Unsung Hero

Benjamin Fulford
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Fujio Masuoka says that Toshiba tried to demote him after he invented a $76 billion product. The loss was America's gain. Will Japan make the same mistake with the next innovation?

Fujio Masuoka invented flash memory, a technology used in semiconductors with sales of $76 billion in 2001. These chips went into products worth more than $3 trillion, including automobiles, computers and mobile phones.

Flash memory was the most important semiconductor innovation of the 1990s, and it should have made Masuoka very rich. But the 59-year-old inventor lives in Japan. His employer, Toshiba, recognized his efforts by awarding him a bonus worth a "few hundred dollars"--and promptly let its archrival Intel take control of the market for his invention. Subsequently, Masuoka says, Toshiba tried repeatedly to move him from his senior post to a position where he could do no further research.

Toshiba is embarrassed by all this. Its public relations department repeatedly told FORBES GLOBAL that Intel invented flash memory. But Intel says that it was Toshiba, and in 1997 the Institute of Electrical & Electronics Engineers in New York gave Masuoka its Morris N. Liebman Memorial Award in recognition of his invention of flash memory while he worked at Toshiba. When reminded of this, Toshiba admits that it did, in fact, invent flash memory but failed to capitalize on its initial lead.

Masuoka, now a professor at Tohoku University at Sendai in northern Japan, expects to have the last laugh. Since quitting Toshiba in 1994, he has been working on what he expects will be an even more important invention: a "three-dimensional silicon-based semiconductor," he says, which will increase the capacity of semiconductors by a factor of ten. If his invention works as he says it will, Intel could make a 20-gigahertz Pentium chip with the equipment it now uses to make a 2-gigahertz chip. The same would go for other semiconductors, such as DRAMs. It would also delay by 30 years, until 2040, the date when silicon semiconductors reach their theoretical limit. The cost per bit would be a tenth of current costs, he says.

This time Masuoka is applying in the U.S. for patents in his own name. He is seeking venture-capital funding so that he can reap the rewards of his creativity in a manner more in tune with Silicon Valley than Japan.

Masuoka's tale illustrates how Japan lost the semiconductor race with the U.S. in part by neglecting basic research in favor of applied work on established products. He is not the only talented Japanese to become frustrated by the lack of recognition. Shuji Nakamura invented a semiconductor-powered light bulb; in 2001 he sued his employer, Nichia, over ownership of the patents. He now works in the U.S.

Masuoka, a shy but confident-looking man, seemed destined for great things. Four months after he joined Toshiba in 1971, Masuoka, who had just received a doctorate from Tohoku University, invented a type of memory known as SAMOS. After five years at Toshiba, he invented another type and was moved to the semiconductor production division, where he developed a 1-megabit DRAM.

What fired him up, though, was an idea that came to him--yes--in a flash. One of the biggest challenges facing the semiconductor industry in the 1970s was to find a way to retain memory so that it did not vanish every time the power was turned off. Engineers found it too cumbersome to build a nonvolatile memory for each bit of information. Masuoka's insight was that information needed to be

stored in big batches rather than in single bits. It was easier to engineer the retention of big batches because this could be done with simpler, more compact circuit designs.

Without permission from Toshiba, Masuoka began spending his nights and weekends working on this idea. By 1980 he had applied for the basic patents on a type of flash memory now known as NOR-type (not/or) flash memory.

It was not until four years later, after a promotion, that he was able to produce the first flash memory. "I was now senior enough that I could go to the factory without permission and order them to make me one," he said. (His promotion resulted from innovations he made in working on incremental improvements in DRAM technology.)

When Masuoka presented his flash memory at the annual International Electronics Developers Meeting in San Jose, California, in 1984, the American semiconductor industry saw it as a threat.

Back home, his superiors at Toshiba were mildly surprised when a number of U.S. computer companies, including Intel and also some automobile manufacturers, asked for samples. Intel immediately put more than 300 engineers to work full time on developing flash memory.

At Toshiba, meanwhile, "they let five guys help me on a part-time basis," Masuoka says. Although Masuoka's group was the first to sell flash memory (in a product used in cars), it was not long before Intel completely dominated the market. In its 25th-anniversary commemorative book, published in 1993, Intel boasted that it had reversed the usual pattern of an American invention's being turned into a Japanese product. It is now one of Intel's top revenue-earners.

Masuoka's work with DRAM, in which Toshiba was by then a world leader, ensured his further promotion. He now had more than 60 engineers working for him full time in DRAM development; DRAMs were earning Toshiba $500 million a year, Masuoka estimates.

Intel, though, was receiving an estimated $500 million a year fromflash memory shortly after its development: It had become a vital component in personal computers and automobile electronics. Other companies, such as Advanced Micro Devices, Fujitsu, Sharp and Mitsubishi, piled into the market.

But Masuoka hadn't given up on flash memory. In 1986 he was spending half his time in America as a witness in a patent lawsuit involving Toshiba and Texas Instruments. While waiting for his turn to testify, he began to work on a new type of flash memory, continuing in his spare time until he was ready to apply for patents.

The idea was a NAND-type (not/and) flash memory that could be used, he hoped, to replace the hard drives of computers. The NAND type of memory sacrifices speed for compactness and a low price. The NOR type needs to be ultrafast because it is directly connected to the central processing unit of a computer and stores its basic input-output system (the operating system used by the microchip that lies beneath user-interface operating systems, such as Windows). The NAND type could contain more than double the amount of information and be slower if used like a floppy disk or hard drive. Masuoka describes the difference as that between an eight-story apartment building and a one-story house. It is much quicker to get out of the house, but you can fit only so many houses on a given surface area.

In 1987, again without permission (Masuoka says), he made some batches of his new type of flash memory. This time he was senior enough to be able to devote resources to the project to ensure that Toshiba gained an insurmountable lead in both patents and production technology. "Toshiba is a

good company in the sense that they give middle managers enough autonomy to do such things," Masuoka says.

His aim was nothing less than to replace the $50 billion-a-year market for hard disk drives on computers. Flash memory has many advantages. It has no mechanical moving parts, it uses less than a hundredth the power of a hard disk, and it can be made very small. Over time, he felt, its biggest disadvantage, high cost, was sure to be overcome.

He was right: These days, for anything under 256 megabytes of memory, including mobile phones, flash is cheaper than a hard drive.

For his work, Masuoka says, he was awarded a few hundred dollars from Toshiba and only after a Japanese newspaper gave his new type of memory an award of invention of the year in 1988. He received job offers from U.S. companies, but Masuoka says that "in those days in Japan leaving your company was just not considered to be an option."

However, shortly after the first of the new memories went on the market in 1990, Toshiba began pressuring him to accept a "promotion" that, at the ripe old age of 47, would have put him in a job with no subordinates.

"They told me ‘We do not need you any more.' They wanted to put me in a job that was labeled as a promotion but where I would work alone with no subordinates and no colleagues; as an engineer, that means you cannot do anything," he says. "I complained and resisted by going over my bosses' heads for three years but was told ‘You are not a team player, you do not obey orders, you go off and do things on your own.'" In 1994 he quit Toshiba to become a professor at Tohoku University.

Toshiba disputes Masuoka's account. A spokesman describes the job as a promotion, in which he could have trained subordinates, and added, "At the time flash memory was not a big market"; DRAM was then Toshiba's bread and butter. A Japanese industry newspaper article from the time describes Masuoka as something of a tyrant who nevertheless had many people who wanted to work under him.

Toshiba announced in December that it was withdrawing from the DRAM business and devoting more resources to flash memory. Toshiba now earns more than $1.2 billion a year from memory chips, an undisclosed amount of it in licensing fees from other manufacturers. But the company is struggling: In 2001 it lost $1.9 billion on sales that fell 9%, to $40.6 billion.

To the public, NAND-type flash memory is most familiar in the form of memory cards or sticks used in digital cameras or portable music players. NOR-type flash memory still accounts for 80% of the market; NAND has the other 20%. NOR memory is used to hold the software that runs the assorted microchips and CPUs in such portable devices as mobile phones and PDAs. It is also used in assorted automotive applications, among them the electronic units that control many different engine functions.

If trends continue, the world market for flash memory will be worth $150 billion in a few years time, divided equally between NOR-type and NAND-type memory. Toshiba is sure to benefit as NAND rises in importance; but of course, Masuoka will not see any of that money.

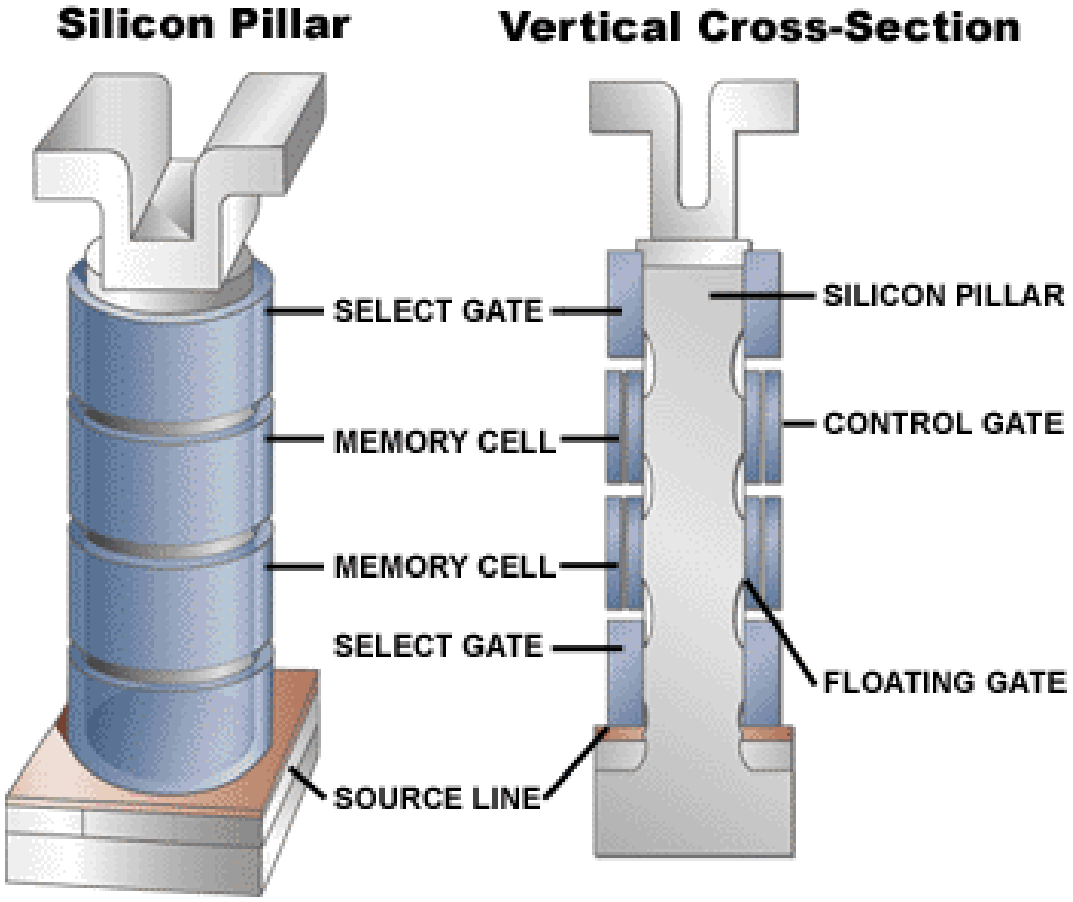
Toshiba says that it has carried out many reforms since Masuoka's day. Researchers can now spend 10% of their time on their own projects. In addition, the annual ceiling on how much inventors are allowed to receive from royalties on their patents has been raised to $80,000 from $8,000. Masuoka

says he has not received anything approaching such sums for his flash memory patents even though, according to Masuoka's estimate, Toshiba earns $50 million a year in royalties from them.

He does not dwell on the past, however. With 189 patents to his name and 50 others pending, he says that his biggest invention has yet to be unveiled. For the past eight years at Tohoku he has been working on a new type of silicon semiconductor that has a three-dimensional design *(see diagram, below)*.

Fujio Masuoka's three-dimensional semiconductor

Making the chip cylindrical rather than flat results in the electrons' traveling a shorter distance. Within five years Masuoka hopes to commercialize a chip design that will be ten times faster than traditional chips and cost only a tenth as much.



Masuoka's semiconductor consists of a pillar made of silicon filled with electrical circuits. As with a flat chip, the key is to alter the flow of electrons on a circuit called a bit line (the v-shaped part at the top of the pillar). The size of the flow determines whether the bit of information that will be held in the memory cells is a zero or a one.

The select gate determines which bit line the electrons flow through. The floating gate affects the amount of electrons flowing through the control gate. The source line is where the wiring enters the semiconductor.

Source: Fujio Masuoka.

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Two-dimensional semiconductor technology is reaching its limits. In perhaps as little as a decade, the circuits will be so thin that the phenomenon known as quantum tunneling, where electrons slip through the silicon walls, will make further progress impossible.

A three-dimensional structure would insure that "we would not have to worry about theoretical limits for 30 years," Masuoka says. It would also increase the speed of semiconductors tenfold for an equally thick circuit.

Masuoka is reluctant to reveal the details but says he is confident that the first such semiconductor will be produced within five years. He has already carefully accumulated a series of basic patents to protect his new invention. A crew of junior professors and Ph.D. students has been helping him.

Although he is a poor self-promoter, Masuoka this time hopes to find venture partners who will provide the money he needs to move his new chip from the drawing board to actual production. The equipment needed to make his three-dimensional semiconductors would cost from $40 million to $80 million.

The irony of it all is that it is likely, yet again, to be an American company that benefits the most from his invention. Despite years of bemoaning their own saying ("A nail that sticks out gets hammered in"), too many Japanese continue to be pushed into the woodwork.

In the late 1980s Japan controlled two thirds of the global semiconductor industry and looked ready to crush the United States. Now Japan's share is down to a fifth, and all its big semiconductor companies are losing money.

Japan's demise in semiconductors was hastened by the entry of the Koreans and Taiwanese, according to Fujio Masuoka, an engineer formerly with Toshiba who invented flash memory (see main story). The Japanese model of copying something, adding incremental improvements and then making it cheaper was borrowed by its Asian competitors.

Japan also failed to realize that in the semiconductor business you need either to be highly creative or to manufacture on a massive scale. The big, strong companies, such as Intel or Samsung, focused on a few areas; the Japanese tried to make everything.

"Toshiba, Fujitsu, Hitachi and NEC all just looked sideways at each other," Masuoka says. Belatedly, they are starting to concentrate on a few things that they do best. Toshiba, for example, is putting a lot of resources into NAND flash memory production.

"The Japanese companies are still not moving fast enough to focus on core competencies," says Michito Kimura, a senior analyst at IDC Japan, an independent consultancy. Unless they do more to unlock the creativity of their staff, the effort is likely to be futile.