Current achievements

v1.15 (June, 2012)

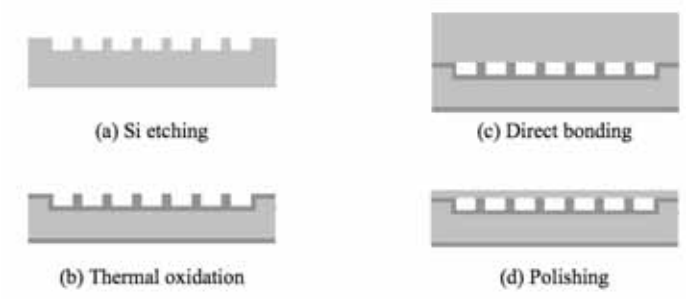
(1) Si deep etching process

(a) Cross section view of Si
by a DeepRIE etcher（ASE-Pegasus）

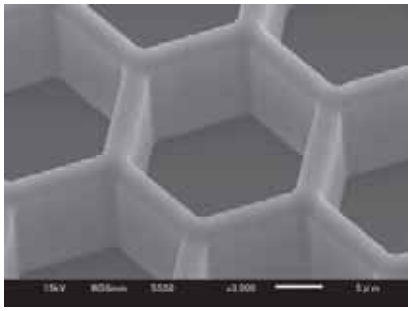
(b) Comb structured electrostatic actuator

(2) Si on Honeycomb SiO2

① Low parasitic capacity wafer

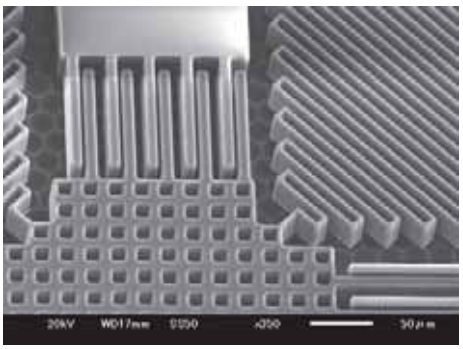


Si on Honeycomb SiO2 process flow

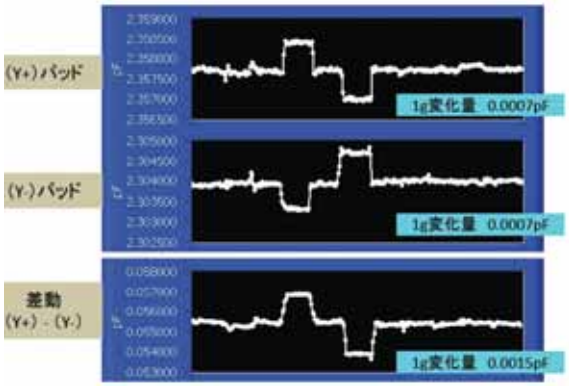


after thermal oxidation

② 3-D accelerometer on the Si on Honeycomb SiO2 wafer



(a) 3-D comb structured accelerometer

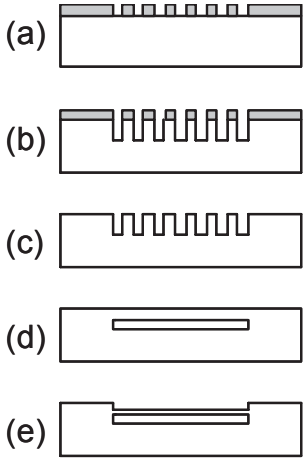


(b) output example

characteristics

capacitance	1.0 pF
sensitivity	0.003 pF/g
resonance frequency	5.5 kHz

(3) Si on Nothing (SON)



(a) resist patterning

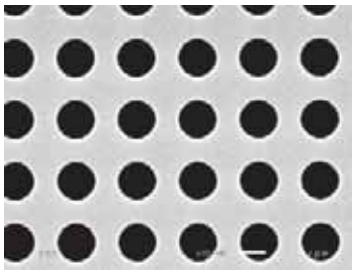
(b) trench formation by Deep RIE

(c) removing resist

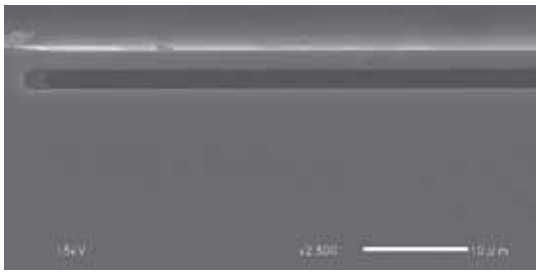
(d) annealing in vacuum

(e) diaphragm formation

SON pressure sensor fabrication process

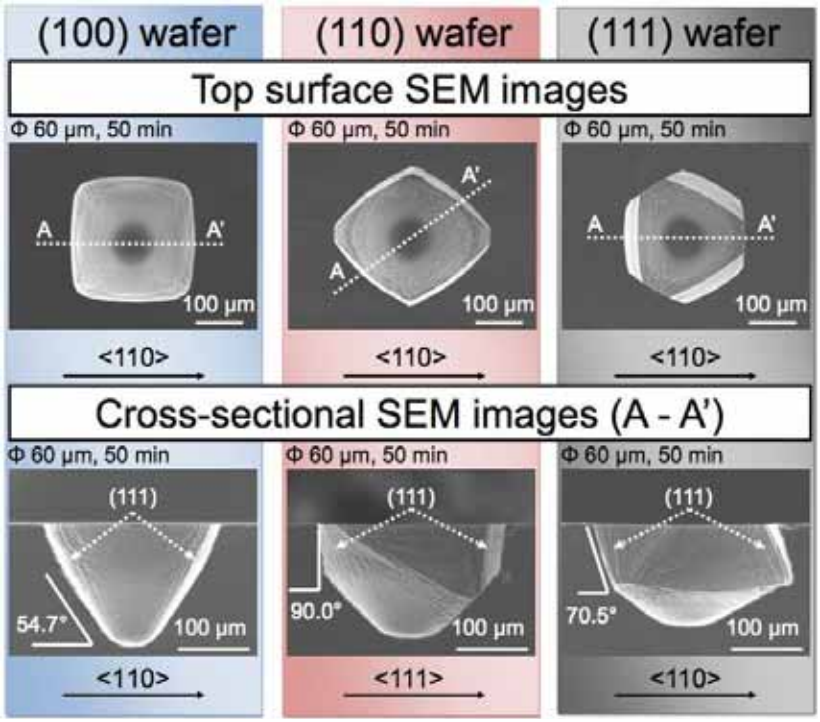


Trench formation

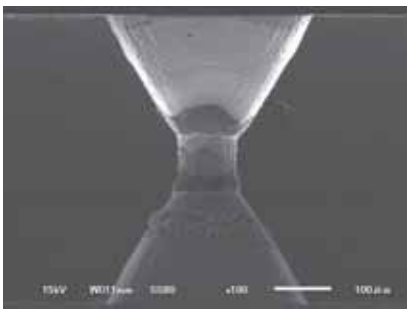


SON diaphragm (cross section)

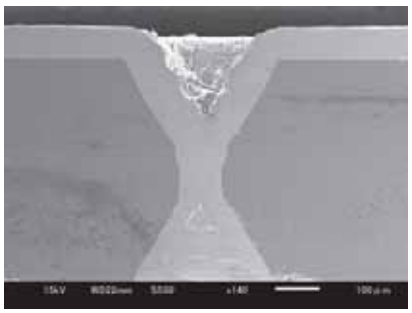
(4) Anisotropic Si dry etching



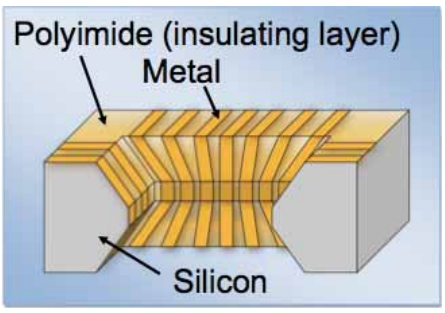
(5) TSV and wiring by anisotropic Si dry etching



TSV formation



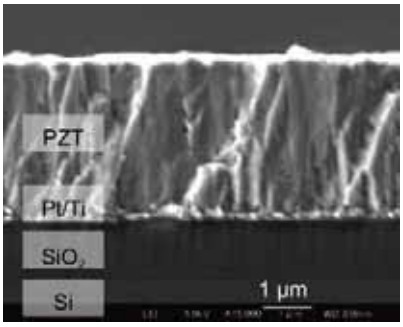
metalizing plating



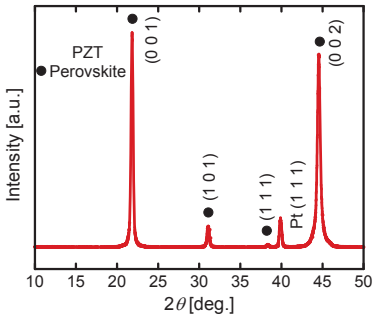
multi-wiring through Si via

(6) PZT piezoelectric thin films processing for a fusion with Si process

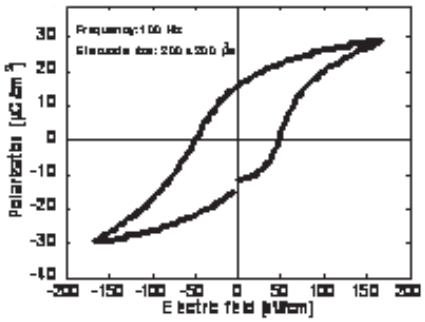
① PZT forming



(a) Cross section view of spattered PZT

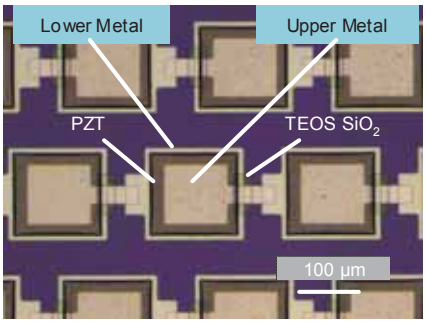


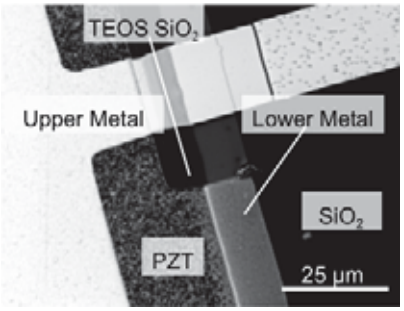
(b) XDM of sputtered PZT (perovskite)

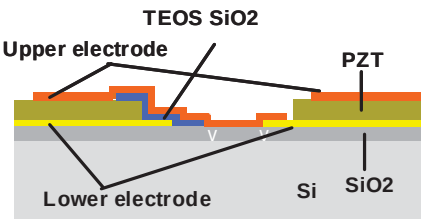


(c) P-E hysteresis loop Pr:~14,16 μC/cm2, Ec:±50 kV/cm, d31： ~80 pC/N

② PZT devices serial connection process

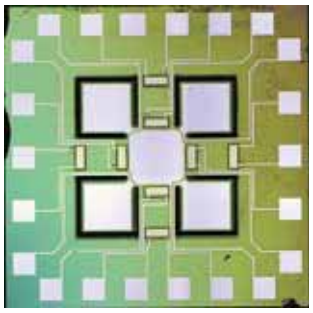




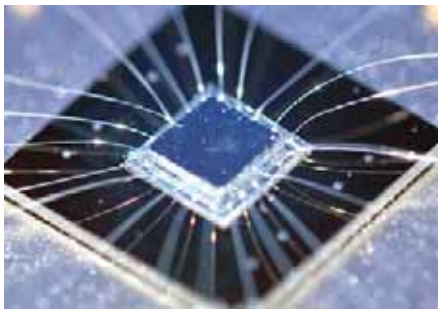


(a) Cascade connected PZT device (b) wiring over PZT step（Upper Metal） (c) a schematic diagram

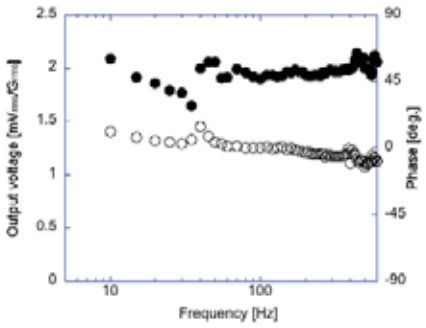
③ Piezoelectric/ Electrostatic hybrid accelerometer



(a) Hybrid accelerometer (removed counter electrode)

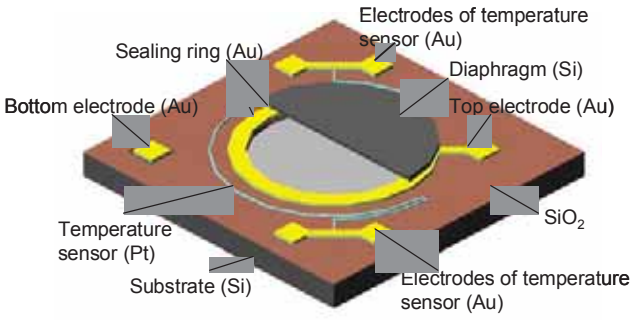


(b) Fabricated chip

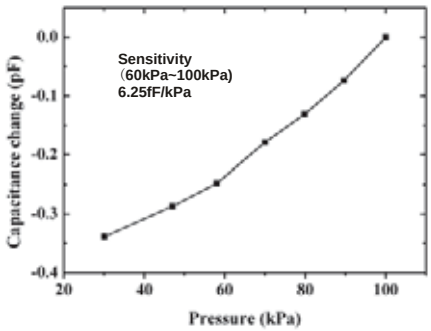


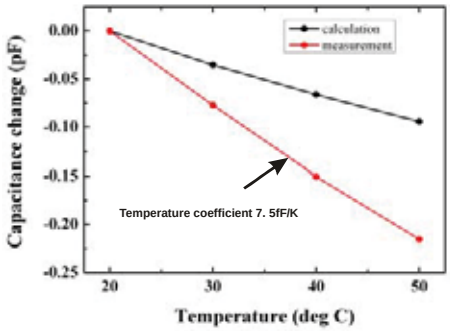
(c) Frequency response of PZT accelerometer

(7) Atmospheric pressure sensor with self temperature compensation



(a) Schematic structure of the pressure sensor

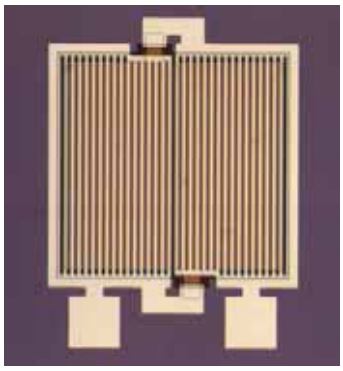




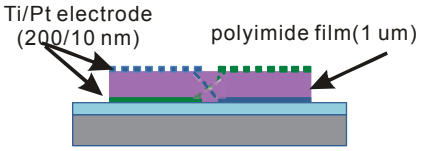
(b) Capacitance VS. Pressure Capacitance VS. Temperature

(Radius of diaphragm=500μm, gap=5μm, thickness of diaphragm=5μm, width of sealing ring = 400μm)

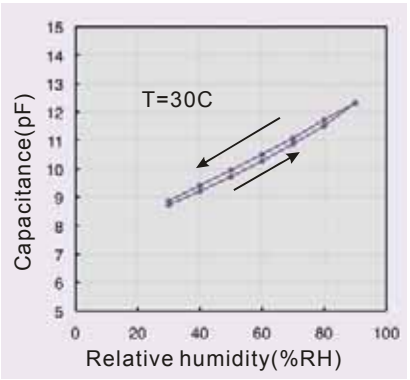
(8) Humidity sensor



(a) Humidity sensor
Bottom electrode 0.6mm x 0.6mm
Top electrode 10um line and space

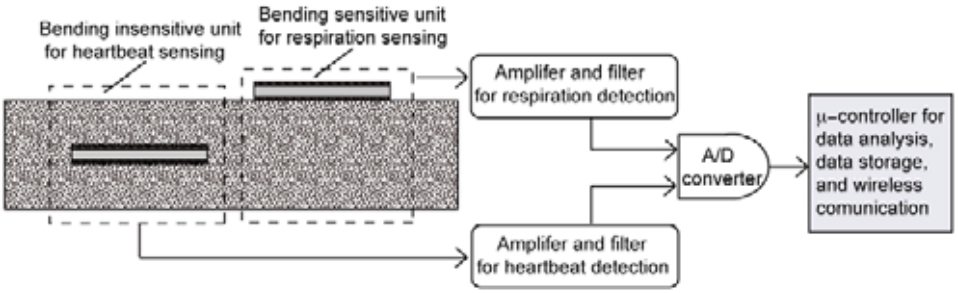


(b) Schematic cross sectional view

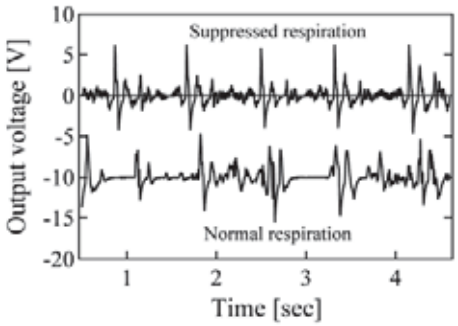


(c) Chracteristics

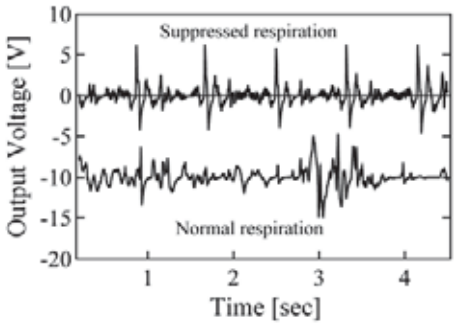
(9) Respiration sensor



(a) Schematic diagram



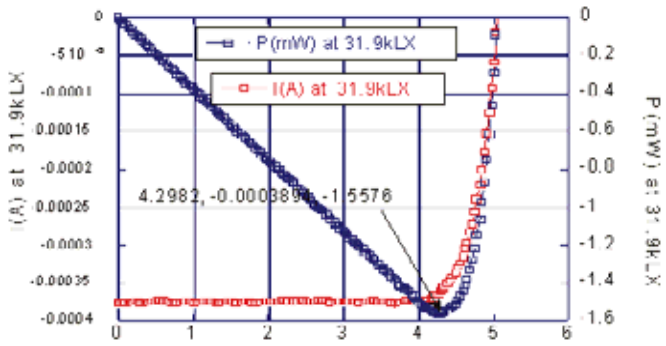
(b) Cardiorespiratory detection results using the bending-insensitive mode PVDF sensor, which is attached to the chest, when the person is with normal respiration and with suppressed respiration, respectively



(c) Cardiorespiratory detection results using the bending-sensitive mode PVDF sensor shown in the above figure, when the person is with normal respiration and with suppressed respiration, r espectively.

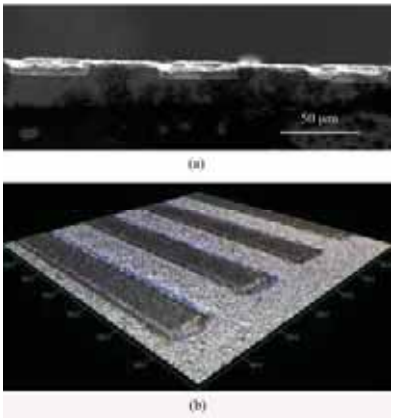
(10) Solar Cell

(a) Ten solar cells in series assembling

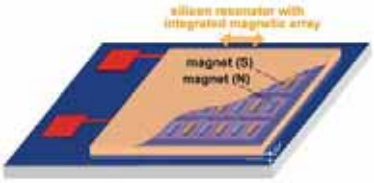


(b) Ten solar cells in series exposed at 31.9 kLX light (This condition roughly corresponds to the shade area in a fine day)

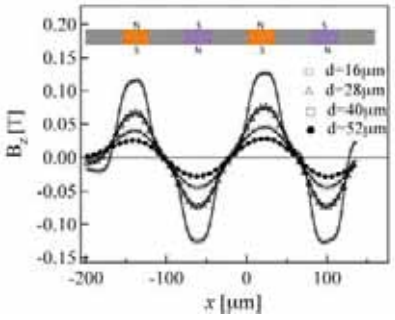
(11) NdFeB electromagnetic power generator



(a)(b) patterned NdFeB films by polishing

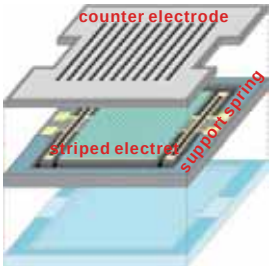


(c)a schematic diagram of an electro-magnetic power generator

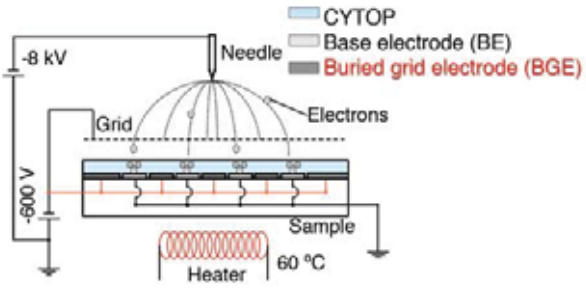


(d)simulated magnetic flux density

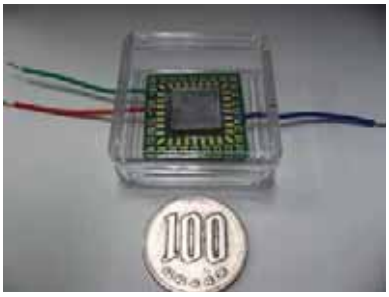
(12) Electret power generator



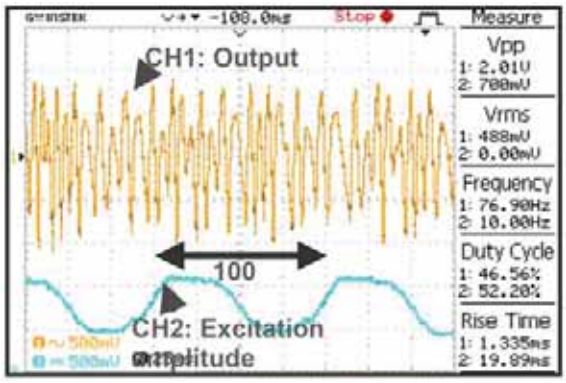
(a) schematic diagram



(b) electret charging method



(c) Fabricated chip

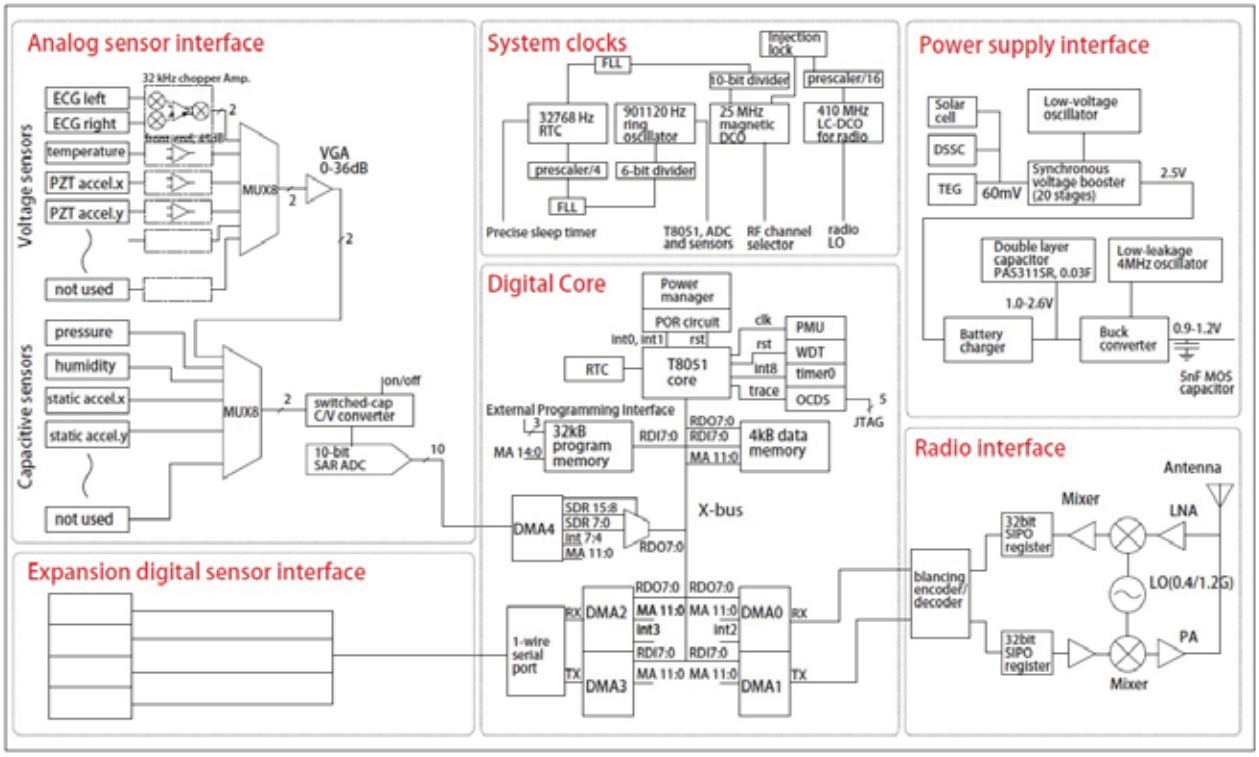


Voltage waveform during power generation.

(Maximum output power of 0.23μW is obtained with an acceleration of 0.1 G at 10 Hz.)

(13) Ultra low power mixed signal processor with RF (CMOS MEMS CUSTOM LSI)

① Architecture

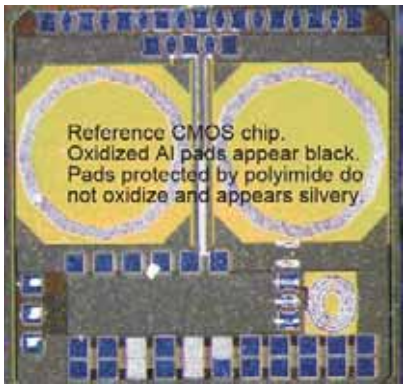


(a) block diagram

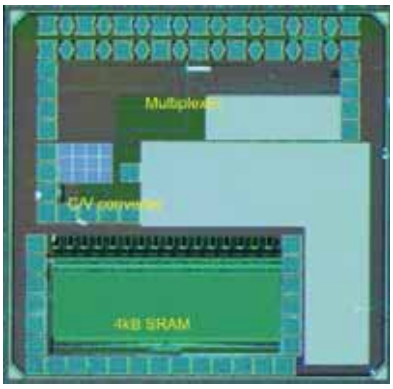
Design parameter	Value
Number of built-in capacitive sensors	Up to 7
Number of built-in voltage sensors	Up to 8
Voltage sensors front-end sensitivity	30 uW
Capacitive sensors' front-end sensitivity	1 fF
Sensors' front-end SNDR	60 dB
Sensors' front-end maximal data rate	2.4 kbps
Radio communication distance in office	10m
Receiver sensitivity	-98 dBm
Transmitted power	-6 dBm
Integrated Sensor size	3 x 6 x 0.5 mm
Total System Maximal size (including pasting part)	60x15x2 mm
Maximal weight	2.6 g
Maintenance	Cleaning only
Installation	Sticky base
Expansion cards, 5x3.5x1mm, I2C and 1-wire interfaces	Up to 4

(b) design parameters (Total power consumption < 10 μW)

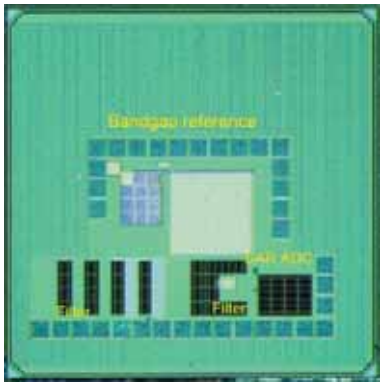
② Prototypes (by foundry shuttle service)



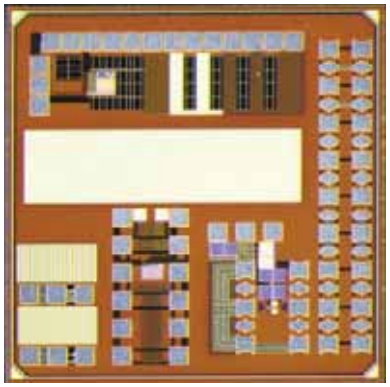
(a) Low noise amplifier



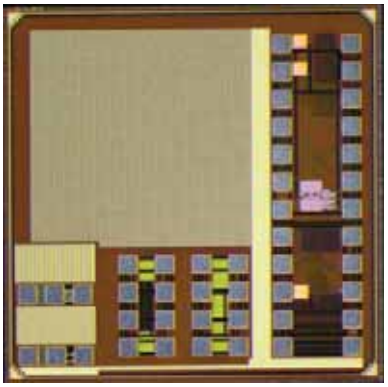
(b) C/V converter, Multiplexor, SRAM



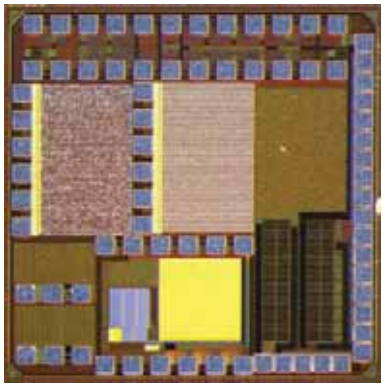
(c) Bandgap reference, SAR ADC



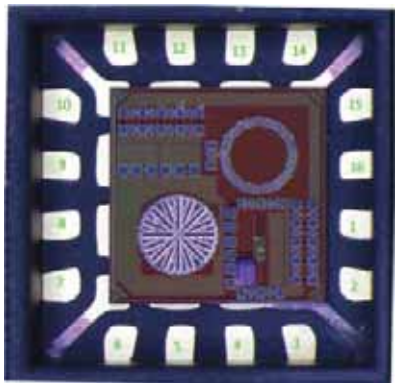
(d) ADC/PowerManagement/LNA



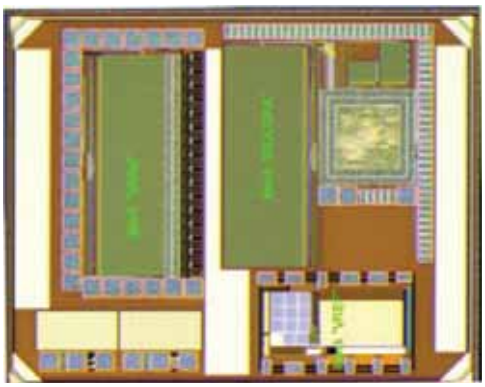
(e) Solar Cell / Real Time Clock



(f) Humidity Sensor / Encorder,Decorder

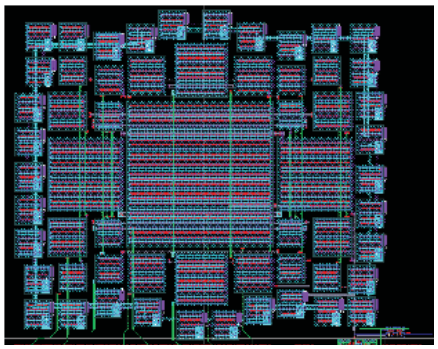


(g) On-chip Indcutor



(h) Lowpower8051/Peripheral

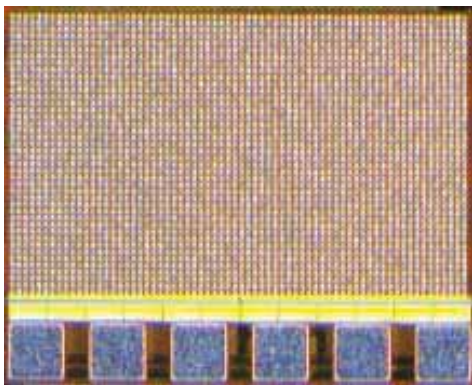
③ Low power A/D converter

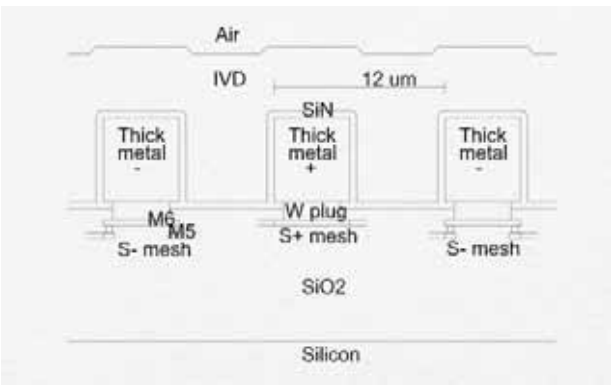


Specifications	ISSCC' 07[1]	ISSCC' 08[2]	JSSC'10 April[3]	JSSC'10 May[4]	JSSC'10 June[5]	This work
Technology	0.18um	90nm	0.13um	65nm	90nm	0.15um
Supply Voltage(V)	1	1	1.2	1	1.2	1.2
Sampling Rate(MS/s)	50	40	50	1	100	0.1
Resolution(bit)	9	9	10	10	10	8
ENOB(bit)	7.8	8.56	9.18	8.75	9.1	7.21
Power (mW)	0.7	0.82	0.826	0.0019	3	0.00153
FOM(fJ/Conv.-step)	65	54	29	4.4	77	103.3
Active Area(mm^2)	0.08	0.09	0.052	0.0258	----	0.0122

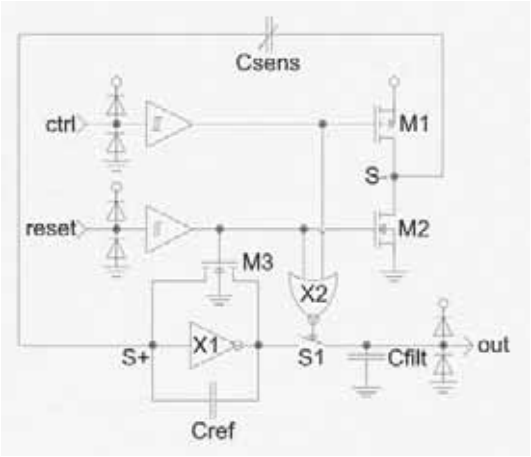
SAR with low-power comparator (VDD=1.2 V, 0.00153 mW, 122 x 100 μm^2)

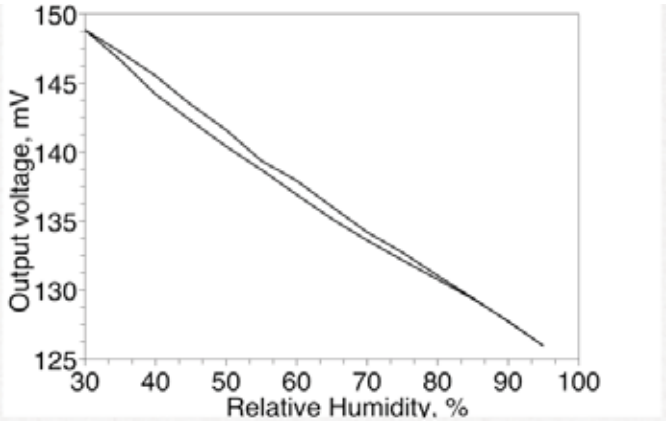
④ Humidity Sensor with a C/V converter circuit





The top metal layer of a CMOS LSI is used as a humidity sensor

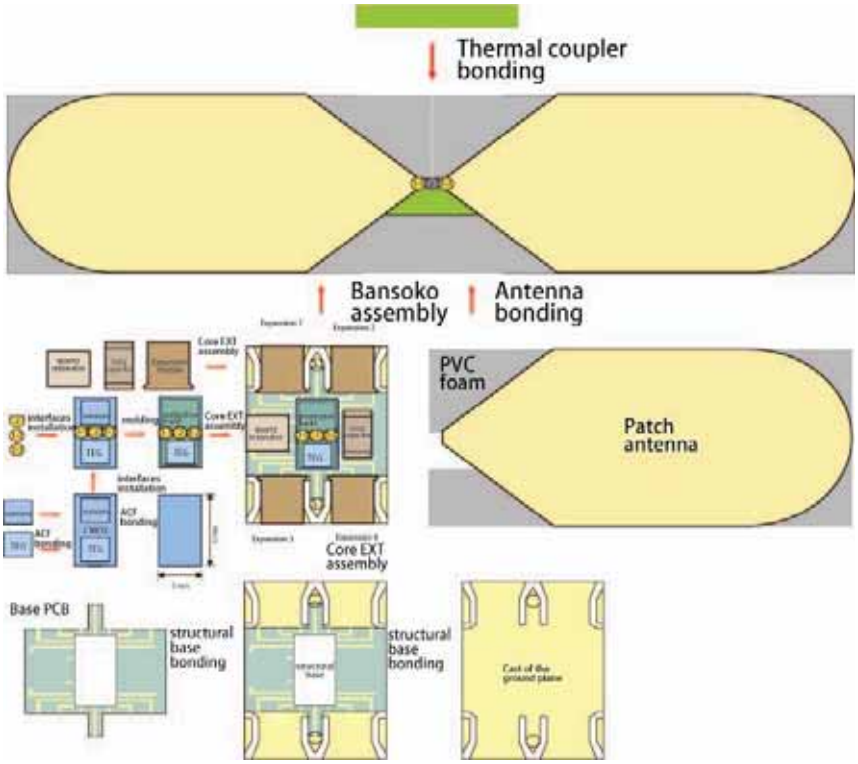




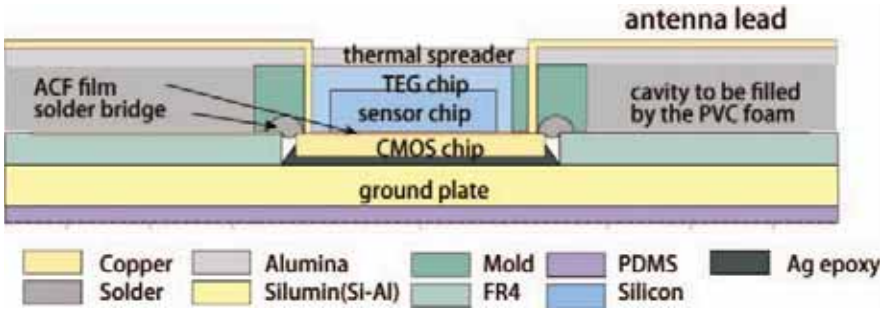
1V 1.6μW operation !

(Simple, low-power C/V conversion)

⑤ Bansoko Assembly with a Thermo Electric Generator and Antenna

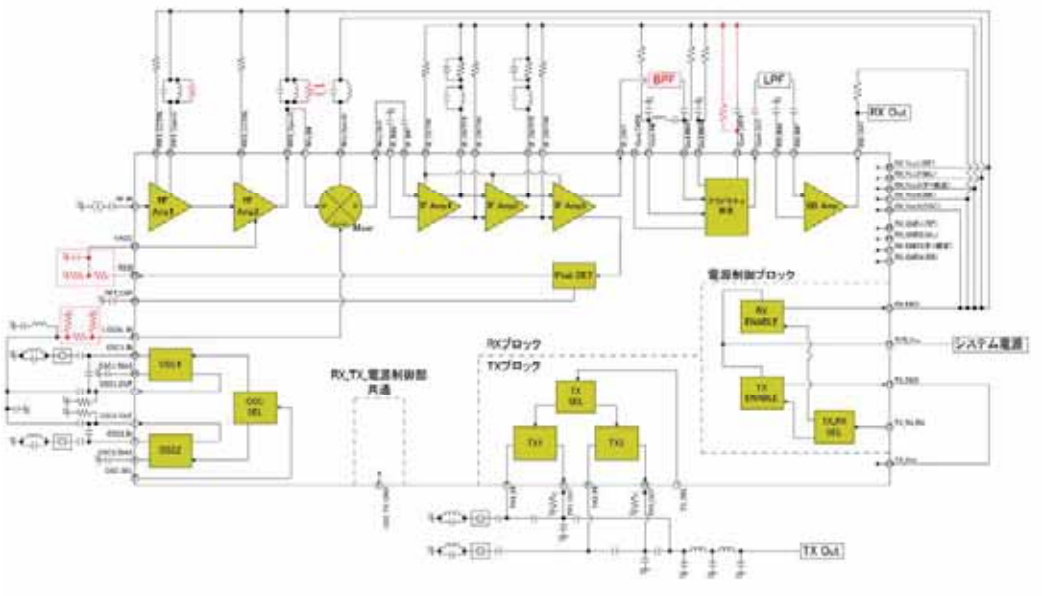


(a) Top view of the main components and the Bansoko assembly

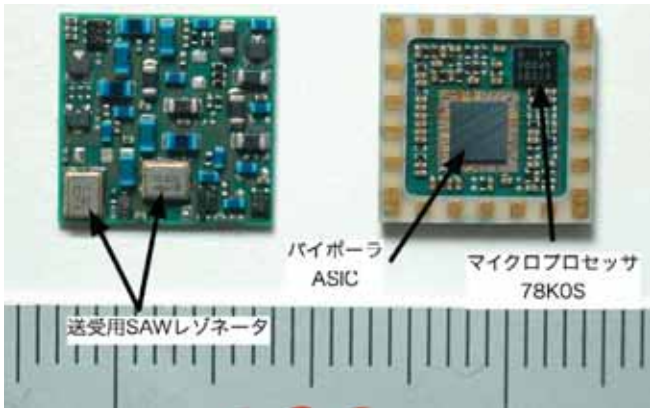


(b) Side view (cut) of the central 10mm section of the proposed Bansoko device

（14）Low power 315MHz RF module



(a) Block Diagram



(b) Top view

Tranceiver frequency	315	MHz
channel	2	
IF frequency	10.7	MHz
Transmitter power	-24	dBm
Bitrate	24	kbps
Receiver Sensitivity	-95	dBm
Power supply voltage	2.2-3.7	V
Consumption current	1 (Tx)	mA
	2 (Rx)	mA
Standby current	<1	μA
micro controller	8bit	
size	11 x 11 x 1.5	mm
weight	0.3	g

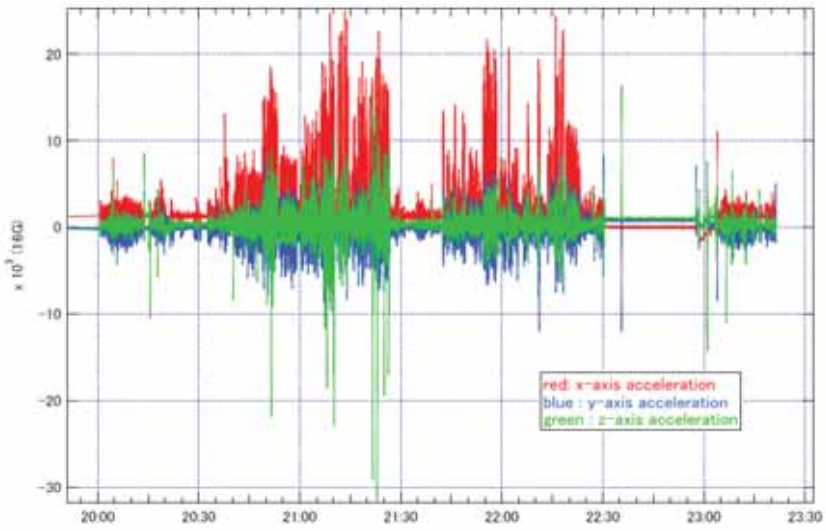
(c) Characteristics

(15) Examination of a system concept by using a large model prototype

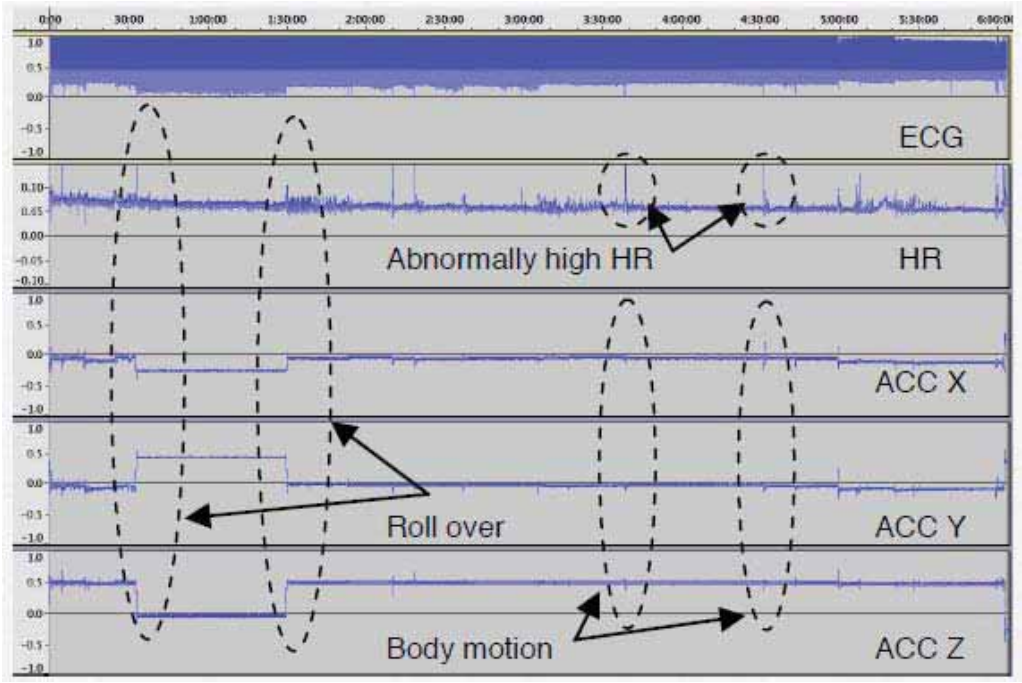
① LM03 large model

(a) LM03 (SD Memory, USB interface, Bluetooth interface and sensors with 3D acceleration,,Humidity, Pressure,Temperature, ECG and Sound

(b) a screen shot of real time receiving

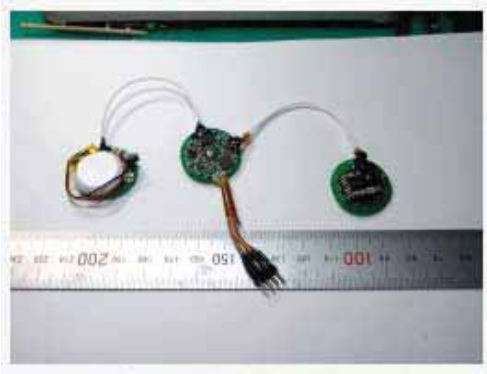


(c) 3-axis acceleration logging data on exercise



(d) ECG and 3-axis acceleration logging data at sleeping

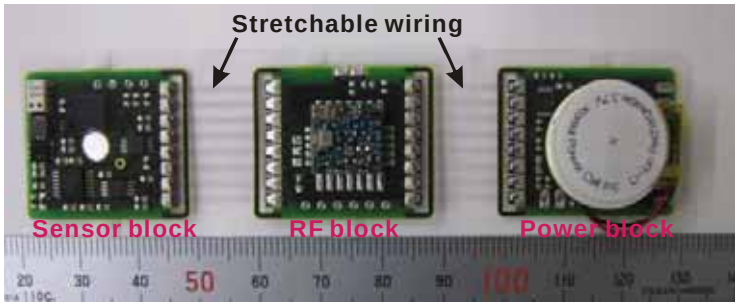
② **Button system** (patch type sensor with ECG/Acc/Temp/Bluetooth)



③ **Next Generation Button system**

Pastable III (Low power consumption model with 315 MHz RF)

(patch type sensor with 315MHz RF module and stretchable wirings on a flexible and elastic film)



PCB (Left): 3-axis accelerometer, pressure, humidity, temperature sensor, ECG amp and microcontroller

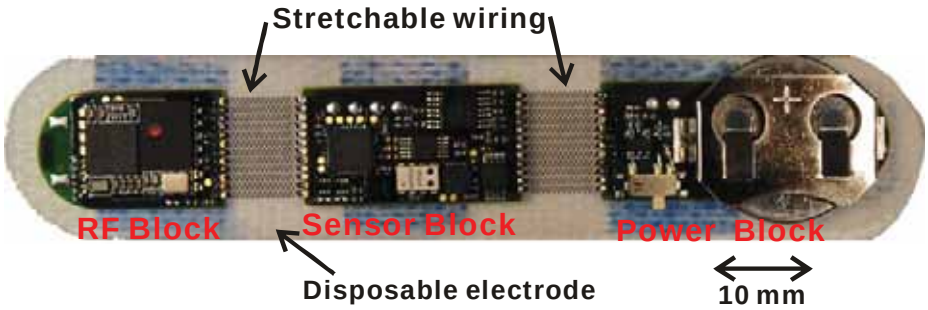
PCB (Center): 315MHz RF transceiver module

PCB (Right): Li-ion battery and charge controller

Each PCB is connected by stretchable wirings.

Pastable IV (Smaller model with 2.4GHz Bluetooth RF)

(patch type sensor with Bluetooth RF module and stretchable wirings on a flexible and elastic film)



PCB (Left): Bluetooth RF module

PCB (Center): 3-axis accelerometer, pressure, humidity, temperature sensor, ECG amp and microcontroller

PCB (Right): Li-ion battery and charge controller

Each PCB is connected by stretchable wirings.