Oral History of Fujio Masuoka

Interviewed by:
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Katz: Good afternoon. We are here at the Computer History Museum in Mountain View, California. We have with us Dr. Fujio Masuoka, and it is now September 21, 2012. Masuoka-san is going to tell us a little bit about some of his early work and especially about his seminal invention of flash memory back in the 1970s. So, good afternoon, Masuoka-san. My name is Jeff Katz.

Masuoka: My name is Fujio Masuoka. Thank you very much.

Katz: Welcome to the Computer History Museum. We would like to start with some easy things for you to remember. Can you tell us a little bit about your early life? Did you grow up in a large family, a small family?

Masuoka: Very small family. Parents and two sisters.

Katz: I had two sisters also. And where was your birthplace in Japan, which city?

Masuoka: In Japan in Takasaki.

Katz: Takasaki.

Masuoka: Takasaki city.

Katz: Did you go to school there the whole time?

Masuoka: Yes until [completing] high school in Takasaki.

Katz: Where was the high school?

Masuoka: Takasaki.

Katz: Oh also in Takasaki. And where did you go to university?

Masuoka: Tohoku University at Sendai.

Katz: I must ask, when did you first become interested in technology and how did that happen?

Masuoka: Technology is very easy to understand using mathematics. But another is that very difficult to words, sentence we cannot—I could not understand that books [ph?].

Katz: So what was the first technology that was very interesting to you?

Masuoka: First technology was integrated circuit.

Katz: Really?

Masuoka: Because [I learned] in my high school [that the] integrated circuit was invented by United States.

Katz: Oh while you were in high school. Yes, that would be about the right time in the late 1950s.

Masuoka: So maybe that technology has grown drastically.

Katz: Yeah.

Masuoka: And I went to the electrical division of Tohoku University.

Katz: I see. Did you have a high school teacher who was a big influence?

Masuoka: No.

Katz: No? What was your major influence? How did you know about integrated circuits when you were in high school?

Masuoka: I belonged to the physics and electronics group.

Katz: A club?

Masuoka: Club, that's right.

Katz: I remember a similar club when I was in high school. Okay so then you decided to go to university. Did you stay in the university completely until your Ph.D. or did you stop for a while to work in industry?

Masuoka: Complete Ph.D.

Katz: And your major course of study was electrical engineering the whole time.

Masuoka: Yes, integrated circuits.

Katz: Working on integrated circuits even in the university. Very interesting. Who was the first company that you went to work for? When you finished with your university degrees, did you go directly to industry?

Masuoka: Yes.

Katz: For which company?

Masuoka: Toshiba.

Katz: Toshiba-san. And what was your first job at Toshiba-san?

Masuoka: [My]first job was a synchronous device.

Katz: What kind?

Masuoka: Floating gate type non-volatile memory.

Katz: You're been doing the same thing your whole life almost.

Masuoka: Because Intel presented non-volatile memory, I.S.S.C.C.

Katz: Yes, did you attend that I.S.S.C.C. meeting?

Masuoka: No.

Katz: Just read about it.

Masuoka: At that time attending [an] international conference was very expensive from Japan to United States so in order [to] attend [an] international conference we had to [have] our paper accepted.

Katz: You had to have a paper accepted by the I.S.S.C.C [International Solid-State Circuits Conference].

Masuoka: Yes.

Katz: That makes sense. I understand that. When you worked on your first floating gate products were you alone working on it, or in a big group?

Masuoka: Only leader, I had a leader but actually only one.

Katz: No coworkers to help you or to work on the same project?

Masuoka: No coworkers [to] help me.

Katz: Interesting. A big company like Toshiba gives one person an important job.

Masuoka: So I belonged to the research center, not to [the] manufacturer.

Katz: So maybe [it was] not so big in that department.

Masuoka: Yeah.

Katz: Interesting. So how long did you work on floating gates before you came to the idea of the flash?

Masuoka: Seventy-one I joined Toshiba. And 1973 I could present the idea to I.S.S.C.C.

Katz: With flash or with an EPROM?

Masuoka: With EPROM.

Katz: I see. And tell us about that EPROM. Why did the I.S.S.C.C. think that was important?

Masuoka: Because our EPROM had a double gate. One of them was a floating gate. Another one was a control gate. But in terms of [a regular] EPROM it had only one floating gate without [a]control gate. The result [was] our EPROM was able to program very fast.

Katz: How fast? How much faster?

Masuoka: Very fast. Much faster.

Katz: I remember it would take maybe a few milliseconds to program an Intel EPROM and a few minutes to erase it. So how does that compare to the Toshiba one that you did?

Masuoka: About 100 microseconds to program it.

Katz: To program it. And what about erase?

Masuoka: Erase the same [as Intel] because [it was] ultraviolet erase.

Katz: Ultraviolet erase, a few minutes maybe five or ten minutes?

Masuoka: A few minutes.

Katz: Okay, did that make you very famous in Japan to have presented a paper at I.S.S.C.C.?

Masuoka: Not famous in Japan but outside of Japan.

Katz: Outside of Japan, interesting.

Masuoka: Because everybody could not believe that excellent technology, they don't come from Japan.

Katz: Interesting. I think about that time Japan was beginning to become very good at some technology but not everybody knew it yet. When you came back from that I.S.S.C.C. conference did you continue to work on the same EPROM product?

Masuoka: Yes. I made flash memory technology.

Katz: Immediately in 1973?

Masuoka: No. After that I moved to the sales engineering division.

Katz: So you had to teach the customers about your fast EPROM technology.

Masuoka: About three years. While in the sales engineering division I sold to many U.S. makers. Of course I couldn't speak English so I couldn't say anything.

Katz: How did you do your job?

Masuoka: So [after] about two years we moved to the engineering division of the manufacturer.

Katz: I think you must have had some success though in trying to sell because people bought your product. Somebody must have bought it. Maybe you started to learn English a little bit. I know I had the same problem when I first tried to sell my chips in Japan, I didn't know enough Japanese. Okay so when you came back to the engineering division was that your first assignment to work on more EPROM?

Masuoka: No. First job is making DRAM.

Katz: Toshiba-san is very good with DRAM. Especially in the late 1970s. It made all the American companies embarrassed because Japanese DRAM were better.

Masuoka: However at the company we did the best work for making a good DRAM. However [in]the future I believed that EPROM would drastically grow.

Katz: It would be better why? Because of non-volatility?

Masuoka: Non-volatility. And CPU [would] also drastically grow. CPU drastically grow, but EPROM with its ultraviolet erasing system would not operate easily.

Katz: Yes you could not use it to move data in and out quickly with so you could only use it to store things that did not have to change.

Masuoka: So if we did not [require] ultraviolet erasing, it would be very easy to use, and the [system] cost would be drastically down. So [we] invented a NOR type flash memory.

Katz: Oh you started with a NOR type flash.

Masuoka: NOR type flash.

Katz: When was that?

Masuoka: Nineteen eighty-four.

Katz: Nineteen eighty-four, interesting.

Masuoka: No, 1974 I'm sorry.

Katz: Oh, '74.

Masuoka: Nineteen seventy-four.

Katz: Okay so let me understand the timing here. So in 1971 you joined and two years later, 1973 you went to U.S. for a conference with EPROM. Then you came back and worked in the sales division for two years or one year?

Masuoka: Two years.

Katz: Two years, so that would be 1975?

Masuoka: Sorry, 1982.

Katz: Eighty-two, that's when you worked on the non-volatile, non-UV erasable. So you tried to make it quick to use in a computer. Okay that's consistent. I think Intel was just thinking about it then also.

Masuoka: Nineteen eighty-four presented to I.E.D.M. first to NOR type flash memory.

Katz: And it was NOR flash. So how did you decide to switch from NOR flash to NAND flash and when did that happen?

Masuoka: At that time 1982 I couldn't invent NAND type flash memory.

Katz: You did or did not?

Masuoka: Did not.

Katz: When did you invent NAND flash?

Masuoka: Nineteen eighty-seven.

Katz: Eighty-seven. Can you tell me what happened between 1982 and 1987 to make you decide to pursue NAND flash?

Masuoka: Because in 1982 Toshiba did the best work for making one megabit DRAM.

Katz: So they were working on DRAM instead, alright. So why did you switch back to flash memory?

Masuoka: In 1986 Texas Instrument attacked Toshiba Japanese company [via the] I.T.C.

Katz: Ah, yeah.

Masuoka: So in order to support I.T.C. trouble I had to go Washington D.C in nineteen eighty-six.

Katz: Eighty-six okay.

Masuoka: Eighty-six to Washington D.C.

Katz: But that was about DRAM, because Texas Instruments was worried about DRAM not about flash or EPROM.

Masuoka: Not flash. During [my time in] Washington D.C. 1986 I wrote NAND type flash memory patents about five patents.

Katz: You brought that with you?

Masuoka: In Washington D.C.

Katz: So how did you happen to have them with you? You must have been working on them.

Masuoka: Pardon?

Katz: You were working on them before 1986 then. How did you decide to work on NAND flash? Was that an assignment or you had a good idea or what?

Masuoka: Only idea. Every day without a court judgment I thought about NAND-flash memory technology for patent.

Katz: Why did you think the world needed NAND flash? Why was it a good idea?

Masuoka: Because we had one megabit DRAM at that time, [the] first in the world at that time 1980, 1986.

Katz: So in 1980 Toshiba had the world's first one-megabit DRAM.

Masuoka: Yes.

Katz: So why did the world need a flash memory, NAND flash?

Masuoka: Because as you know [the] memory market [was] still big.

Katz: Yes it was very big.

Masuoka: Big means the biggest memory market was the hard disc area.

Katz: Yes it was hard disc.

Masuoka: Hard disc market area. Hard disc type recording area.

Katz: So it was the densest memory.

Masuoka: So I had to overcome the hard disc area.

Katz: I see.

Masuoka: So [if I could do that,] maybe the semiconductor business would be able to continue to grow.

Katz: Is NAND flash better to pursue hard disc drive than NOR flash?

Masuoka: NOR flash could not bring the cost down [enough to compete with hard disc].

Katz: It cost too much.

Masuoka: NOR type. NOR type has a very high speed characteristics but cost reduction is very difficult to do in that technology.

Katz: So you decided NAND flash would be easier to bring the cost down?

Masuoka: That's right.

Katz: How did you know that? What gave you the idea for NAND flash?

Masuoka: Yes, I think my head made that.

Katz: How? What taught you that it would even work? How can you even think of NAND flash?

Masuoka: So NAND flash in Washington D.C. I wrote about five patents, first patent.

Katz: While you were in Washington?

Masuoka: While yes, while in Washington.

Katz: But you were there to discuss DRAM. And while you were bored you thought up NAND flash. I understand.

Masuoka: <laughs> Because first three months were very severe discussion at the court.

Katz: Yes.

Masuoka: But after that discussion I didn't know about the discussion between the judge and the attorneys. Maybe it [was a] separate legal matter. After my half [of the discussion, another half without me].

Katz: So we have to thank Texas Instruments for NAND flash. They gave you the opportunity.

Masuoka: <laughs>

Katz: But you took the opportunity. So when you had the opportunity and you thought up the idea and applied for some patents, did Toshiba welcome you to try to build that product?

Masuoka: No. <laughs> No, During [my time in] Washington D.C. I belonged with a business group. At the end of [the] T.I. court judgment I moved to the research center.

Katz: Back in Japan.

Masuoka: In Toshiba.

Katz: Yes, okay. And did Toshiba say "Please work on NAND flash"? Or did you have to do it on your own?

Masuoka: In Toshiba I started NAND flash memory technology without permission.

Katz: Without permission.

Masuoka: Without permission. Every time without permission [in] my jobs in Toshiba.

Katz: How did you finish the job? You must have been working on something else with permission. So you had to do two jobs one with permission and one with NAND flash without permission. What was your with permission job?

Masuoka: With permission, nothing.

Katz: Nothing? Okay. So how long did it take you to develop a chip that would work as NAND flash?

Masuoka: So basic technology for example four weeks.

Katz: One fab cycle.

Masuoka: In four weeks NAND flash memory was designed my colleague.

Katz: Oh you had a colleague working with you.

Masuoka: Of course [I] worked [with] colleagues but such colleagues had other work. But using private communication they supported me.

Katz: I see. How many colleagues helped you, one, two, ten?

Masuoka: Two colleagues. So you don't know both of these colleagues.

Katz: No I don't.

Masuoka: However we call it "under desk".

Katz: "Under the desk". Yes. In this country we say "Under the table."

Masuoka: Under the desk they supported it. And in 1986 NAND flash memory was presented at I.E.D.M. [International Electron Devices Meeting].

Katz: Interesting. So did your colleagues come with you to present or did they just stay back and inside Toshiba? They didn't want anybody to know they helped you maybe.

Masuoka: So I developed four-megabit NAND flash memory, four-megabit NAND flash memory chip was designed by us.

Katz: By Toshiba?

Masuoka: By us, not Toshiba, by us.

Katz: Just you personally.

Masuoka: My boss said to me "No money to develop four-megabit NAND memory."

Katz: So how did you do it? All under the desk?

Masuoka: So in 1987 I asked to Mr. Hiseo Tajiri who was the head of Toshiba consumer electronics development, if the digital camera with four-megabit NAND flash memory would replace film.

Katz: So was it the consumer division's idea or your idea?

Masuoka: My idea, my idea. It was my idea. So Tajiri understood my proposal that NAND flash memory could replace film.

Katz: Can you spell Tagima [ph?]?

Masuoka: Tajiri, T-A-J-I-R-I, Tajiri.

Katz: Tajiri, okay.

Masuoka: Hiseo Tajiri.

Katz: And the consumer division liked the idea, good idea, huh? They thought it was a good idea?

Masuoka: Good idea from me. He followed me. Of course before my proposal, Mr. Tajiri could not believe by using NAND flash memory we could replace the film. He couldn't understand that. .

Katz: And after your proposal he said "Good idea, please make it for me."

Masuoka: Yes.

Katz: I see.

Masuoka: Yes.

Katz: Did that mean they found some funds, some money for you?

Masuoka: Yes. One hundred thousand yen.

Katz: That was paid for by the consumer division.

Masuoka: Yes.

Katz: And with that funding you could develop the chip and I guess the consumer division developed the rest of the camera. Who made the control unit in the camera?

Masuoka: So he, Mr. Tajiri, consumer electronics development, succeeded in developing [a]digital camera with four-megabit NAND flash memory, the first in the world [in]1990.

Katz: That's all the memory that was in the camera, one chip? Four-megabit?

Masuoka: Not one chip, eight chips.

Katz: Eight chips, okay thirty-two megabits. Not much by today's standards.

Masuoka: However, [the] cost of [the] digital camera with four-megabit NAND flash memories was U.S. 20,000 dollars.

Katz: With a C.C.D. [charge-coupled device] image sensor?

Masuoka: Of course. C.C.D. made by Dr. Harada. However as a result nobody did buy [the] very expensive digital camera.

Katz: Yes indeed, very expensive. So you could not buy it at the local store.

Masuoka: However [the] camera developmental engineering [team that used] flash memory, all [those] engineers moved to Fuji Film from Toshiba.

Katz: Oh they all left together? Interesting. Fuji Film? And Fuji Film had another good idea to make digital camera.

Masuoka: Fuji Film had no idea at that time. But [the] top [management] of Fuji Film believed that in future film will be replaced by by NAND flash memory. So all [Toshiba] engineers about this camera using NAND flash memory moved to Fuji Film.

Katz: That's from the consumer division or from your memory division?

Masuoka: Consumer division.

Katz: Did you move also to Fuji film? You personally.

Masuoka: [No, the] NAND flash memory [chips were made by] semiconductor engineers.

Katz: Yes.

Masuoka: But [the] consumer electronics development engineers [who made the camera system] were not semiconductor engineers.

Katz: I understand.

Masuoka: But NAND flash memory would [have to] be made in production by a semiconductor company. Fuji Film could not buy [or build a] semiconductor factory. Too high cost.

Katz: So maybe Fuji film bought their memories from Toshiba-san?

Masuoka: Toshiba or Samsung.

Katz: Did Samsung have NAND flash right away or after later?

Masuoka: Later.

Katz: That's what I thought, yeah.

Masuoka: After this project Samsung proposed that Samsung would like to make 16-megabit NAND flash memory with Toshiba.

Katz: When you come back to the first four megabit product, not yet 16 megabit, how long did it take you to make working parts for either Toshiba consumer division or for Fuji film? How long from the first idea until you had working parts?

Masuoka: After [the consumer electronics development engineers moved from Toshiba [to Fuji Film], they could not begin the development quickly, because at that time the cost of flash memory was very expensive.

Katz: Why? Poor yield?

Masuoka: Not only poor yield, but also only Toshiba could do NAND flash production. And—

Katz: And Toshiba was busy making DRAMs.

Masuoka: That's right, that's right. And also, at that time, Toshiba had not many engineers for NAND flash memory technology.

Katz: So how long did it take the first time, one year, more than one year?

Masuoka: About four years.

Katz: Four years from your good idea until Toshiba had good NAND flash product. Maybe the consumer division got tired of waiting.

Masuoka: So in the 1994, I moved [to] Tohoku University.

Katz: So by 1994, was Toshiba already making NAND flash or not yet?

Masuoka: They were making NAND flash a little.

Katz: A little.

Masuoka: After 1994, when I had retired, Toshiba began to make 16 megabit NAND flash memory with Samsung.

Katz: With Toshiba and Samsung together?

Masuoka: Together.

Katz: Yes, I think I remember that. At that time, I was competing with NOR flash, nowhere near that capacity, we had maybe one megabit flash, but because it was more expensive. I was at Atmel then.

Masuoka: So [after] about two years, from 1996, both Toshiba and Samsung were able to begin to produce initial volume [of 16 megabit NAND flash].

Katz: And was the main application always digital cameras, or were there other applications?

Masuoka: At that time, one was digital camera. But USB at that time, so—

Katz: USB was just coming out in the late '90s.

Masuoka: Yes, we had a solid state disk [product].

Katz: Small capacity, though.

Masuoka: Yes, small capacity.

Katz: A few kilobytes.

Masuoka: Yes, not [even a] megabyte. After that, [there was the] mobile phone [application], [for which] we used that NAND type.

Katz: I think first mobile phones used NOR type, but just for [the] program.

Masuoka: Yeah, that's right, yeah. Just for [the] program. But that's a single chip I believe. NOR type was used, see, combined [with a] CPU. One [single] chip consisted of a CPU and a NOR type flash memory. That's what we called a Micom, [or Microcomputer]. And that Micom began to [be] used for controllers, in consumer electronics, all consumer electronics [not just cell phones].

Katz: Yes. Who made that Micom chip, was that Toshiba-san?

Masuoka: Of course Toshiba. Not only Toshiba, but also NEC Hitachi, Fujitsu, every semiconductor, [maker] made Micom, which was NOR type flash memory and controller CPU [combined on a single chip].

Katz: Interesting.

Masuoka: It was very cheap. One chip was one dollar, one US dollar.

Katz: I'm trying to remember: at Atmel we started about the same time making single chip microcontrollers with flash and CPU, in the mid '90s.

Masuoka: So as you know, [a] digital camera has [a] Micom, and NAND flash memory [for image data].

Katz: Was the music player application there in the beginning, an MP3 player or iPod?

Masuoka: Oh, that, that's right, but not so much.

Katz: Not as much as camera.

Masuoka: And not so much as other consumer electronics. And there was the car [application].

Katz: Cars?

Masuoka: Car. Car have many Micoms.

Katz: Oh I know that today's cars do, yes. Even in 1990s?

Masuoka: The first [automotive application for] Micom using NOR, and CPU was used for engine control. Until [the] Micom, engine controller had a CPU and a lot of [separate] wired UV-erasable EPROMs.

Katz: But that was only for the computer program, no data.

Masuoka: No data, only [the] computer program, it was required for [the] United States Environmental Protection Agency.

Katz: Environmental Protection Agency. They wanted to keep some data, too, to keep a record in the vehicle.

Well, when you were working on the original four megabit NAND flash, what problems did you have? What did you have to solve?

Masuoka: Ah, at first we had many problems.

Katz: For example?

Masuoka: For example, the electrons were stored on the floating gate. The floating gate was surrounded by silicon dioxide. So most of the reasons for failure with the floating gate was electrons leaking off from the floating gate.

Katz: The charge can leak off. If you have poor quality silicon dioxide, you have a leakage path.

Masuoka: Yes, yes, yes. So we debated how to reduce leakage characteristics from floating gates. It's how to do annealing, during production, how to anneal is very important.

Katz: Interesting, so you had to work closely with the process engineers to improve the production.

Masuoka: To improve production, so how to [improve the] annealing [in] production, [the] annealing condition. Not only [the] annealing condition, but also before annealing, how to clean [the wafer to eliminate contamination, and how to make] [high quality] oxide.

Katz: But weren't solutions to those same problems available— I mean, didn't the DRAMs have the same problems? So if they could make very good DRAMs, maybe they should have been able to make very good NAND flash.

Masuoka: Very similar, but— very similar, but DRAM is easier than non-volatile memory.

Katz: Okay.

Masuoka: Usually. The DRAM [issue] was how to store [charge for] about three milliseconds or ten milliseconds because refresh time.

Katz: Yes, a few milliseconds only, until refreshing the charge in a DRAM cell.

Masuoka: But not for NAND flash memory, at 100 degrees C, leakage can not occur.

Katz: It has to last ten years or longer, even at high temperature, not just a few milliseconds.

Masuoka: Yes, so it's very diff— of course, we checked it by stress test.

Katz: Stress test, yes. Interesting. All right, so that was one problem, to make the process very good. Did you have some other problems at all, like, architecture or interface with the rest of the system or anything?

Masuoka: Of course. Many, many write/erase cycles were needed in the system, in order to replace ferrite [storage] bits.

Katz: Ferrite bits. So what was the endurance? How many cycles could you get on the first NAND flash? How many times could you reprogram, one thousand, one million, ten million?

Masuoka: Ah, the first chip had an endurance [of] about one thousand [cycles].

Katz: One thousand.

Masuoka: It improved.

Katz: So that had to be improved. What did you have to do to improve it?

Masuoka: So [the] most important item was that the process needed to be improved.

Katz: Just improve the process. Okay.

Masuoka: At that time.

Katz: Good.

Which other divisions did you have to work with, besides the process engineering, who else in the company needed to work with you to make sure that the NAND flash chip would work well with the controller and in the rest of the camera? Were there other engineers in other divisions?

Masuoka: The first four megabit NAND flash memory was a conventional use design. And camera engineer did not say a spec. Did not say.

Katz: Oh, he took what he got. You gave the spec?

Masuoka: He did not specify.

Katz: He did not specify, okay.

Masuoka: And so [the] consumer electronics sector development engineer could design for [the] digital camera using a [standard] peripheral set.

The memory itself, was not specific to [the]consumer application.— It was a conventional four megabit NAND flash memory, that could be applied to any users.

Katz: Did it have a standard five volt interface?

Masuoka: Yes.

Katz: No high voltages required outside the chip?

Masuoka: No, no, we had a charge pump on chip [to generate the required high voltage].

Katz: Like the E2PROM.

Masuoka: Yes.

Katz: Okay, so it was easy to use, and they just took it and used it to make the camera.

Masuoka: So camera design engineer moved to Fuji film, and they could use all design methods for using NAND flash memory.

Katz: I see. If it's a standard interface, it should be easy for any system engineer to use. It took a long time, you said, four years. Why so long?

Masuoka: The boundary conditions were different about 30 years ago.

Katz: In what respect? How was it different?

Masuoka: For example, 40 years ago it took two years or three years to develop a new device, usually.

Katz: Yes, Same that was also true with microcontrollers or microprocessors. But two years is not four years. So why was the flash even longer?

Masuoka: Well, if we had 100 or 1,000 engineer, [we could do] the same as [a] CPU or DRAM. But anyway, our team was less than ten at any time.

Katz: Until your retirement, the whole time?

Masuoka: Yes, yes.

Katz: There must be more engineers now.

Masuoka: More, maybe 1,000.

Katz: One thousand, yeah. What finally convinced Toshiba that it's a good business and they should invest in it more? Why did Toshiba decide to increase the support for NAND flash?

Masuoka: When four megabit NAND flash memory [was developed], [we had] about ten. However, after [Toshiba] succeeded in four megabit NAND flash memory, Samsung proposed to Toshiba 16 megabit NAND flash memory. Actually I didn't know. About 30 engineers came to Toshiba from Samsung.

Katz: So Toshiba had to give also at least 30 engineers.

Masuoka: At least thirty, too. And as a result, NAND flash memory made much money for Toshiba. After that. So Toshiba decided that— to have 1,000—

Katz: The whole division, maybe, or department.

Masuoka: Maybe— engineers. And another—

Katz: When Toshiba decided with Samsung, to make a big department, were you still there?

Masuoka: No.

Masuoka: After I left Toshiba. If I stayed in Toshiba, I [would have been] denied that core development,

Katz: If you stayed there, would you have been the leader for the flash division?

Masuoka: No. No. If I stayed in Toshiba, I would not have been the leader. : Only one researcher.

I [would] have no supporting team, only myself.

Katz: I see. So you must have been, by that time, a famous researcher inside Toshiba, because Samsung came and said they liked the technology, too. They wanted to cooperate. So Toshiba must have thought you were very valuable. If you were valuable to them, why did they let you leave?

Masuoka: I don't think [Toshiba thought] so. I don't think so.

Katz: You don't think they thought so, okay.

Masuoka: Because my boss [had trouble telling me what to do]— my boss orders go to A, and silently, I go [to] B.

Katz: So maybe because of that they didn't like you. But why did you decide to leave? It's very unusual in Japan for a successful researcher to leave his company. Why did you finally decide to leave Toshiba?

Masuoka: It is a very easy question. My boss said to me, [there would be] only one position, without a supporting team, without research fee, but we have one room [for you]. So I would not [have been] able to do anything. Because in my current, my position, myself, I could not do anything [alone].

Katz: Only one person, yeah.

Masuoka: Uh-huh, for example, e-mail, and myself. I cannot do anything myself.

Katz: All right, so you must have had some friends back at the university, and you decided to return there. What did you teach then at university, or what did you do for the university?

Masuoka: Oh, semiconductor device technology.

Katz: Were you a Sensei, a professor?

Masuoka: Professor.

Katz: How long were you at the university?

Masuoka: Eleven point five years.

Katz: Maybe almost the same time as at Toshiba—did you have the same job the whole time, professor?

Masuoka: [For the] full time [there a] professor, But at a Japanese university if you are 63 years old, you must retire.

Katz: Must retire?

Masuoka: It depends on the age.

Katz: That's unfortunate, I think, because some of us still have many good things to share when we are over 63 years old.

Masuoka: But that's a rule in Japan.

Katz: Since that retirement from the university, what have you been doing?

Masuoka: [As you saw on my business card, I consult in semiconductor technology and design.]

Katz: Ever since the retirement? When did you retire?

Masuoka: About five years, six months ago.

Katz: Five years ago, okay. So—

Masuoka: So semiconductor consulting.

Katz: And who are your consulting customers now? Big companies like Toshiba?

Masuoka: No, this company [is] a small company, no customers, just research and development.

Katz: Who gets the benefit of your research and development; somebody pays you to do that, right?

Masuoka: No, our company does, not make profit, no profit.

Katz: No profit.

Masuoka: No profit.

Katz: Well I hope you invent something good, and somebody buys it from you.

Masuoka: Thank you very much.

Katz: We're almost finished here. In your consultancy, have you made any important developments in your research, in the new company, the small company?

Masuoka: [It's a] very small company. For example in the office only one, myself.

Katz: Okay, I can understand a small company, but in the five years, you have worked there, maybe you had some good ideas. Maybe somebody will like those ideas in the future.

Masuoka: Thank you.

Katz: Okay, we will finish up with some questions about the future. Do you have some advice for young people who want to become famous scientists?

Masuoka: Thank you very much.

Katz: What do you advise to young people, either students or children, even?

Masuoka: Mathematics and physics are very important. You have to study the mathematics, from the basic step.

Katz: Basic mathematics is very important, yes, of course. I know in my own career, I was an engineer, but I have done many mathematics studies. And it helped me in engineering.

Masuoka: I finished [some university] mathematics courses during high school—

Katz: University math?

M1: University.

Katz: Very interesting.

Masuoka: [To help] in admission for the university.

Katz: I think we're about finished.

Masuoka: Thank you very much.

Katz: For that, I thank you very much for your kind attendance to come here, and for your very interesting story of your career and especially your development of flash memory. With that, we will end the interview.

Masuoka: Thank you very much.

END OF INTERVIEW

