Column

Merger of Integrated Circuits and MEMS

- At the Toyohashi University of Technology -

Makoto Ishida, Toyohashi University of Technology

Although sensor and MEMS technology are derived from integrated circuit (IC) technology, it is not a simple matter to fabricate sensors or MEMS and ICs on the same chip. Because the microfabrication of ICs has developed to the nm level, the barriers to this kind of merger are high. This is because ICs involve ultra high precision engineering, while sensors and MEMS involve precision engineering. Ultraprecision ICs basically are not amenable to further processing besides the manufacturing process. On the other hand, the requirements of sensors and MEMS include materials, structures, and fabrication processes that enable a range of further processing. Fulfilling these contradictory requirements is the key to merging the two. One method is to fabricate the sensors and MEMS after fabricating the IC. Another is to constrain the fabrication of the sensors and MEMS to the extent possible with IC processes. However, it is difficult to fabricate sensors and MEMS with the fullest capability, so compromises must be made somewhere. We faced the same conflicts at Toyohashi University in merging sensors and MEMS with integrated circuits, but we worked to ensure that both were satisfactory as far as possible. Here I will explain how we built a research and development environment at the University with the goal of merging integrated circuits with sensors and MEMS, and I will offer an example of smart chip development.

Twenty-six years ago now, there were very few universities in Japan that were actually producing integrated circuits from the design stage, while seriously pursuing teaching and research. The University of Technology was established in Toyohashi as the 88th national university, and the current President Tatau Nishinaga, the late Tetsuro Nakamura (from NEC), and Yukio Yasuda currently at Kochi University of Technology (from Toshiba) took the lead in starting unified semiconductor-related courses with the aim of building an environment where serious teaching and research, and fabrication of integrated circuits could be pursued in one place. The main equipment at first was a 2-inch line from the NEC Tamagawa Factory, and in the autumn of 1979, as the 4th year laboratory experiment (a 3-month experiment called the big experiment), students succeeded in fabricating a simple npn bipolar transistor, whereupon a great cheer went up in the clean room. This was the start of it all. The radio produced from these six transistors is still running in the VBL exhibition room. Roughly speaking, if you can make a basic transistor, you can make however complicated an IC. Then we received a request from Genyo Mitarai of the Research Institute of Environmental Medicine in Nagoya to develop an EEG IC chip for the cerebellum of carp for exploring space sickness in a space experiment, for which we pursued development as a Master's research theme. This chip was used in experiments on the Endeavor in 1992, when Mamoru Mohri went into space and when this chip first left the earth.

In the meantime, up to this year, a course with the same content as the big experiment has been held 25 times (25 years) for 1 week continuously during the summer holiday. (More than 400 people have taken part.) All the teaching staff participated and it was a tough business getting through the hot summer with the students, but besides maintaining the equipment in operation, it is an excellent opportunity for checking the machinery (since one member of the staff is an engineering official).

Currently a 4-inch CMOS, 1 micron process is possible using a stepper. In 1994, the department moved to the Electron Device Research Center from the original building where it was established, and in 2002 it was incorporated in the VBL (Venture Business Laboratory) facilities. A clean room where micro and nano processing is possible was set up on the first floor of the VBL, and MEMS processing was enhanced. We have fabricated many kinds of smart chips that merge sensors and MEMS with integrated circuits, but MEMS manufacture requires special process other than the CMOS process, so it has often become necessary to use the equipment separately. How to organize and manage this is a difficult matter, and success rests upon being able to adjust for the interests of both. It is necessary to have a relationship where both can allow compromise as far as possible. It is also necessary to design hitherto unknown processes.

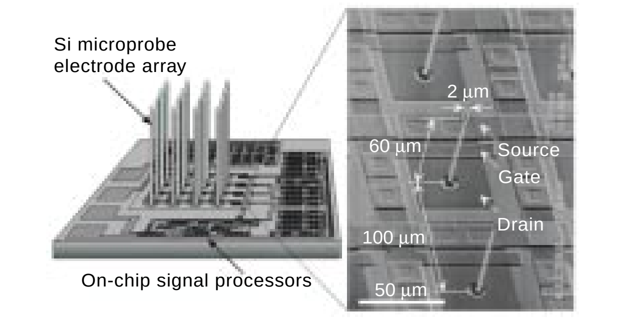

Figure 1 Conceptual diagram of a nerve potential sensor integrating a miniature electrode array and signal processing circuit, and electron microscope photograph of a prototype chip

My proposal for a nerve potential measuring smart chip with a silicon microprobe formed by crystal growth on an IC chip shown in Figure 1 is clearly one such example. This chip which was at first thought to be completely impossible probably met with many objections in the laboratory too. That's because if you give a reason why something cannot be done, any number of others can also be found. With this background, separate groups worked on the crystal growth and integrated circuit processes so that a system was achieved for assessing the problems and limitations of each process, and for pursuing solutions by pooling the knowledge of each group. As a result we were able to develop the chip to a state where it detected a signal from living cells which had been our ambition at the start of last year. [1] In this way we have proposed or prototyped many smart microchips that incorporate sensors and MEMS with ICs, but in order to raise the level of these chips further, we are proceeding through discussion of the problems involved in merging ICs with sensors and MEMS.

1) T. Kawano et.al "Three-dimensional multichannel Si microprobe electrode array chip for analysis of the nervous system", IEDM 2004, pp.1013-1016