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Bio-Medical applications of smart sensing devices

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1. Introduction

Development of silicon sensing devices with Integrated Circuits using MEMS/NEMS technology will realize an ideal sensing chip, which may be called as “Smart micro chips”, and results in ideal sensor chips, which have several sensor devices (Multi-modal sensors), signal processing circuits, RF transmitters, and power supply using natural energy in Fig.1. In this presentation, smart micro-sensor-chips for monitoring of neural activities, real time monitoring of pH images developed in our laboratory to biochemical, biomedical and clinical applications are presented. Also, a novel Radio Frequency (RF) induced power supply system and on chips antenna for micro sensor nodes is developed. Integration of radio frequency transmitter (RF) technology with CMOS/MEMS micro-sensors is required to realize the wireless smart micro-sensors system.

2. Si microprobe/tube array chips

In our developed chips as shown in Fig.2, new type sensor chips for bio-medical applications are presented especially here. One is Si microprobe electrode and tube array chips for recording of neurons in the tissue and drug deliver use. The probe array can be fabricated on IC chip, using standard IC process followed by a selective vapor-liquid-solid (VLS) growth method.[1,2] The developed chips are a smart silicon microprobe array chips to record neural activities for analysis of the mechanism of retina and brain, or for neural interfacing. Our group proposed the microelectrode array chip with extremely fine, in other words, low-invasive silicon probes of 1-2μm diameter, and fabricated using standard CMOS process followed by the VLS growth. Using the chip, the feasibility of in-vitro recording of neural activities in a carp retina and of in-vivo recording of the peripheral nervous activity of a rat was demonstrated. [4] The fine tube array with SiO_2 on chips was fabricated and was used to deliver drug (lidocaine) for nerve block test as shown in Fig4.[3]

3. pH image sensor chips

Another one is pH image sensor chips with 32 × 32 pH image sensors were successfully fabricated as shown in Fig 5 by using the CCD/CMOS image sensor technique, and real time imaging of a chemical reaction and pH distribution was carried out.[5,6] The pH variations by a chemical reaction are observed by 200 ms step (i.e. 5 flames per sec). The pH image sensor was able to take a pH image of mouse stomach successfully. It means that the novel image sensor can be applied to a biomedical and biochemical field. The technique of this pH sensor is based on the principle of a charge-coupled-device (CCD). The ion-sensing region is the thin Si3N4 film that acts as an ion-sensitive membrane. We tried to observe a living related material. From these results, the novel image sensor can be applied to a biomedical and biochemical field. Recently, neural communication imaging was demonstrated using label-free acetylchorine imaging by this pH sensor chip.[7]

4. RF transmitter& power supply for smart chips

Integrated techniques for the RF transmitter and power supply circuits by CMOS compatible and MES processes have been successfully developed for ideal smart sensing chips[8]. After matching by inserting the bonding wire inductor between the on-chip integrated antenna and the VCO output, the signal emission was confirmed near a few m distance[9]. The integrated RF induced power supply system with a large capacitor of Surface Mount Devices (SMDs) is also developed to integrate. By these research results, smart micro sensing chips with thermopile sensor, RF(300MHz) transmitter and a small ($1.2mm^2$) antenna on a Si chip in same package were demonstrated and signals were confirmed to be transmitted at a distance of 3m with 64.6dBμV/m as shown in Fig.6.[10,11]

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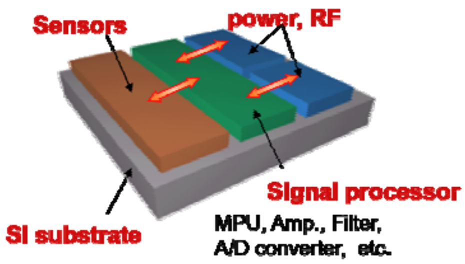

Fig.1**.** Concept of "Smart Microchips"

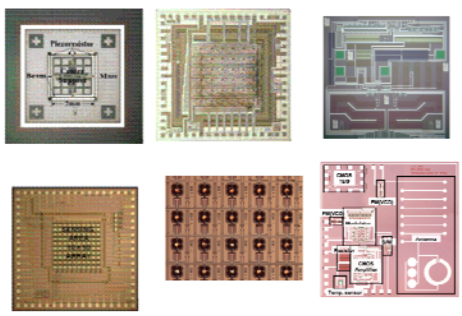

Fig.2. Smart microchips developed in TUT

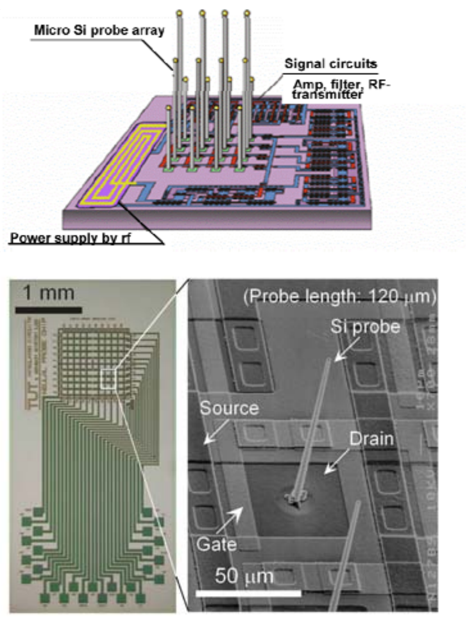

Fig.3 Ideal smart array chip concept image, and Si 1μmΦ microprobe electrodes grown at drain region of MOS FET by a selective VLS Si growth

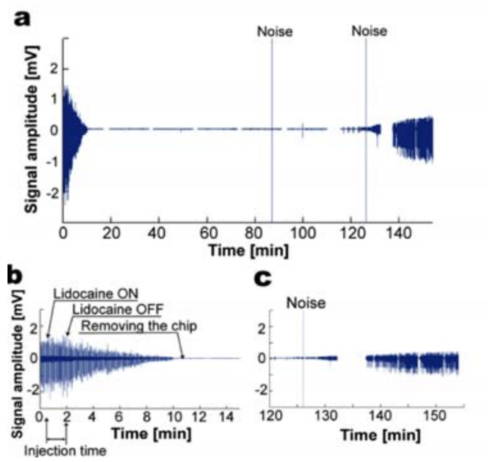

Fig.4. Myoelectric potentials of the rat lef tibial muscle during nerve block test by lidcaine injection with a fine tube chip.

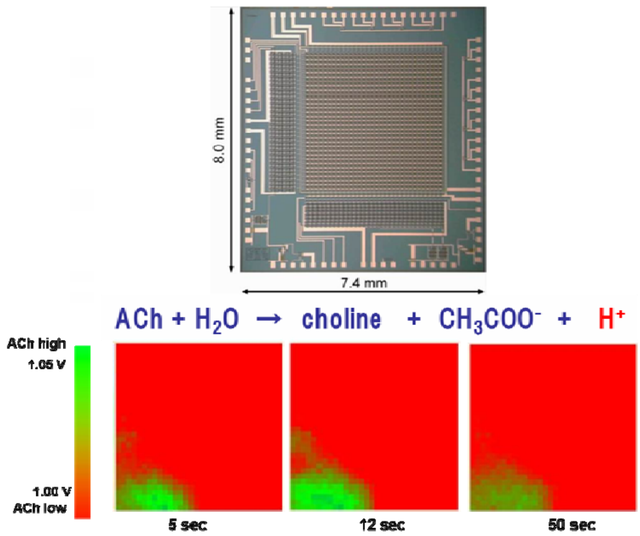

Fig.5 Photograph of a 32x32 pH image sensor chip, and label-free imaging of acetylchorine from neuron cell.

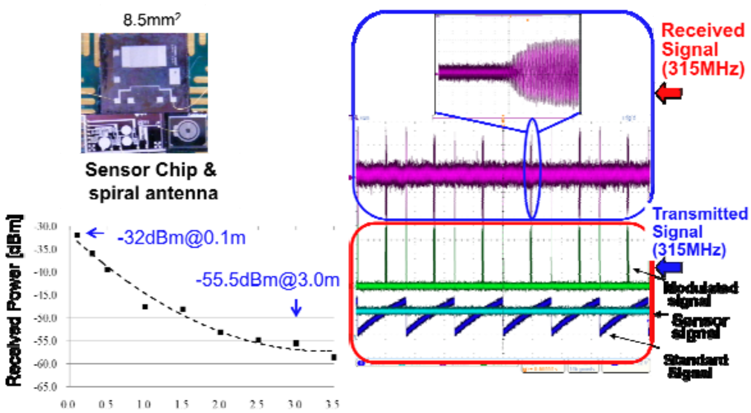

Fig.6 Sensor, rf transmitter and spiral small antenna on a chip, and the transmitted power depending on distances. The transmitted modulated signal and received signal.