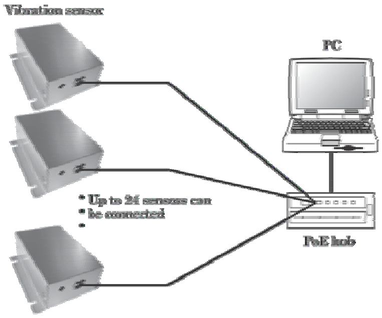
Current Status - Infrastructure

Monitoring by using Vibration Sensor for Infrastructure



Cross-sectional schematic drawing of sensor device

Building with installed vibration sensors



Connection example of vibration sensor

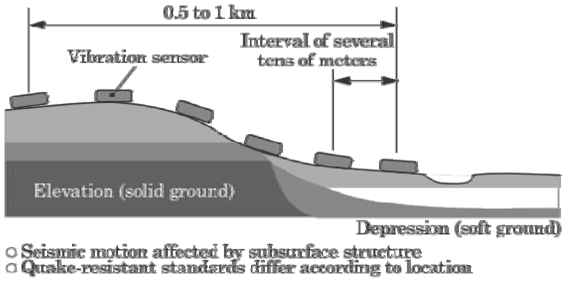


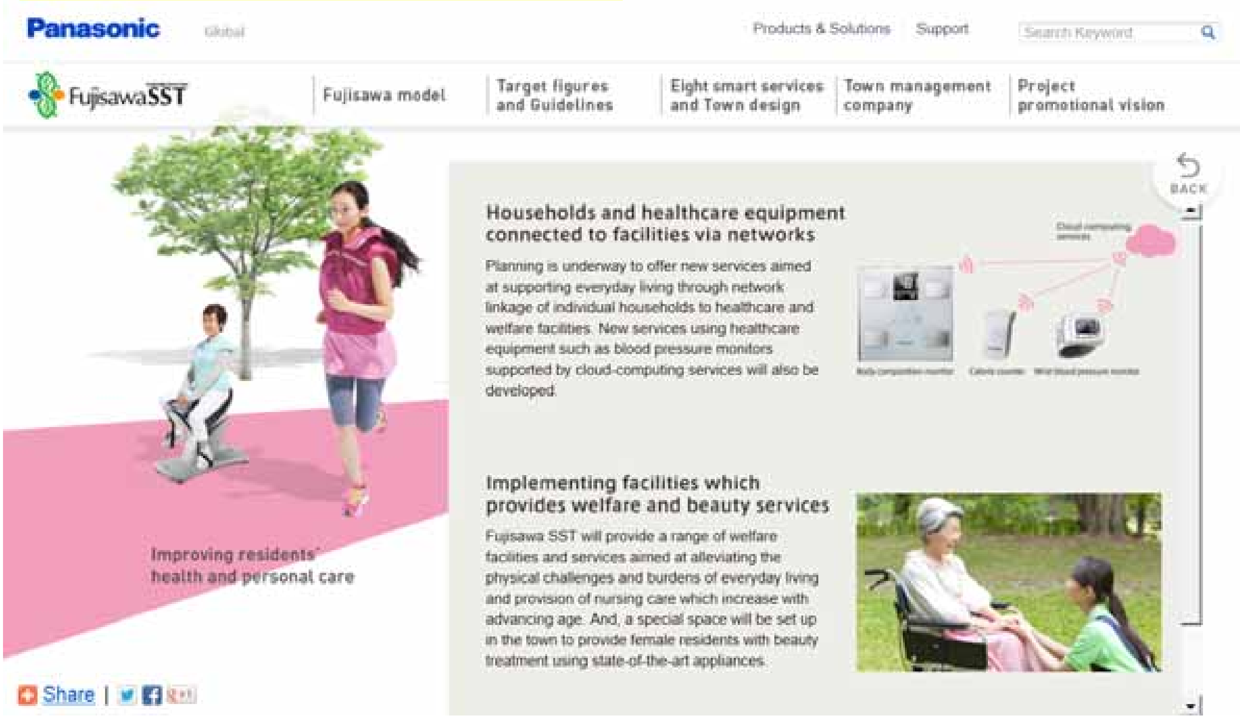
Illustration of ground measurement

Fuji Electric

(Source: S.Sakaue, al et., FUJI ELECTRIC REVIEW, Vol.58, No. 1, pp.32, 2012)

Current Status - Smart City

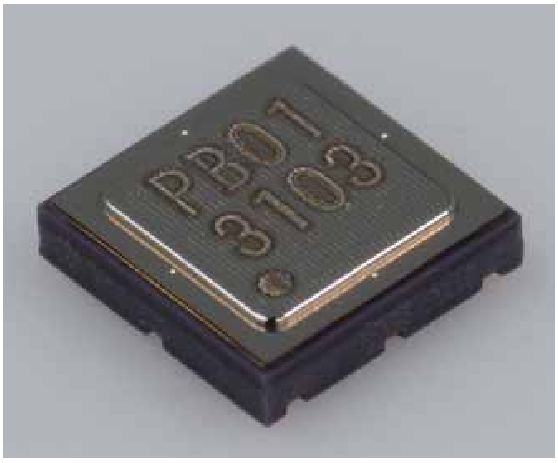
Fujisawa Sustainable Smart Town



(http://panasonic.net/es/fujisawasst/)

Current Status - Healthcare

MEMS Absolute Pressure Sensor for Healthcare and Wearable Devices



MEMS absolute pressure sensor

Features

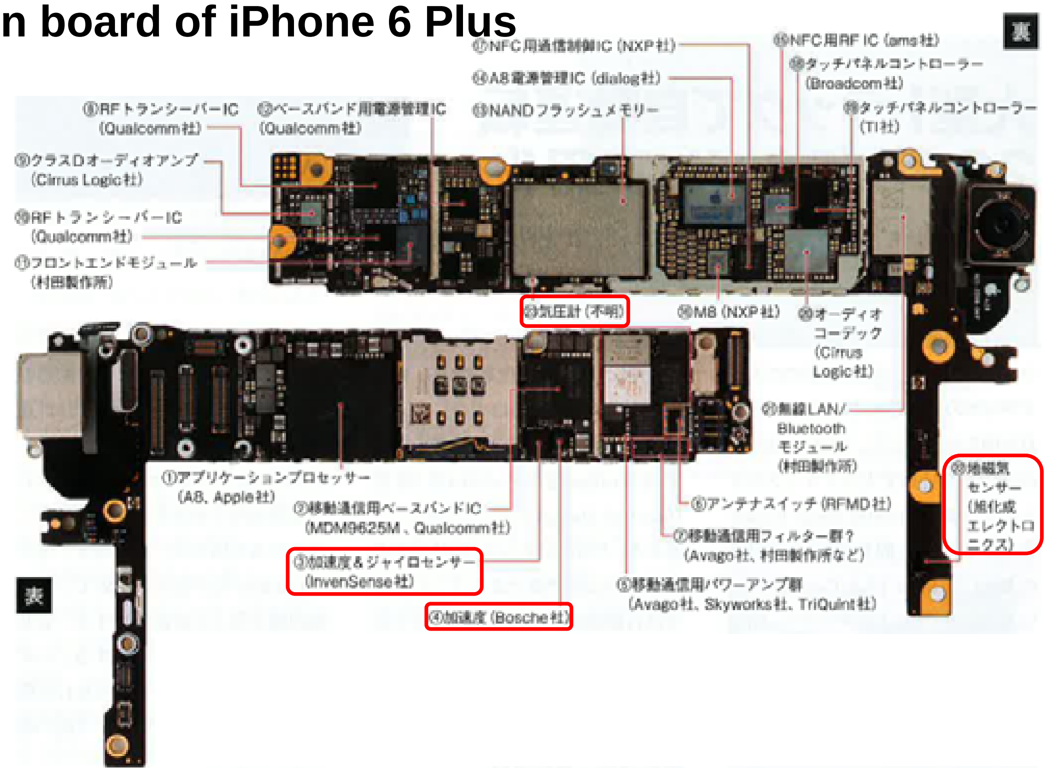
- Able to detect the relative difference of approximately 6 Pa in air pressure that exists between 50cm variations in altitude
- High resolution of 0.06 Pa (5 mm equivalent)
- Subminiature dimensions (3.8x3.8x0.92 mm)
- Integration of CMOS circuitry and MEMS sensors, chip size is only 1.9x1.9x0.5 mm
- Wide detection range of 300 to 1100 hPa
- Low current consumption of 0.5 to 9.0 μA

OMRON

(http://www.omron.com/media/press/2013/06/e0628.html)

Smart Phone (Apple - iPhone 6 Plus)

Main board of iPhone 6 Plus

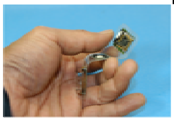


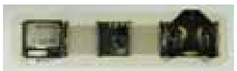
(Source: NIKKEI ELECTRONICS, October 13, 2014, pp12-13)

Current Status - Healthcare

Products from AffordSENS corporation (http://www.affordsens.com)

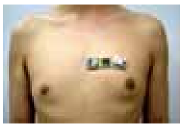
1. Background
   - Founded at Nov/2013 (from Maenaka project)
2. Products
   - Vitalgram™ wearable human monitoring sensor
   - Application development support



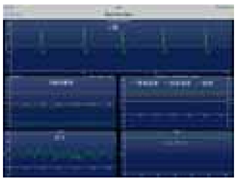


Vitalgram

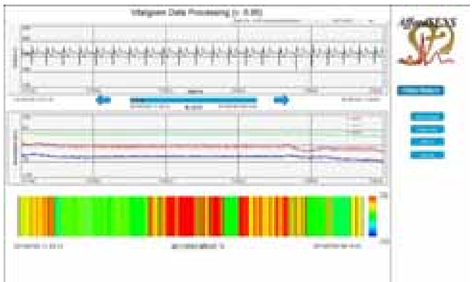
Vitalgram BLE



2.4GHz
Nordic RF protocol
or Bluetooth BLE
protocol



Real time data display and
data logging on PC or
iOS terminals
(SQLite data format)



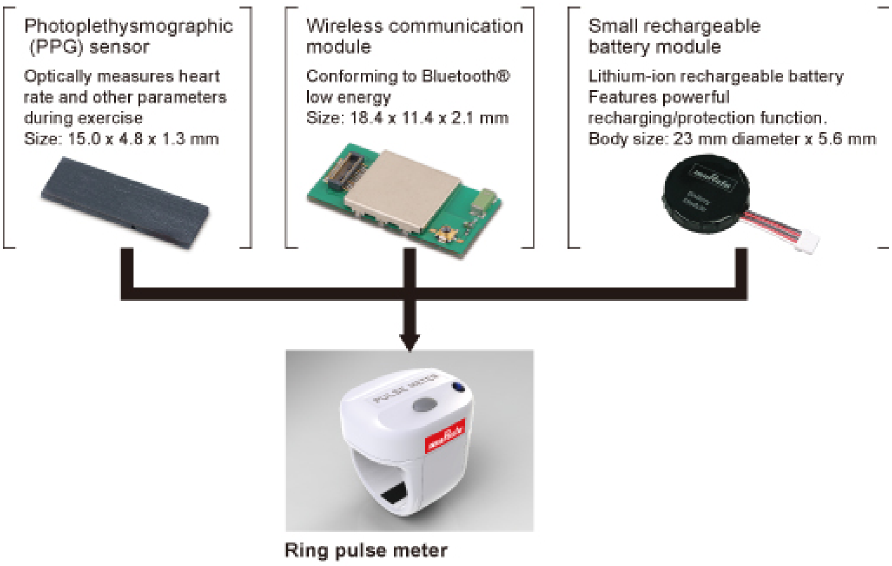
Data processing on a server

AffordSENS

(Courtesy of AffordSENS)

Vital Sign Sensor

Ring Pulse Meter(Photoplethysmographic (PPG) Sensor)



Murata Manufacturing

(http://www.murata.co.jp/products/article/ta10d3/#003)

Radiation Monitoring

Radiation Monitoring “Pocket Geiger”

- **Development Period: 3 Months.**
- **Unit Price: 18 USD (Type1)**
- **50,000+ Users, 2,000+ Active Facebook Users**
- **1 Million+ Data Sharing Points**

Yaguchi Electric

(Courtesy of Yaguchi Electric - Ishigaki)

Taste Sensors

Taste Sensors

Taste Sensing System
「TS-5000Z」

Taste sensors and the related taste information

Taste information		Sensor	Characteristic	Targets
Initial taste (Relative value)	Sourness	CA0	sourness produced by citric acid and tartaric acid	beer, coffee
	Saltiness	CT0	saltiness evoked by dietary salts	soy sauce, soup, stock sauce
	Umami	AAE	umami (savoriness) by amino acids and nucleic acids	soup, stock sauce, meat
	Acidic bitterness	C00	bitterness derived by bitter substances found in foodstuffs and beverages, but can also be perceived richness with its concentration being low	bean curd, stock sauce, soup
	Astringency	AE1	pungent taste by astringent taste materials	wine, tea
	Sweetness	GL1	sweetness produced by sugars and sugar alcohols	sweets, drink
After taste (CPA value)	Aftertaste from acidic bitterness	C00	aftertaste by bitter taste materials	beer, coffee
	Aftertaste from astringency	AE1	aftertaste by astringent taste materials	wine, tea
	Richness	AAE	richness, also called “continuity,” evoked by umami substances	soup, stock sauce, meat
	Aftertaste from basic bitterness	AC0 AN0	bitterness of medicines	basic drugs (such as quinine hydrochloride, famotidine)
	Aftertaste from hydrochloride salts	BT0	bitterness of medicines	hydrochloride drugs

Intelligent Sensor Technology (Collaboration with Kyushu University - Prof. Toko)

(http://www.insent.co.jp/en/products/products_index.html)

Acceleration Switch

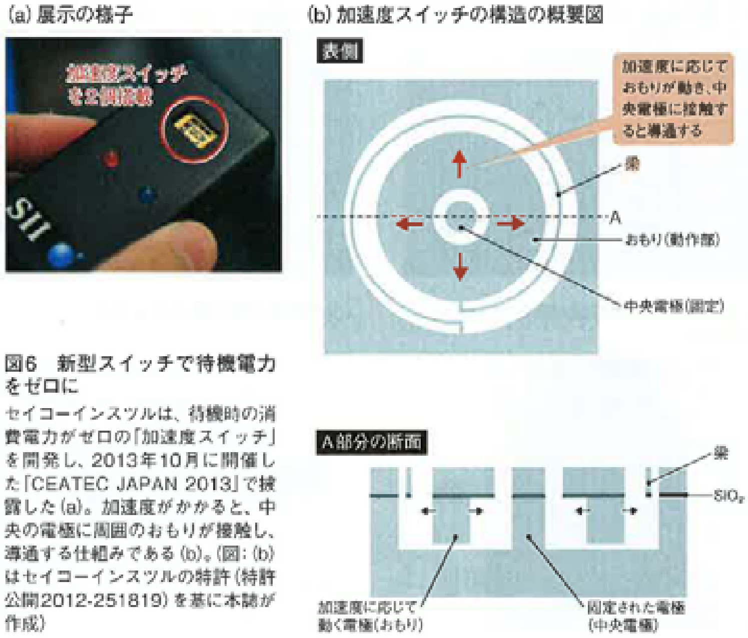


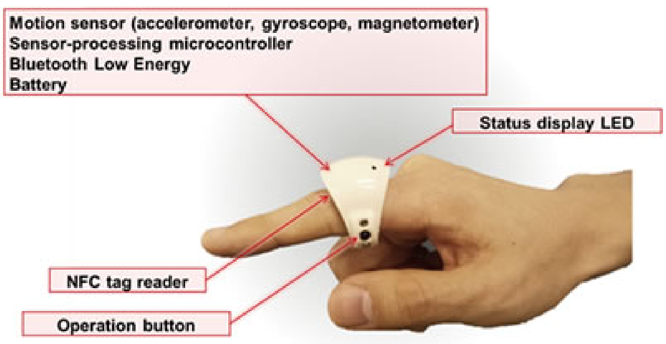
図6　新型スイッチで待機電力をゼロに

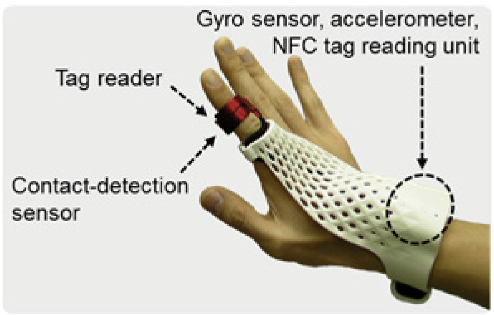
セイコーインスツルは、待機時の消費電力がゼロの「加速度スイッチ」を開発し、2013年10月に開催した「CEATEC JAPAN 2013」で披露した(a)。加速度がかかると、中央の電極に周囲のおもりが接触し、導通する仕組みである(b)。(図：(b)はセイコーインスツルの特許(特許公開2012-251819)を基に本誌が作成)

Seiko Instruments

(Source: NIKKEI ELECTRONICS, November 25, 2013, p43)

Wearable Devices of Ring-Type(Left) and Glove-Style(Right)





Fujitsu Laboratories

(http://www.fujitsu.com/global/about/resources/news/press-releases/2015/0113-01.html
http://www.fujitsu.com/global/about/resources/news/press-releases/2014/0218-01.html)

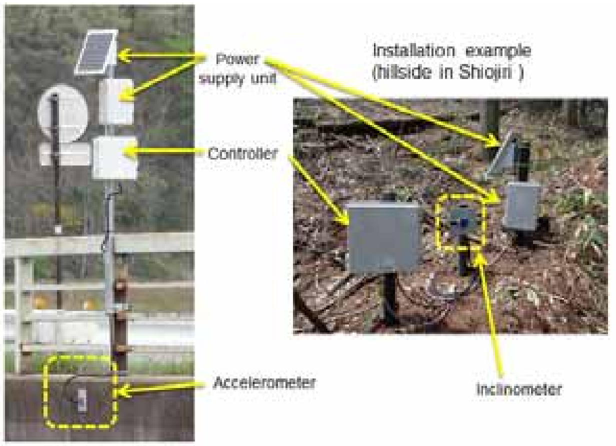
Monitoring for Bridges, Monitoring for Landslides

Monitoring the state of bridges and hillsides

Epson Sensing System Selected for ICT-based Urban Monitoring Project:

- **Looking to use a sensor network in an effort to improve urban safety, Shiojiri in April installed and began testing Epson accelerometers and inclinometers on five bridges and five hillsides.**

Accelerometer and inclinometer



Installation example (bridge in Shiojiri)

Sieko Epson

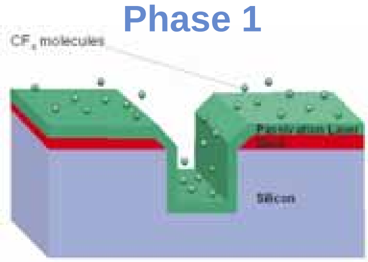
(http://global.epson.com/newsroom/2014/news_20140820.html)

MEMS Development with SPP/SPT Involvement

Si DRIE Equipment

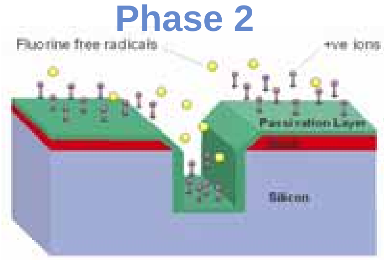
- SPTS /STS is Synonymous with the MEMS industry!
- In 1994, STS began working with Robert Bosch to develop a production version of an Etch Process that they had patented.
- In 1995, STS shipped the world 1st DRIE Equipment (*ASE*®) with Bosch Process in the market.
- This was an enabling technology in MEMS manufacturing.
- Today >95% of MEMS manufacturers use this technique.
- The development of the technologies and business managed under control of SPP.

Phase 1



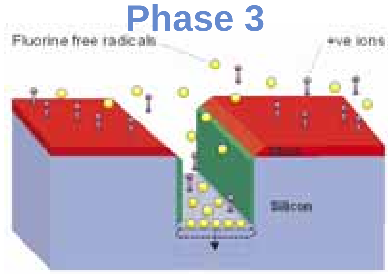
Passivation

Phase 2



Passivation Removal

Phase 3

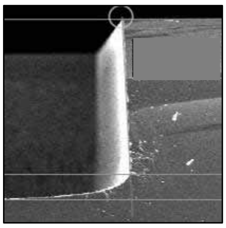


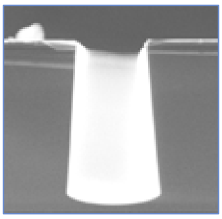
Etching

Back to Phase 1

Leading DRIE Etching Capability

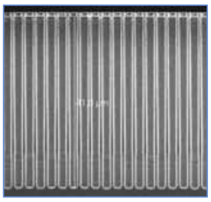
High Rate
Cavities, Caps, ink-jets



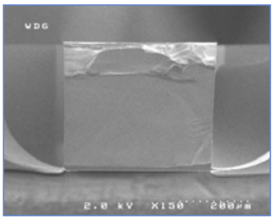


High Aspect Ratio
~0.4 µm trenches
100:1 AR

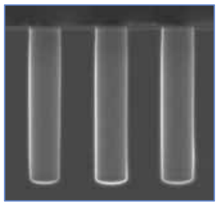
High Aspect Ratio
1.7 x 41 µm
24:1 AR

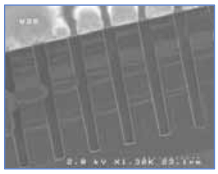


Through Wafer
Sensors
Microphones

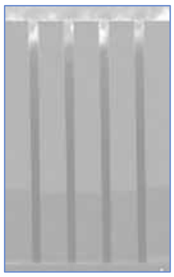


Scallop Free
<6nm 'waves'





SOI
3 x 50 µm
17:1 AR



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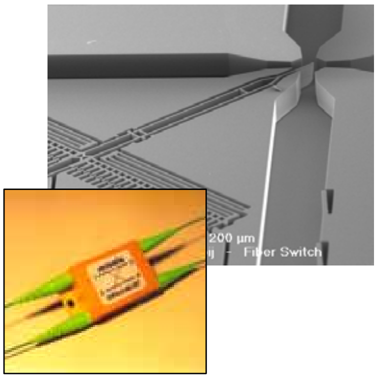
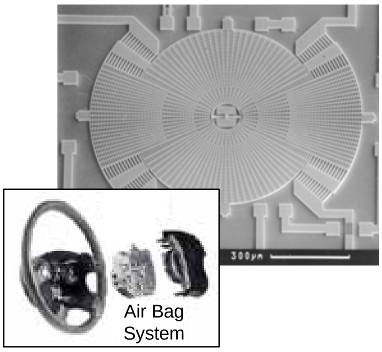
Applications using DRIE

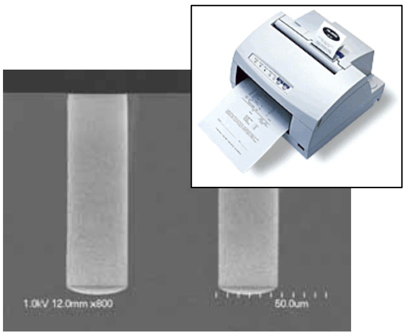
Optical MEMS
(Courtesy of IMT Neuchatel)



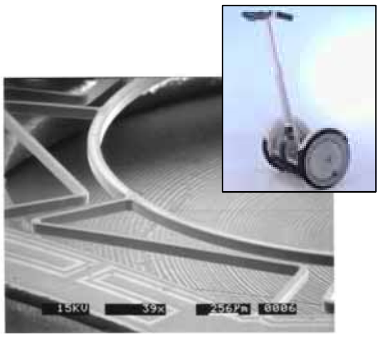
Inertial MEMS
(Courtesy of Bosch)



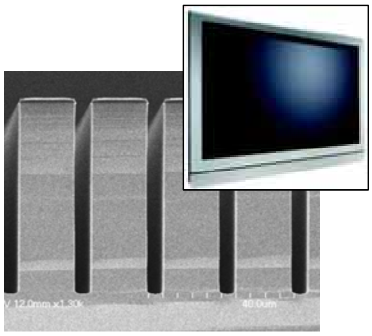
Si Microphone



Ink Jet Head Device

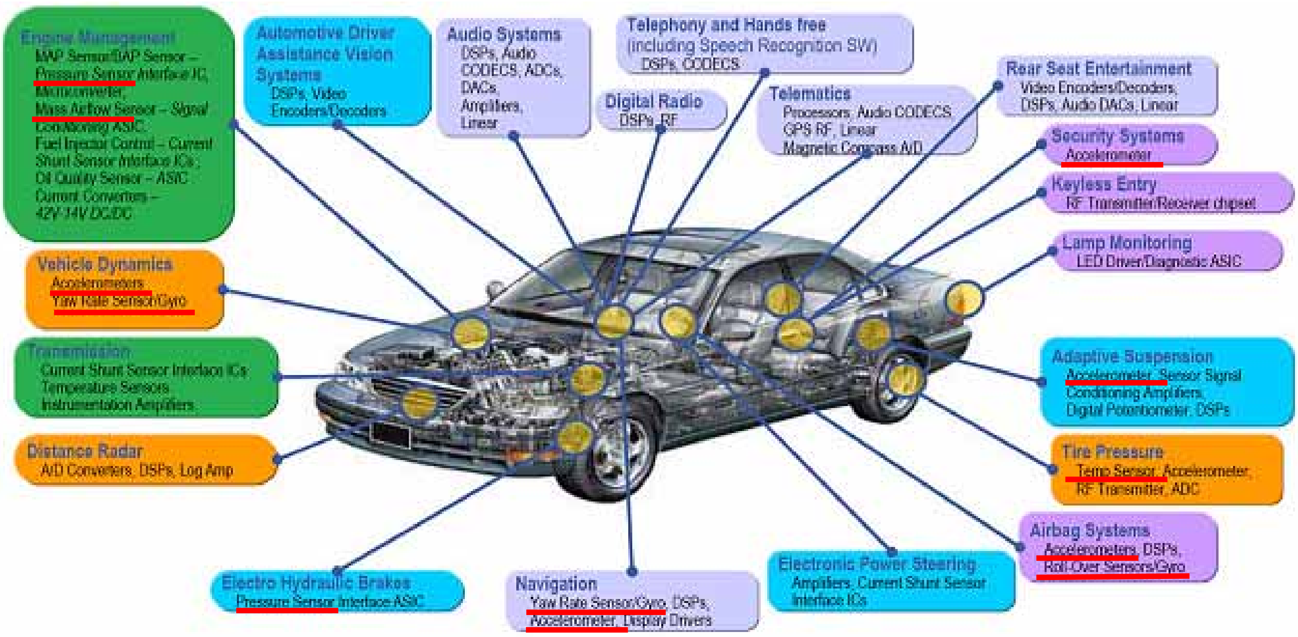


Gyro Sensor(Courtesy of SSS)



Power Device Isolation

Device for Automobile



Device for Automobile: **60~100 pieces (present)**
MEMS Sensor: **Innovative miniaturization, weight saving, low power consumption**

Ink Jet Head

SEIKO EPSON

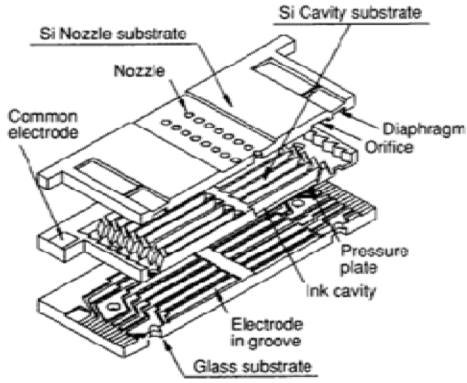


Fig.2 Exploded perspective view of the head chip

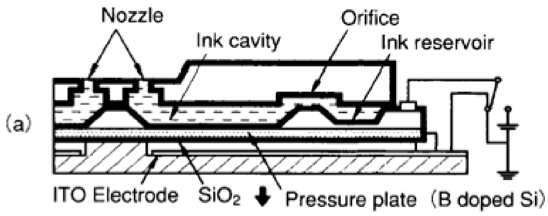


Fig.4 The mechanism of ink ejection

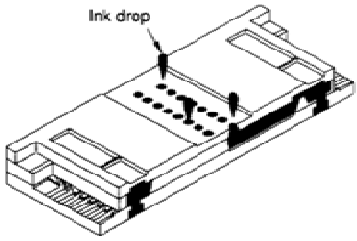


Fig.3 Perspective and cross sectional view of assembled the head chip

(Masahiro Fujii, "Micromachining Process for Inkjet Printer Head "SEAJet"", Japan Institute of Electronics Packaging Vol.5, No.6 (2002))

Game, Smart Phone

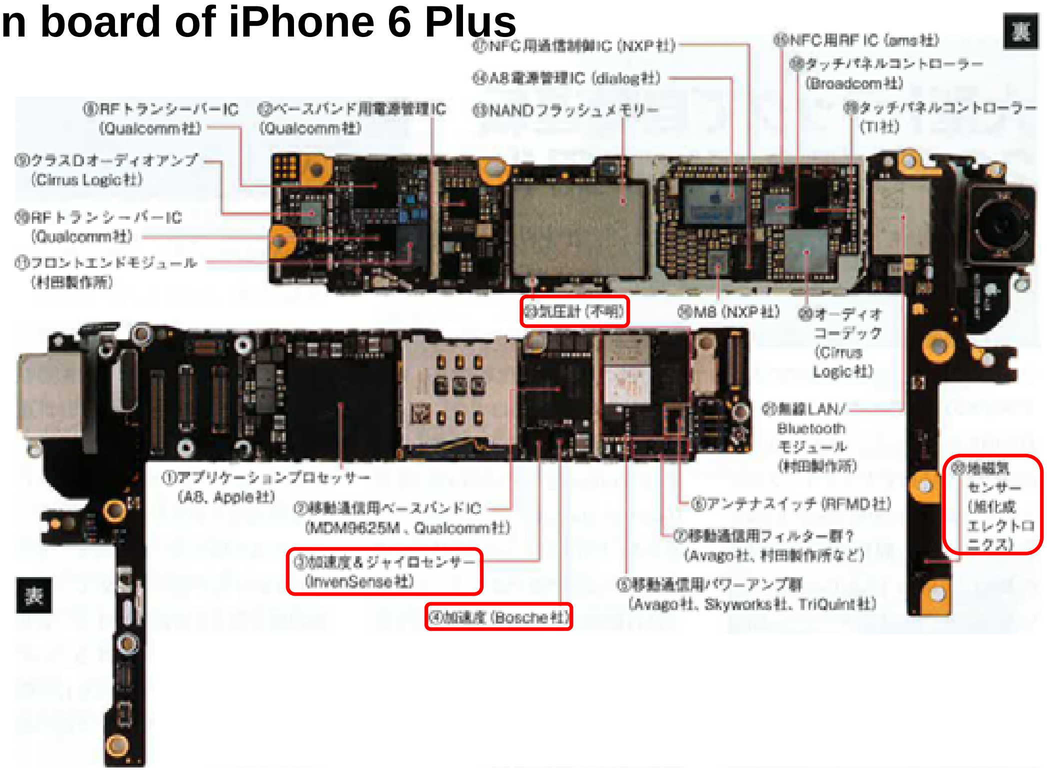
Game console(2006~)

(Nintendo - Wii controller)

Smart Phone (2007~)

(Apple - iPhone)

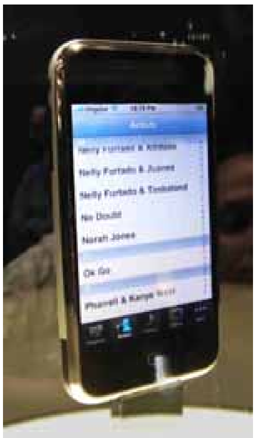
Main board of iPhone 6 Plus



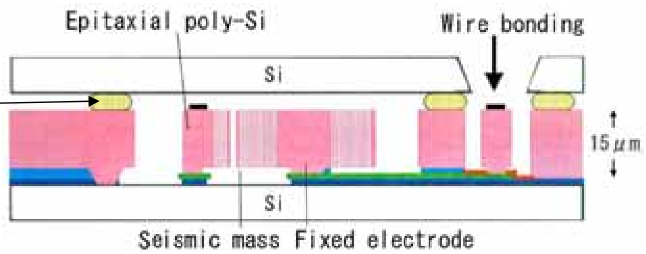
(Source: NIKKEI ELECTRONICS, October 13, 2014, pp12-13)

Device for Smart Phone

~ Accelerometer ~



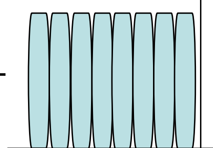
Frit glass seal



① Deposition of 125nm thick poly-Si seed layer on SiO_2 by LPCVD at 650℃.

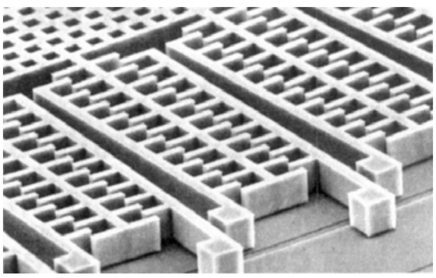
② 15μm thick poly-Si is grown in low pressure epitaxial reactor at 1000℃. Column like poly-Si with low stress (3MPa) and high deposition rate (0.4 – 0.7μm / min).

Si epi layer



Low stress epitaxial poly Si

(M.Kirsten, B.Wenk (Fraunhofer-Inst.), F.Ericson, J.A.Schweitz (Uppsala Univ.) Thin Solid Films, 259 (1995) pp.181-187)



Accelerometer (ST Microelectronics)

(Courtesy of Prof. Esashi of Tohoku University)

Devices for Smart Phone

~ MEMS Gyroscope, Motion and Magnetic Sensor ~

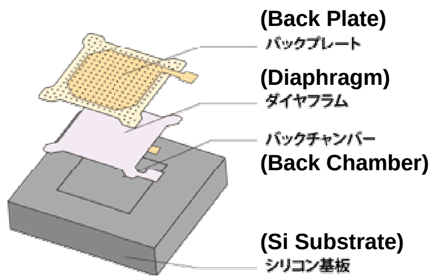
Gyroscope

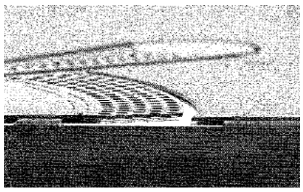
Motion and Magnetic Sensor

(http://www.st.com/internet/com/press_release/p3198.jsp)
(http://www.st.com/jp/com/press_release/p3154.jsp)

Devices for Smart Phone

~ Si Microphone ~

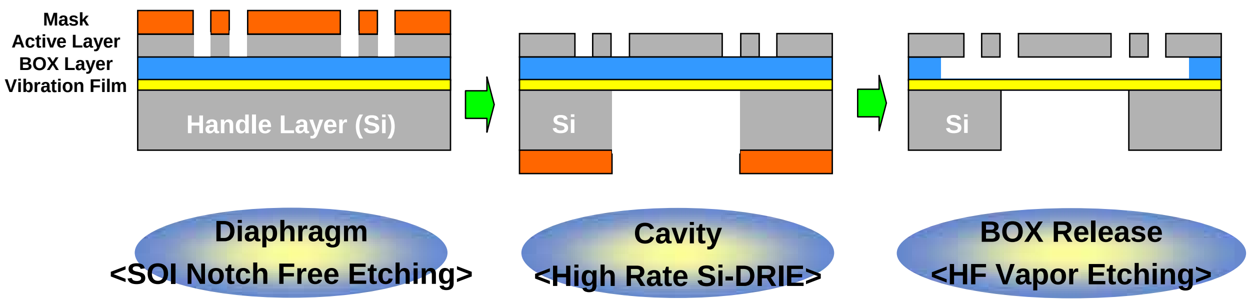




(Courtesy of Hitachi Haramachi Electronics)

(http://www.omron.co.jp/ecb/products/memsmicro/index.html)

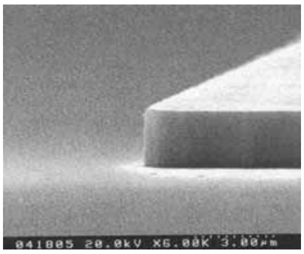
Process Flow



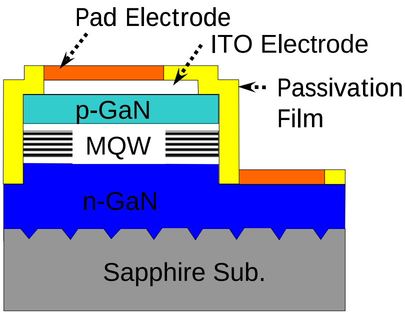
Devices for Smart Phone

~ LED ~

5 megapixel camera with <u>LED flash</u> in iPhone4



GaN Etching

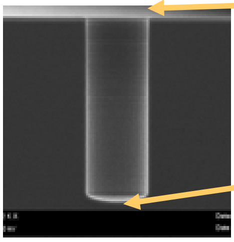


Devices for Smart Phone

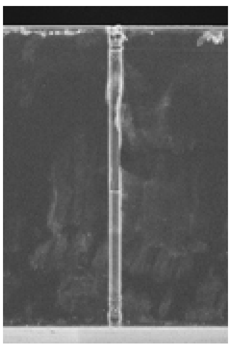
~ Advanced Packaging - TSV ~

3D Interconnect

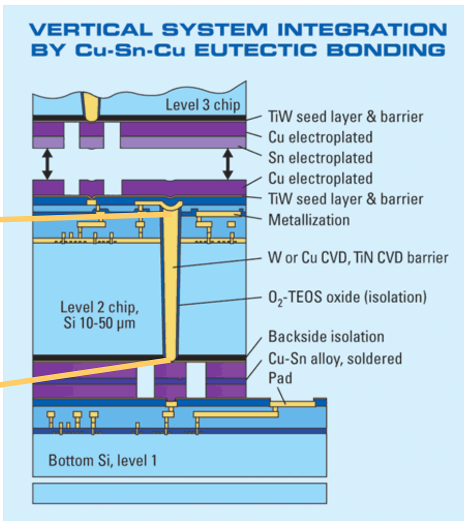
- **Enables wafer level, chip scale packaging**
- **Increased device speed due to shorter interconnect**



60µm Diameter Via Hole etched to a depth of 200µm

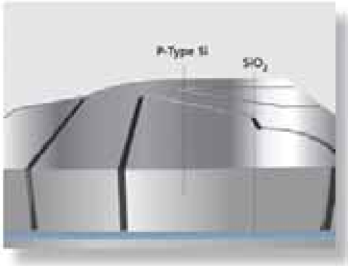


400µm Via Hole courtesy of STMicroelectronics

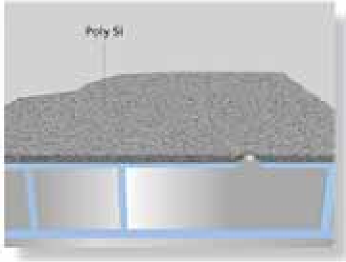


Si MEMS Oscillator

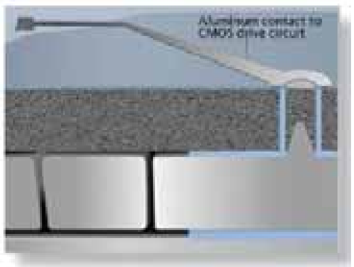
~ SiTime: DRIE and Sacrificial Layer Etching ~



Si-DRIE

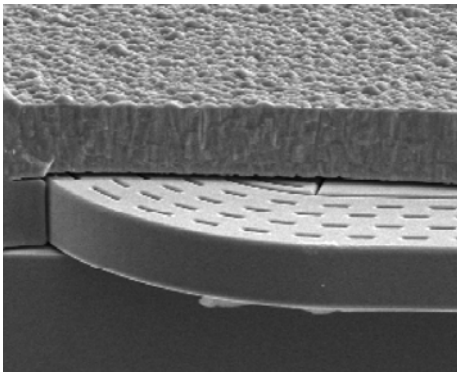


Oxide layer fill→
poly-Si Cap



Etching & release
Thick poly-Si Cap

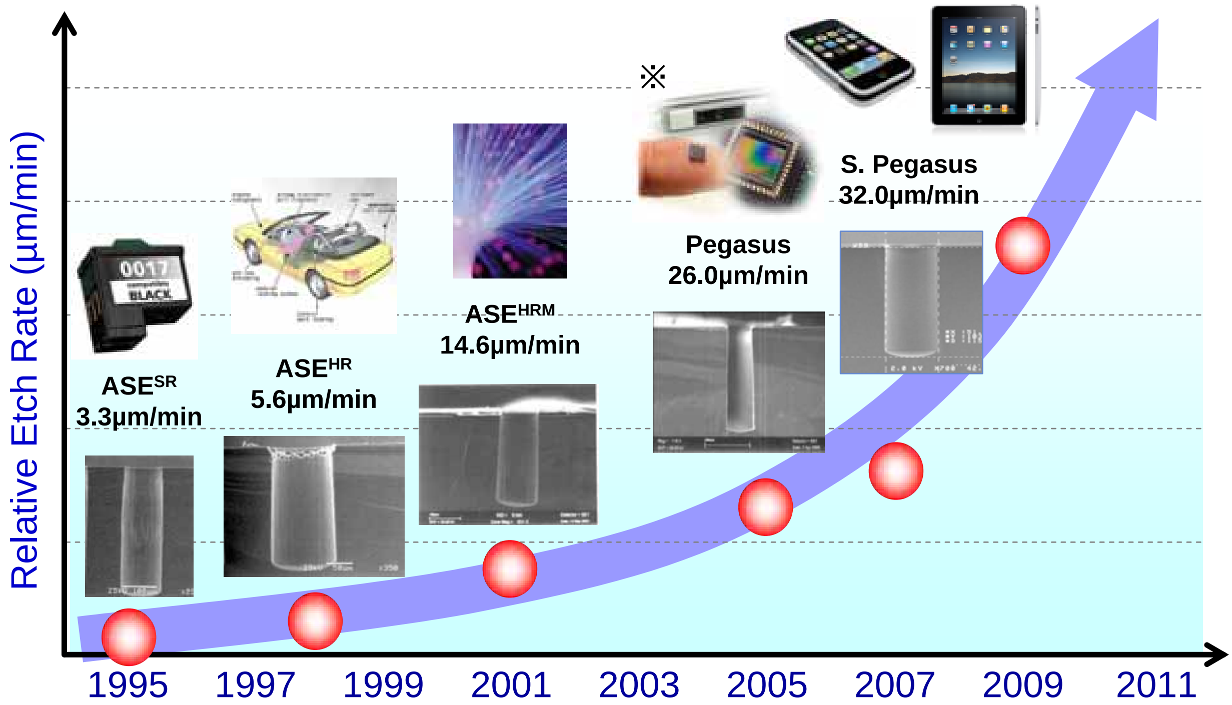
Process combination with Si-DRIE (ASE) and Sacrificial layer etching (Primaxx CET)



(Courtesy of SiTime)

MEMS Applications

Technology for Process Continuous Evolution



(※: http://www.xintec.com.tw/index.php?lang=ja&p=cis)

SPT's Product Line-up

Si DRIE

ASE-Predeus / Pegasus / Pegasus300 / SRE

Comp.Semi. / Dielectric Etch

APS / ICP / SPTS-Omega

Isotropic SiO_2 Release Etch(HF)

SLE-Ox / SPTS-CET25 / SPTS-uEtch

Chemical Vapor Deposition

PE-CVD / SPTS-Delta

Physical Vapor Deposition

SPTS-Sigma

Furnace

SPTS-AVP / RVP / RVP300plus

Isotropic Si Release Etch(XeF_2)

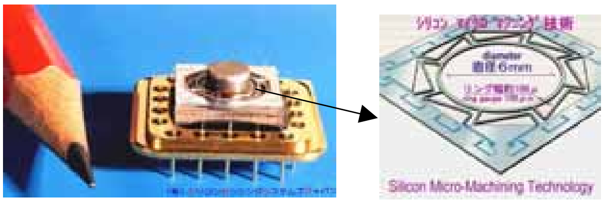
SPTS-XACTIX-Xetch / CVE

Si Ring Vibrating Gyro

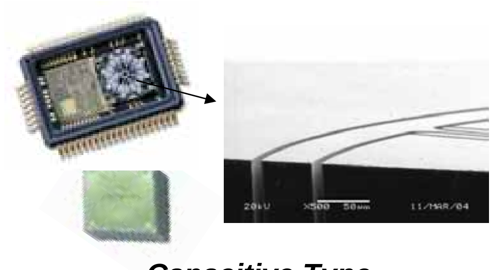
- **Silicon Sensing Systems Angular Rate Sensor**
  - Si MEMS Bulk Micromachining with DRIE
  - Its Unique Si MEMS Ring Structure (D: 6mm, W: 0.1 mm)

- **Features**
  - Accurate up to 50x than others (automotive condition)
  - Robust for shock & vibration
  - Long life (over 15 years)
  - Operating temperature: –40 ~ +85℃

- **Applications**
  - for Automotive
  - for Aircraft
  - for Robot
  - Segway HT etc



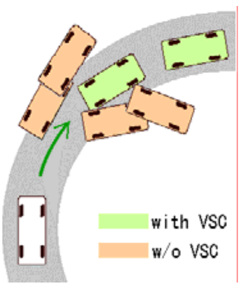
Inductive Type



Capacitive Type

Applications of Si Ring Vibrating Gyro

Application for Automotive



VSC : Vehicle Stability Control

Segway HT

Balanced Sensor Assembly
(XYZ+2units)

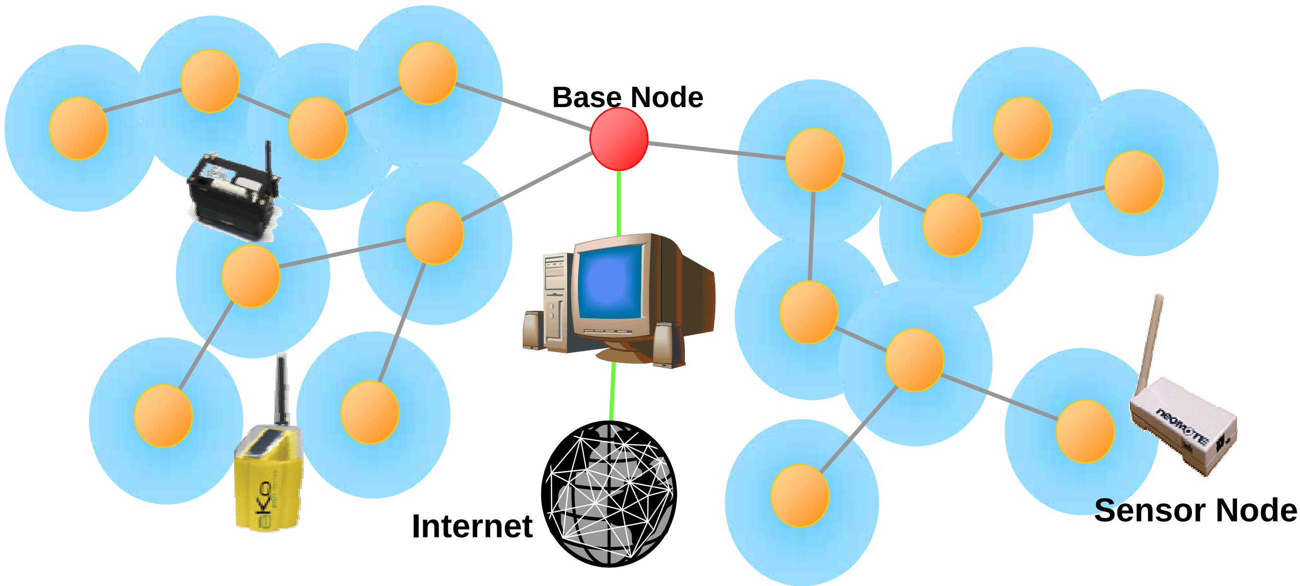
Application for Aircraft

Flight Navigation Systems

Unmanned Helicopter Control

Technology for Systems
Wireless Sensor Network

- Each sensor node forms multi-hop wireless route to the base station; AND self-heals.
- Saves wiring costs on industrial metering or energy-saving system. Because of wireless, a layout change requires no re-wiring costs.
- SPP/Crossbow's NeoMOTE has numerous deployment cases in various situations: proven immunity in communication robustness.



Technologies for WSN

Computing
- Higher performance
- Miniaturization
- Lower power consumption
- Various I/O
- Lower Cost

Sensor
- MEMS
- Lower power consumption
- Lower cost
- More sensing applications

Wireless Network
- Technologies like WiFi, Bluetooth, ZigBee
- Lower power consumption
- Miniaturization
- Lower Cost

Lots of MEMS Technology

Each technology requires
Miniaturization/ Lower Power/ Lower Cost

Wireless Sensor Network

Wireless monitoring the electric power, temp etc

--> Control the energy saving (Smart Grid)

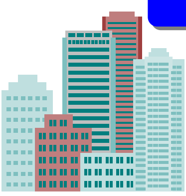
▲ Wireless monitoring the temp and vibration without circuiter

Monitoring the state of conservation ▼

Information by mail alarm

Technology for Systems
Applications of WSN

Power Savings

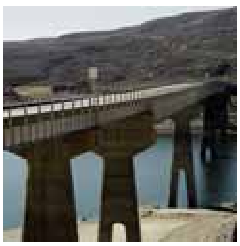


- Energy management
- Building management
- Micro Smart Grid

Agri/Natural Environment

- Outdoor sensing
- Precision farming
- Forestry

Civil Engineering



- Structural- Health-Monitoring

Security

- Elderly Well-Being monitor
- Location system
- Intruder detection

Maintenance

- Equipment operation rate
- Predictive maintenance
- Wiring reduction of metering
- Monitoring storage conditions

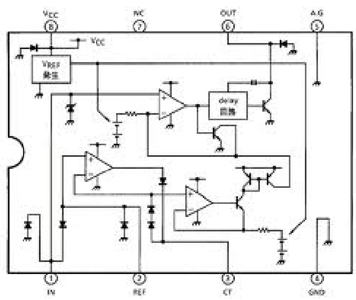
Healthcare/Medical

- Health monitoring
- Medical sensors
- Pharmacology storage

Summary

WSN and MEMS Technology - Challenges

Low power MEMS sensors



Sleep operation and quick wake-up, accurate instantaneous measurement;
Stable and accurate in supply voltage changes

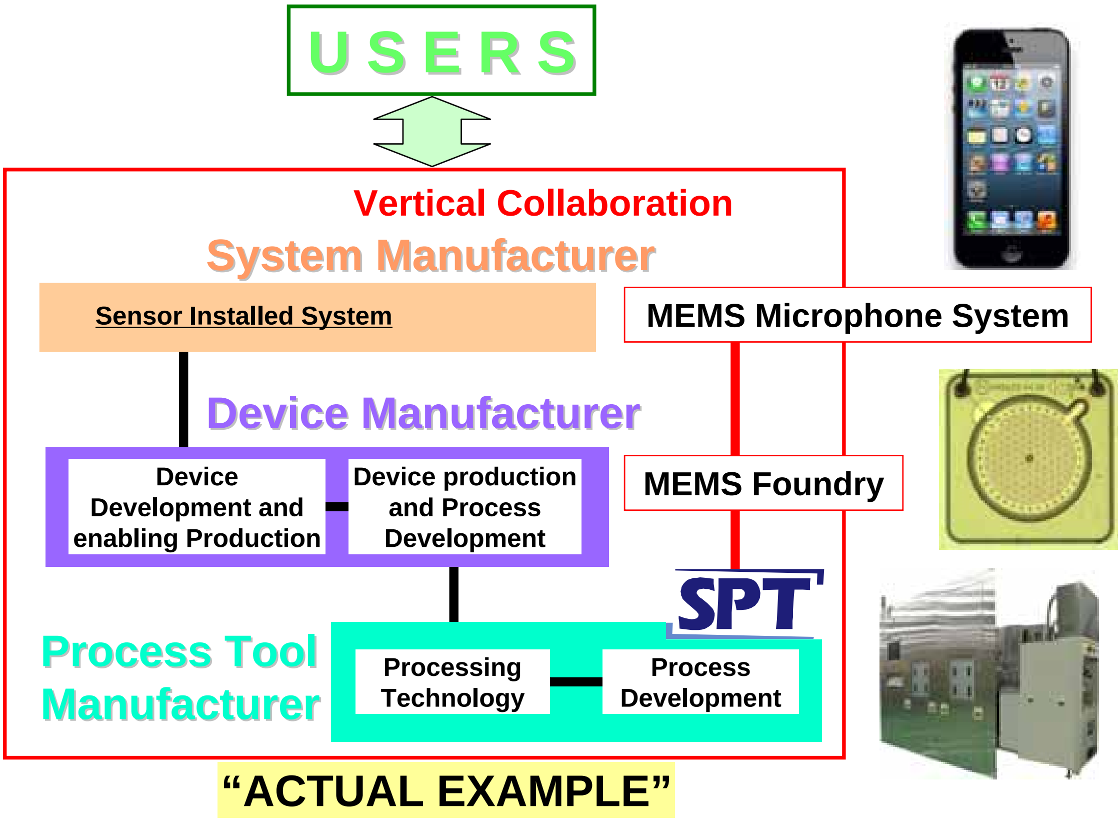
Energy Havesting

Should be a stable power supply, self-content, even in unfavorable conditions

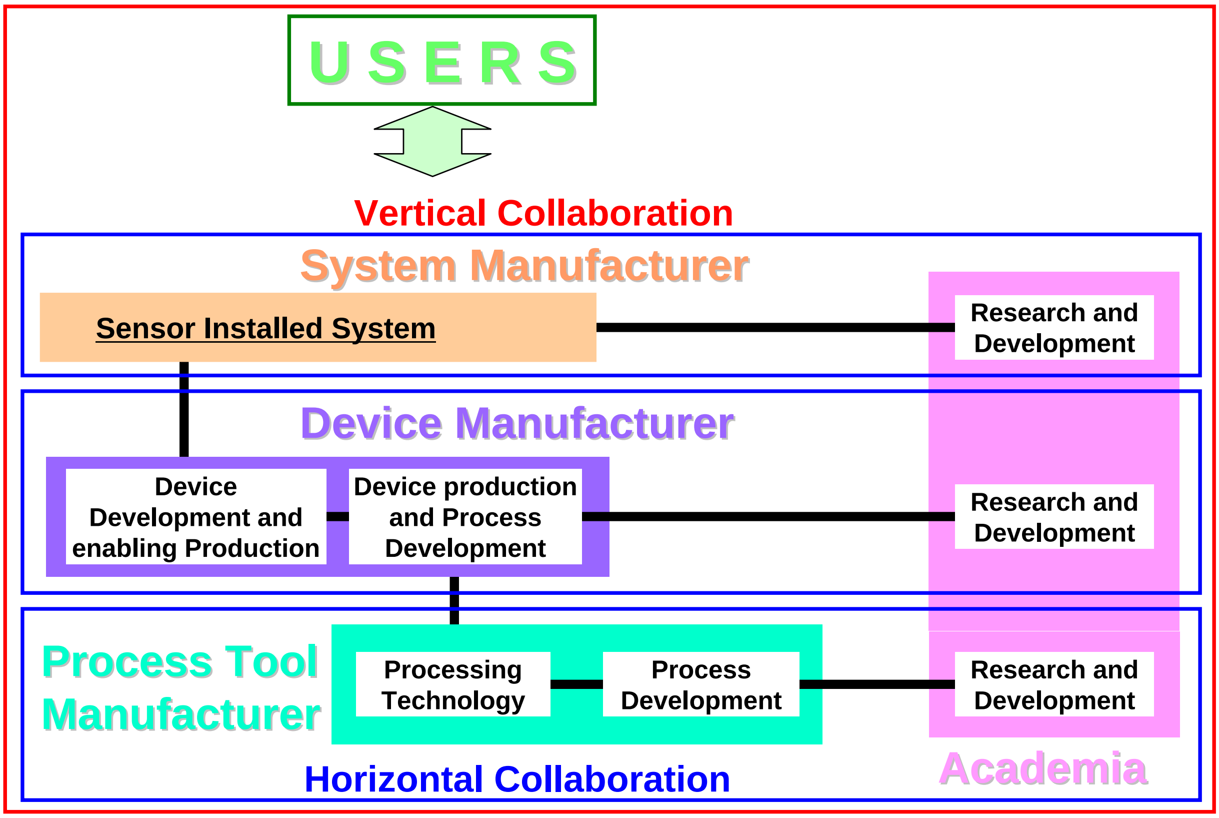
Integration of various sensors and processing

Various MEMS sensors are integrated with processors and be one single chip, in very near future (e.g. Smartphone sensors)

How to Accelerate the Development Cycle



How to Accelerate the Development Cycle



Summary

- Technologies for Processing, Devices and Systems widely available to support Networked Sensors Development
- Technologies can be developed to support emerging requirements
- MEMS to play the key role to make Trillion Sensors possible
- Networked Sensors to create explosive expansion of application
  M2M (Machine to Machine), IoT (Internet of Things),
  and IoE (Internet of Everything)

⇓

- Emerging New Applications are essential
- Technologies and requirements in Japan to contribute to solving Global Problems

Trillion Sensors Initiative worldwide
⇒ Japan's active involvement
⇒ New Industry Creation
⇒ Contribution to the World