Episode 9

Challenge to Intel with High Speed CMOS

There may not be any other industrial fields that are shaken more drastically than semiconductors. In addition to the cycles of booms and bottoms that are in a relatively short period of time, large structural transformations occur at longer periods, which can lead to a major depression. For example, the oil shock that occurred in the 1970's brought such a major depression, causing drastic changes in the field of semiconductors.

As mentioned earlier, the product development department that I was in charge gained great success with calculator LSIs and secured an overwhelming market share, but it was badly hit by the market change after the oil shock.

I was dismissed from the development manager in 1976 and became Deputy Chief Engineer. I was losing the prospects for the future, thinking "This might be my final post in Hitachi".

However, suddenly in August 1977, I was assigned to the Dept. Manager of the newly established Memory and Microprocessor Design Dept., or M&M Design Dept. for short, and returned to a managing position in a way like the revival of a loser. However, the number of members was about one tenth as compared with the former department, and its official status was "Design Group" because of its small operation size which could not be named as "Design Dept." It was half a year later that our Design Group officially became Design Dept.

At that time, it was Intel who was leading the field of memories and microprocessors. Let's chase the movement of the company in chronological order since its foundation in 1968.

In 1970, it released 1K bit DRAM, 1103, and opened up the age of semiconductor memory.

In 1971, 2K bit EPROM and 4-bit microprocessor (4004), were commercialized, both of which were the first in the world.

In 1972, the company commercialized 1 Kbit SRAM as the first NMOS device for the company. Furthermore, they introduced the 8-bit microprocessor, 8008, (PMOS version) to the market

In 1974, 8-bit microprocessor "8080" in NMOS version was put on the market, which became the best seller boosting Intel to the leader of the microprocessor era.

Those products were all astonishing and epoch-making innovative products. At that time, Intel had established an overwhelming position in the four fields of DRAM, SRAM, EPROM, and MPU.

From our newly organized M&M Design Dept., the back of Intel was seen faded far away. And studies were made from various perspectives to find a breakthrough somehow.

At such a time, Hitachi's Central Research Laboratories made a breakthrough invention on high speed CMOS technology. This is the invention of "twin well CMOS" by Yoshio Sakai and Toshiaki Masuhara.

The twin well structure enabled the optimization of circuit parameters, and it became a basic patent to drastically improve the operation speed of CMOS, which used to be regarded as "low power but slow".

Later, they received the National Invention Award with this invention.

Meanwhile, on the factory side, development of memory cells using high resistivity polycrystalline silicon load was being carried out by Tokumasa Yasui and his team, establishing a technology to greatly reduce the cell size of SRAM.
When I got an explanation about these technologies from the inventors, I intuitively acknowledged that “These technologies are superb in nature!” and decided to take it up as a priority theme, as the head of M&M Design Dept.

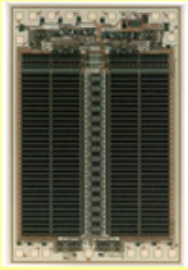
My task was to turn these new technologies to real businesses. What is important in the business operation of semiconductors is to conduct thorough management throughout the entire process from basic invention to device development, to mass production, and to sales. It is MOT (Management of Technology) as it is called today, and its skill will decide the success or failure of the project.
My role was to manage the whole process of new product development, manufacturing, and all the way down to sales, based on this epoch-making invention. It was like conducting an orchestra.
Immediately, the most capable members were selected from both the laboratories and the factory, and the project for production was organized.
The inventors, Masuhara and Sakai, and other members from the Central Research Laboratories participated in the project. And from the factory side, Yasui as the center of memory design, Nagasawa and others for process development, and Kiyota and his team for the yield improvement, all joined the project.
After the product was completed, domestic and overseas sales groups focused on promoting this product. Indirect sales system was adopted in our US sales operation, and sales agents, or Sales Representatives, were contacting with customers.
One of my important tasks was to make the presidents of the agents to understand how innovative and unprecedented this product was. Fortunately, they understood it quickly and they contributed to the rapid development of the business.
In all processes from development to sales, the most powerful members of Hitachi semiconductor were gathered here, and they worked hard to make the new business a great success.

At that time, the fastest 4Kbit SRAM was Intel's NMOS device, 2147, with its operation speed almost comparable to or better than bipolar devices. We set the goal of the project to realize the performance of this device based on the new CMOS technology.
It was a goal that seemed reckless in a common sense of the industry at the time, but the project members struggled with their strongest efforts and accomplished it perfectly. And the result was presented by Masuhara at ISSCC (International Solid-State Circuit Conference) in 1978.
Market introduction of the product was in October of the same year, and we named it HM 6147. The last two digits were tailored to the Intel device, but the upper two digits “61” was intended to distinguish from “21” of the NMOS version to show that it was CMOS.
The table below compares the performance of Intel's 2147 and Hitachi's 6147.
As can be seen from this table, the power consumption is reduced by an order of magnitude while achieving the same speed as NMOS.

Comparison of NMOS and CMOS

		2147/Intel (1977)	6147/Hitachi (1978)
Product		4K Static RAM	4K Static RAM
Technology		NMOS (HMOS)	CMOS (HiCMOS)
Speed		55/70 ns	55/70ns
Power	Active	110mA	15mA
	Standby	15 mA	0.001mA
Chip Size		16.2 mm²	11.5mm²

Chip photo of 6147



(2.7x3.95mm²)

Fig. 9.1 Comparison of 2147(NMOS) and 6147(CMOS)

It was a general understanding in the industry at that time that “NMOS is the mainstream of the industry” and “CMOS is a niche device for low-power applications”. The 6147 has overturned the industry consensus, and it became the world's first device which clearly demonstrated that CMOS would become the future mainstream of the industry.

This innovative product was given the IR-100 award in 1979. The picture below shows recipients of awards at this time.

From left, T. Yasui (Circuit designer), the author, and T. Masuhara (Inventor of new CMOS structure)

Photo 9.1 Recipients of 1979 IR-100 Award

Let's look back on the history of CMOS here.

CMOS was invented by Fairchild's Frank Wanlass in 1962. And he presented the concept at ISSCC in the following year. However, at Fairchild, no effort was made to commercialize it, and it was the group at RCA, led by Gerald Herzog, that actually succeeded in commercializing the product. The company started selling CMOS in 1968.

CMOS expanded to a large-scale market after it was applied to electronic watches and calculators, and Seiko and Sharp of Japan played the important role for the development of the market.

Today, it is taken for granted that the semiconductor mainstream device is CMOS. However, I dare to repeat that CMOS was regarded as a so-called niche technology for slow speed / low power applications in the world market up until the 1970's. The first product that broke this consensus was HM 6147 high speed 4 Kbit SRAM developed in 1978.
In August 1979, it was reported, through semiconductor research company Data Quest, how Intel saw this device. The report said that Intel made the following comment at the analyst meeting, "The biggest rival at the moment is Hitachi. If this device of Hitachi (meaning HM 6147) can be mass-produced, it will be very competitive. Intel will carefully watch the development of Hitachi's situation."
Although it was a local warfare of 4K SRAM, we finally caught up with the challenging target, Intel, and could surpass their device in terms of performance. Following the 4K bit, a 16K bit memory was also developed, and the result was presented by Yasui at the ISSCC in 1980. It was introduced to the market with the type name of HM 6116.

Until then, things went all very well and our dream spread that we would be able to lead the world in the new technology field. However, clouds always follow the sunshine, and the reality was not that sweet.
Let me introduce an episode of a bitter experience that took place in the process of launching the 16 Kbit SRAM.
Since I visited many domestic and foreign customers myself, and was getting a lot of favorable responses to our new product, I had a strong belief from my past experiences that "We will definitely succeed with this product!" So, we decided to stock the products as the inventory prior to receiving actual orders.
However, inventory levels were strictly controlled by the administrative department, and it was not allowed to have inventory more than necessary to support the daily business. Therefore, we changed the name to "strategic inventory" to make it different from ordinary inventory. "Strategic inventory" was a name that we came up with to persuade them to have inventory which would otherwise be unacceptable from the viewpoint of the administrative department. However, orders matching to the inventory level did not come. The inventories accumulated month by month, and concerns of having bad asset came up. It was called "6116 inventory problem" and it developed into a problem of the entire business division, and my responsibility was pursued.
At that time, the business division manager was a person who had been transferred from the heavy electric machinery division for rebuilding the semiconductor operation, and he was skeptical about CMOS, based on the industry consensus that NMOS would continue to be the mainstream of semiconductors. He stuck to his view and insisted that "If the function is compatible with NMOS, the type name should also be "2116", instead of "6116", to match it to NMOS type name".
One day his opinion turned into an order, and it was decided to change the name of "6116" to "2116. However, the goddess of business smiled to us, in almost at the same timing of such name change, and large orders started to come. As a result, "HM 2116" ended as a phantom product.

Once the market started to rise, its momentum became stronger, and in the year of 1981 we received orders that we could hardly fill.
In July of the same year, the top three manufacturers of 16 KSRAM were announced from Data Quest as follows (Quarterly production quantities in parentheses).
No.1: Hitachi (450,000), No.2: TI (360,000), No.3: Mitsubishi (20,000).

Four years had passed since M&M Design Dept. was organized in 1977, and all of us who were engaged in this project were filled with ineffable emotions, that we were able to acquire the world's top position for the first time with advanced devices.
The HM6147 (4K SRAM) and HM 6116 (16K SRAM) showed CMOS's superiority to NMOS, and the core of worldwide semiconductor technology would shift from NMOS to CMOS. I will touch on this point in the later section.

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