



Oral History of Shozo Saito

Interviewed by:
Douglas Fairbairn

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Douglas Fairbairn: We're here in the New Otani Hotel in Tokyo, Japan. It's June 23rd, 2016. I'm Doug Fairbairn, and I'm here to interview Shozo Saito. Welcome, and delighted to have you here. Thank you for joining us.

Shozo Saito: Thank you very much for inviting me that.

Doug Fairbairn: As I said before, we'll concentrate most of the discussion on your technical career and the contributions and decisions made during that time. But we'd like to start way back in the beginning and understand a little bit about when and where you were born, what sort of family life you had and how that might've influenced your decision to pursue a technical career. So, if you would just start with a little introduction to when and where you were born and family life, I'd appreciate it.

Shozo Saito: Okay. I was born in the Gifu prefectures. That is the middle of the Japan, and that time, in 1950. So, then, I grow up in Gifu prefectures almost 10 years. And after that, I moved to Tokyo, and to junior high school and high school and university in Tokyo. So, I was going to Waseda University. I'm going to the applied physics, some section. During that time, I was learning physics.

Doug Fairbairn: Before you get into university time, were either of your parents technical? Did you do any electronic experimentation or hobbies when you were younger?

Shozo Saito: Okay, my father was working truly different area. My father was working in some consultant of some company, so that no technical area. <laughs>

Doug Fairbairn: No influence <laughs>. Do you have brothers and sisters?

Shozo Saito: Single.

Doug Fairbairn: Just a single child.

Shozo Saito: That mean there is no relation, the technical areas, but I'm just considered to the universities about some physics areas. I like the physic areas, so that's why I decided to go to physics.

Doug Fairbairn: What year did you enter Waseda University?

Shozo Saito: Okay, it could be <inaudible> 1969, but my high school is connected the university, from the high school.

Doug Fairbairn: I see.

Shozo Saito: So, that why in the high school to move to just-- no examination. <laughs>

Doug Fairbairn: I see. You just keep going.

Shozo Saito: Yeah, it's just escalator. So, during the high school times, I'm interested in the physics areas so that I learn some physics. So, then I'm going to the university, so it's the same areas.

Doug Fairbairn: Is Waseda University in the Tokyo area?

Shozo Saito: Tokyo areas, yeah.

Doug Fairbairn: So, you graduated from there in 1973?

Shozo Saito: And I'm wondering if going to some doctor course or some companies. Then I finally decided to go to some company. Then I selected the company. It's so many famous companies there in the Tokyo areas. During that universities, the senior guy in the same applied physics course, the senior guys go to Toshiba. So, I ask him that, if I'm going to the doctor course or some company development and researching centers, which is better? His answer is clear that you should go to the company. <laughs> So, that is so easily to be <laughs> decided: go to the company. Then I'm just asking the company and some high class levels in there if to the some researching. The area is the same to universities, and I go to the company; same kind of development-- if I can do that, then I will go in Toshiba. Then I checked that company, what kind of--

Doug Fairbairn: What kind of researcher--

Shozo Saito: Researcher in that applied physics areas. So, Toshiba is the one of the best for research and development centers, the big one. And I finally decided go to the Toshiba research and development centers.

Doug Fairbairn: So, did you immediately start working on semiconductor technology?

Shozo Saito: Little bit different <laughs>. That the strange things <laughs> there. Okay, during the university, I was studying research of the ferroelectric materials areas. So, ferroelectric area-- some electric company started research and developed. And I'm asking that ferroelectric is very important for the futures electric company-- that the basic technologies to develop is important. Then there's somebody there already in this research area. I want go to that laboratories going in [to start].

Doug Fairbairn: So, you thought you wanted to go into ferroelectric--

Shozo Saito: Yeah. Then, my image was they are already committed that, <laughs> but finally different <laughs>. So, then very close to the memory areas-- that the semiconductor, that is truly semiconductor technologies, not DRAM. But they said this is the same technologies for the ferroelectrics. Oh, it's very interesting. <laughs> So, then I'm going to that laboratory. That the technologies now is the same area we said is the MNOS.

Doug Fairbairn: MNOS?

Shozo Saito: Yes. So, usually, in the semiconductor structure is MOS, metal-oxide-semiconductors. But that position is between metal and oxide is the nitride; that's non-volatile memory. That's initial non-volatile memory development in Japan. So, finally I understand that; that so great <laughs> technologies. Then I developed for the MNOS devices in Toshiba, almost 1975 or 1976 time frames.

Doug Fairbairn: So, you worked on that for two or three years?

Shozo Saito: Okay, that time, almost six or seven years for the MNOS. I developed some MNOS devices; it is so many devices. Then, we try to expand for the market, but there is some problem that. They are not so acceptable for that non-volatile memory in the market.

Doug Fairbairn: Was it a technical problem or an application problem?

Shozo Saito: Application problem—mainly application problems. So, during that time, in the other side, the DRAM, there were developing in Toshiba, and that time, it is 64K DRAM. It is magnitude different <laughs> now-- 64K DRAM.

Doug Fairbairn: That was in development at that time?

Shozo Saito: That time is the development <inaudible> by the other groups. So, that time, so NEC or Hitachi, the big companies already developed for the 64K DRAM, but Toshiba is behind in that

technology. So, one of newspaper there, famous newspaper in Japan <laughs>, said Toshiba exit from the DRAM market, that news is going there, so we are very surprised that <laughs>. Then, that time, the top management decided to much more technologies must developed inside Toshiba, and there are many resources between the other areas. So, myself is the target to <laughs> move from the MNOS to the DRAM <inaudible>.

Doug Fairbairn: So, they wanted to move more resources into DRAM. They didn't really want to get out of the DRAM business; they wanted to put more resources in--

Shozo Saito: Much more resources.

Doug Fairbairn: And grow the business.

Shozo Saito: Yes. Then I'm just started for the next generation-- the 64K; next is the 256K DRAM. Then I'm just learned and starting, then also moved from the research and development center to some division laboratory <inaudible>. So, I already change that area, researcher to move engineer <laughs> that time. <laughs>

Doug Fairbairn: And were you working--

Shozo Saito: Already gave up on the research

Doug Fairbairn: Are you working on the device part of it, improving the device characteristics?

Shozo Saito: Okay, that time also strange. I'm a physician that applied physics, but device develop already some material. But they are asking me to do the circuit design <laughs> for the DRAM-- oh, big change. But unfortunately, my boss, all right? Everybody goes to <laughs> there. I couldn't say that <laughs> I'm stay here. Then I move to the DRAM design group. Then I'm just started for the 256K DRAM in the NMOS—n channel MOS transistors-- and the 256K DRAM. and developed. Then I'm circuit designer, and also, I'm interested in some marketing that. Then that time, those kind of high-density DRAM to use at IBM, HP and Digital all kind of big companies. Then I'm going there.

Doug Fairbairn: You're going to those companies?

Shozo Saito: Those company going to for sales <laughs>. I'm changing from an engineer to sales. <laughs>

Doug Fairbairn: But this is before the product was developed, you were going out and--

Shozo Saito: Just developed, but nobody used that. Toshiba, had already exit their thinking. <laughs> Then Toshiba going into new market. Then I'm going to IBM, HP.

Doug Fairbairn: So, you actually worked on the circuit design for the 256K?

Shozo Saito: Yes, just the main designer for the 256K, and also, I'm doing the marketing.

Doug Fairbairn: So, did Toshiba come out with the 256K at about the same time as the other major manufacturers?

Shozo Saito: Okay, and that time, our competitors are much faster that developed, and they are already selling that [256K DRAM]. Then our position is maybe five or six position to some making samples. Then I said to IBM or HP people, and they are coming with the purchasing guy. Then I developed for the 256K DRAM. That DRAM function is good! So, please listen to my presentation, then they are going to the US, two or three guy; the purchasing guy is coming that. Then I develop for that kind of DRAM. And then they said, "Ah, okay." And that funny story is, at that times, I give them some presentation, but he bring me to the cafeterias. The corner of cafeterias is a round table, some <inaudible> give me that <inaudible>. <laughs>

Doug Fairbairn: You mean give them samples?

Shozo Saito: Sample and some presentation at first. That only three people in the corner of the cafeterias and the employees are there eating lunch. <laughs>

Doug Fairbairn: Nice.

Shozo Saito: <inaudible> Then finally, they said, "Oh, you are five or six positions. We don't need more. If you want some testing, then put on the sample there. <laughs> "Okay, there." <laughs> Bye. <laughs> That's it. <laughs> Oh, that Toshiba position is bad. <laughs> Then, unfortunately-- so that our 256K at the end not going to the majorities. But the small company, they are using our devices, but not majority.

Doug Fairbairn: Not the bigger companies.

Shozo Saito: So, I'm decided it 256K, it don't more need for Toshiba product. Then also, our top management said we should move to the next generation.

Doug Fairbairn: One megabit.

Shozo Saito: One megabit. But the problem is one megabit NMOS is already started in other groups, different groups. Then our top management said, "Your group, you are project managers, so different type of one meg DRAM you should develop."

Doug Fairbairn: 'Cause the other groups had already developed--

Shozo Saito: NMOS. Then my target is moved to the CMOS DRAM.

Doug Fairbairn: So, were your competitors designing CMOS?

Shozo Saito: Only Hitachi there.

Doug Fairbairn: Only Hitachi.

Shozo Saito: But the other guys, it's NMOS. Then I decided to CMOS DRAM. Then there are also Toshiba, their static memory, one of CMOS static memory, they are develop-- that famous one. But that technology developed too high; NMOS DRAM is too low . <laughs> So, combine that <laughs> technologies-- that is one of solution, that. Then I developed to CMOS DRAM.

Doug Fairbairn: So, were you doing the circuit design again for--

Shozo Saito: Yeah, circuit design and that total project manager of the one meg CMOS DRAM.

Doug Fairbairn: Oh, the whole--

Shozo Saito: The whole things, and designer also in the technologies-- everything.

Doug Fairbairn: But you were behind, right? They'd already developed the NMOS.

Shozo Saito: NMOS ideas.

Doug Fairbairn: So, you had to work very quickly.

Shozo Saito: Yeah. So, I managed some people to do the circuit design also the device technologies, process, and the combine, then moving target date inside of Toshiba. <laughs> One meg NMOS DRAM people almost took half a year or one year delay behind that. So, we are running that.

Doug Fairbairn: You were 6 to 12 months behind the NMOS version?

Shozo Saito: Mm-hmm. Then we developed for the CMOS and the NMOS at the same time. Then I present at the ISSCC 1985. This time, almost 10 DRAM is the product: the one meg, including Toshiba NMOS one meg DRAM and also the one meg CMOS DRAM-- also other companys' NMOS DRAM. Only Hitachi has CMOS DRAM. But this technologies and also performance is the super technologies and also characteristics. So, that time, in the ISSCC is proving that. Toshiba one meg CMOS DRAM is the best one.

Doug Fairbairn: It was the fastest?

Shozo Saito: Fastest and the low power.

Doug Fairbairn: Lowest power.

Shozo Saito: And the new function there, so everything. So, then I bring backed in Tokyo, and also everybody to some-- that develop parts going to mass production, but only Toshiba CMOS DRAM is successful for the mass production. And the other time, everybody to some behind us.

Doug Fairbairn: So, the other CMOS DRAMS were not successful, or you were ahead from any other one meg--

Shozo Saito: Any other NMOS or CMOS, they are behind.

Doug Fairbairn: They all had problems.

Shozo Saito: Then only Toshiba is going to the mass production of the products.

Doug Fairbairn: So, now you were in the lead.

Shozo Saito: Yes. Then I go to the US again-- <laughs> IBM, HP people. That, I'm present that. Everybody listened to that. I have a sample. Oh, strangest things: I'm going that-- oh, big conference room! <laughs>.

Doug Fairbairn: Not just a little table in the corner.

Shozo Saito: Not a little-- almost 20 or 30 people to listen to me, my presentation. Wow, big different . <laughs>. Why isn't that--? So, that simple, that you are first.

Doug Fairbairn: By this time, I guess, maybe at the 64K level, the Japanese companies had established a leadership position in DRAM, right?

Shozo Saito: Yes. 16K in the US company; 64K some middle, and 256K some Japanese DRAM makers <inaudible>; the one meg, almost Japanese <laughs>.

Doug Fairbairn: Was the reason for that because of the technical quality or bigger investment? What were the reasons that Japan was able to take the leadership position in DRAMs?

Shozo Saito: Maybe both, and I'd first say the CMOS technologies. That one of key technologies that Japanese company some moving that areas. And second things is just time. Every semiconductor company invest in all their factories, but Toshiba at first to started some invest their clean rooms. So, that timing is good.

Doug Fairbairn: So, they put more investment up earlier to get the volume--

Shozo Saito: For one meg, because Toshiba is almost tiny in the 256K, but new investment--everything-- into one meg. But the other company, they have to also to produce for the 256K, so some behind. So, new equipment, they install at first in the Toshiba factories. So, that timing is the second things-- and the technologies and the timing-- and also third one is market. So, that timing is computer market in the growing fast. So, everyone need the high-density memory-- so memory target, every computer makers is looking for that in the high-density DRAMs . So, that good timing on everything.

Doug Fairbairn: And also, the quality and the yields for the Japanese product was much better and the price lower, right?

Shozo Saito: Yeah. So, especially to the high-end computers need for some reliabilities and also, it is performance itself. So, that timing is everything's meet for that time.

Doug Fairbairn: So, you were able to take a leadership position in the one megabit DRAM. You presented this paper in 1985; did you also start delivering volume production in 1985?

Shozo Saito: 1987 was? Something <inaudible>.

Doug Fairbairn: 1987?

Shozo Saito: Yeah. Then maybe 1989 or 1990 time frames, and the total semiconductor market, the Japanese share almost 50 percent. So, that every to going <inaudible>, but Toshiba is the top maker. Then one meg DRAM top makers is ranking is Toshiba. So, 64K before <inaudible> <laughs> that, and they're going up to the number one position. Also, for the company levels, that profit is a huge profit there <laughs>. That is a record, <laughs> because the DRAM, they are always some prices going, and they go down, and they change to the next generation. But one meg case, Toshiba is still keep all some levels, so higher profit. So, that, image was something bad (?). <laughs> So, next generation, next generation is always keep to the top level. That is too difficult.

Doug Fairbairn: So, did Toshiba maintain a leadership position at 4 meg and 16 meg?

Shozo Saito: Unfortunately, no. <laughs>

Doug Fairbairn: Hard to stay there. <laughs>

Shozo Saito: And that Toshiba is top, and the second is maybe Hitachi or something. I <inaudible> that. Some ranking change.

Doug Fairbairn: So, did Toshiba--

Male: <Japanese>

Shozo Saito: <Japanese>

Doug Fairbairn: It's okay.

Shozo Saito: Yeah.

Doug Fairbairn: So, once you had the leadership position for one megabit, then you had the problem of maintaining that and so perhaps were slower to make investment in the 4 megabit and 16 megabit?

Shozo Saito: Maybe I think that the one meg is the key to production-- some quantities. Then the customers required someone meg DRAM in some quantity-- keep that. But our competitors already gave up on the one meg. Then they are developing four meg at first before our develop--

Doug Fairbairn: Like you did. <laughs>

Shozo Saito: Yeah. That is the same strategies <inaudible>. <laughs> Then, unfortunately, six year later, the Japanese competitors developed for the 4 meg. Then I also tried to-- if that 4 meg is not number one, we want to escape the 4 meg and then going to the 16 meg. <laughs> We tried that.

Doug Fairbairn: You skipped a generation?

Shozo Saito: Skipped a generation. But development- was it's okay that, but its production level-- that not for us for some many factories, they are keeping that one meg. The two-generation skip is too difficult.

Doug Fairbairn: Too difficult, right.

Shozo Saito: So, that's why our DRAM position is going down.

Doug Fairbairn: So, when did Samsung and the Koreans become a major supplier?

Shozo Saito: 4 meg program and the 16 meg-- 1 meg is small, but the 4 meg, our competitors-- Japanese competitors; also Korean competitors-- they are starting for the 4 meg and the 16 meg.

Doug Fairbairn: And was that largely because of their investment in fab capacity?

Shozo Saito: That only development, and also, they are invest for the huge investment to their factories.

Doug Fairbairn: Did they get their design technology from Japan? How did they develop the technology to design 4 meg and 16 meg?

Shozo Saito: We called it dead copy. Dead copies means so easy that there is some purchasing in some market and open it. They can get chip and analysis the design--

Doug Fairbairn: And you look, yeah.

Shozo Saito: Yeah, then to analyze and the circuit. Then they are same way they are developed. Then that technologies move to the 4 meg-- applied to 4 meg, then to 16 Meg. So, that the usual case. Then I think that they done to our one meg DRAM. Basically, it's the same circuit they are using that.

Doug Fairbairn: What production technology was required for the 16 megabit DRAM? What line width or minimum line width?

Shozo Saito: <laughs> Maybe 10 micron something? I don't know ask. Sorry that <laughs> I'm <inaudible> to say.

Doug Fairbairn: That's okay. I was just curious. What was the evolution of DRAM technology within Japan? How long did they keep going, and what is the current status of DRAMs in Toshiba today?

Shozo Saito: Okay. And that's started the one meg 1985. Then they are mainly to the mass production in the 1990 time frames. And finally, Toshiba quit the DRAM business in 2001.

Doug Fairbairn: 2001?

Shozo Saito: 2001. Then that 10 or 15 years, Japan had some majority of DRAM areas. Then Toshiba quit the DRAM in 2001. After that, the Korean people, that share went huge up.

Doug Fairbairn: What was the largest DRAM that Toshiba put in production? Was it 16 meg?

Shozo Saito: 4 meg or 16 meg, yeah.

Doug Fairbairn: That was the last generation?

Shozo Saito: Yeah. No, no. Okay, 64 meg, also, Toshiba developed. **Doug Fairbairn:** Okay, 64?

Shozo Saito: That time-- so, DRAM, to the main users, is moving from to the mainframe computer to PCs. So, that time, the function is some changed. Then 1 meg DRAM is the usual data access schemes, but the 16 meg or 64 meg is level, or the change to the-- we call the static column; almost static memory operation-- much easier than the usual DRAM access. Then at the 64 meg, where we started that static columns memory. That invented myself, <laughs> so that technology, I have a patent. <laughs>

Doug Fairbairn: You have a patent on it.

Shozo Saito: Yes. That applied for the static columns memory. That also Toshiba-- some first time to the applied to the market. So, that time is also some recovered that <laughs>. But that technologies is the static column more usual for the PC companies. Probably they are using the static columns.

Doug Fairbairn: It was still DRAM technology, but it had internal refresh or something? It would act like static RAM?

Shozo Saito: Okay, refresh is controlled by the control pin in the usual DRAM. But static column, internally, to generate-- refresh-- the almost static memory. Now, current DRAM everything is static columns. That a good invention, that. That the first time that Toshiba is <inaudible> that technology <inaudible> that we can. But technology-wise, everybody can copy that, so there are Korean people, they are also the static column. That only patent that I have <laughs> but <inaudible>.

Doug Fairbairn: An important one.

Shozo Saito: It's only patent P there back to the Toshiba <inaudible> <laughs> onto other things.

Doug Fairbairn: So, as you went to 16 and 64 meg, the configuration was more byte-oriented, or were there multiple bits accessed at once?

Shozo Saito: Yes. For the PC application and that they are fast and I/O static column type of things and the wide I/O type, so many variety that. They usually "by one" or "by four", but that 64 meg, that variety that. Everybody started to go to a variety of DRAM. So, it is too difficult to keep for some volume. Toshiba side it is too difficult to develop for many things.

Doug Fairbairn: So, there were many different varieties, and each one didn't have enough volume? Is that right?

Shozo Saito: Yes. So, that kind of business model, Korean people is much more good.

Doug Fairbairn: So, when did Toshiba make a significant investment in flash?

Shozo Saito: Okay, just decided for 2001 quit all their DRAM business, so that time, Toshiba has all the big, big factories-- many big factories. And we just started for the DRAM production in Oita prefectures, and that time, we already start in Yokkaichi_____? a big factory. Then they quit the DRAM-- all empty, but the equipment that we have, so that time, we change to some equipment, but it almost is same equipment. Then we develop for the NAND flash memory and to using old the DRAM equipment. <laughs> And also, that time, in the DRAM cases, we are going to the US factories-- Manassas, close to Washington. And that, we also start the flash memory, that US factories. But that quit for the DRAM business, and that factory to sell for the other company. Then their old flash memory equipment moved to the Yokkaichi factories. Then we started all the NAND flash memory in the Yokkaichi_____ factory.

Doug Fairbairn: So, you shut down the US factory?

Shozo Saito: Shut down.

Doug Fairbairn: And moved the equipment back to Japan.

Shozo Saito: Yeah. We sell to Micron <laughs>.

Doug Fairbairn: Oh, you sold it to Micron Technology? So, in 2001, you started switching over from DRAM to NAND flash.

Shozo Saito: Yes. Same factories. <laughs>

Doug Fairbairn: And equipment. <laughs>

Shozo Saito: And equipment! <laughs>

Doug Fairbairn: Very important. And Toshiba is still a leader in NAND flash now. Is that correct?

Shozo Saito: Yes.

Doug Fairbairn: So, you've had to continue to build additional factory capacity and newer factories to handle that. Is all your production coming out of Japan, or are you building factories somewhere else?

Shozo Saito: Now, the front end is only Japan. But back end - to assemble that-- that is foreign countries.

Doug Fairbairn: So, to get back to your own personal career, were you continuing to manage the DRAM business up through 2001? And how did your career go with the--

Shozo Saito: Okay. So, my career is some different. It strange-- for started all the research and development, and then moved to the design for the memory, and I also move to marketing guys-- technical marketing guy, because I'm really interesting to the customers -- going to customers and listen to their requirement and to realize all our technologies. So, then I to move to the technical marketing position. Then the 64 meg or 128 meg, I am going to the majority companies; that time it is change to the PCs. Then I am selling that DRAM and also new type of memories. That time, we call the special video application use memory. That area that time is some of the people that some graphic board, they are required some video RAM that I developed, and also that time is Rambus. Rambus is the famous tech company. That is the first company to use their Rambus technologies in the DRAM, and Toshiba is the first one. But the new type of memory developed; and I go to the customers, we developed those kind of new memories. So, that position to <inaudible>

Doug Fairbairn: So, was that when you were in the United States?

Shozo Saito: Yeah. That time, I was <inaudible> go to the United States.

Doug Fairbairn: So, you could meet with the customers and understand better what their unique requirements might be.

Shozo Saito: No, before 2001, going to the US and then back to the US. And I'm to the some working that is DRAM <inaudible> another company <laughs> business <inaudible>. Then I sell all the DRAM business. Then I stay in some technology executive to the NAND flash memory, and still that engineer <laughs> at that time.

Doug Fairbairn: You say still doing engineering?

Shozo Saito: Still engineering. The technology executive is the top of the engineering.

Doug Fairbairn: Oh, I see.

Shozo Saito: Then after that, I change a job to the management side.

Doug Fairbairn: And what year was that?

Shozo Saito: Memory divisions-- total memory divisions.

Doug Fairbairn: What year did you finally leave technology to get into management?

Shozo Saito: Oh. <laughs> Okay, so-- <Japanese>

Female: <Japanese> corporate vice president.

Shozo Saito: <Japanese>

Doug Fairbairn: So, in 2002, you were a memory technology--

Shozo Saito: Executive.

Doug Fairbairn: Executive.

Shozo Saito: Yeah.

Doug Fairbairn: And then, in 2004, you became vice president and general manager of the memory division.

Shozo Saito: Yeah.

Doug Fairbairn: So, that was a non-technical position.

Shozo Saito: Non-technical position.

Doug Fairbairn: Right.

Shozo Saito: 2004, yeah.

Doug Fairbairn: So, at that point, you were managing all of the memory.

Shozo Saito: All of the memory.

Doug Fairbairn: Toshiba wasn't making pure static RAM anymore.

Shozo Saito: That time, already gave up.

Doug Fairbairn: So, most of the other Japanese companies did some merging and combination of companies, but not Toshiba in semiconductors. Is that right?

Shozo Saito: Yes. So, other competitors, their semiconductor division to spin out, and they merged, but only Toshiba is keeping all the semiconductor business inside. So, that reasons Toshiba is also-- customers, so inside customers is good position to the learning, <inaudible> how to use for the memory or some semiconductors-- so inside, especially TV. So, TV, that market-- inside almost semiconductor. So, that time, Toshiba TVs much more high share that-- that connect for the inside our company. Or PCs, laptop, or something; that Toshiba laptop is high share that. So, that communication is important to the outside company-- compared to the outside company. So, that Toshiba keep to the-- only Toshiba keep to the semiconductor divisions inside company. So, that a good timing.

Doug Fairbairn: Today, the NAND flash memory is by far the biggest piece of your semiconductor business. Is that correct?

Shozo Saito: Yes.

Doug Fairbairn: What are the other areas where Toshiba has a significant investment in semiconductors? What type of semiconductors are you continuing to build other than NAND flash?

Shozo Saito: Flash memory, the high tech in the market, the investment, but still, we have all the discrete power devices, our LED devices, and also our system LSI and some analog type of things. That area we

have, but not huge investment. But still some keep to the some technology levels or some production levels. So, that areas is still to input the some investment.

Doug Fairbairn: So, NAND flash is by far the biggest piece, then?

Shozo Saito: Almost 80 percent, 90 percent is flash memory, but still, we have the other areas.

Doug Fairbairn: And the flash memory business continues to grow rapidly. Is that right?

Shozo Saito: Yeah. So, now the smartphone is some booming in that, and not only US; in China or some the other developing countries, and they are starting for the huge memory for the smartphone. That market is big. The other things, the data centers-- now there some change to hard disk drive to the flash memory, SSD. So, that a huge market now is growing. And also now, little bit change to the things in IoT. So, they are IoTs to market is coming, and each module has <inaudible> some data. So, that is a small datas; that area so good for the flash memory application, so that area, it now is growing that. So, still storage area is the good market for us.

Doug Fairbairn: Do you see technologies coming along that would change that, that would displace the NAND flash? Is there anything coming along that would threaten that position?

Shozo Saito: Okay, and this is very difficult to see in the future, that area. Technology-wise, some going to some breakthrough, but some physical limitation is coming soon for the flash memory. For example, now our device is 15 nanometers, but 10 nanometers something? It is too difficult for the physical dimensions. And we are now going to the 3D <inaudible> to dig for the trench and each layers, and now <inaudible> developed for the 64 layers the memory 3D.

Doug Fairbairn: 64 layers?

Shozo Saito: 64-layer chip at-- no, no-- cell in the chips. And also, some limited for that areas within five or ten years. So, we need for another type of memory devices to have to developed, so we are now considering to that areas. But we don't know which area in the future devices is coming up for displacement for the flash memory. But sometime, it's coming that, the physical limitation that times.

Doug Fairbairn: So, there's the physical challenge, but there's also the fiscal challenge; there's the money part of it, right?

Shozo Saito: <laughs> Yeah, yeah. <laughs>

Doug Fairbairn: How much does it cost to build a 15-nanometer fab for flash memory? What is the size of the investment?

Shozo Saito: That <laughs> huge investment, yeah, especially, for example-- and to lithography technologies, some limited. Then now, we are using for the immersion to i-line steppers—immersion steppers. That prices, or the huge prices, compared to the usual one. But they are some limited for the physical image and for the lithography, so we are going to the next lithography, the EUV, extreme ultraviolet <inaudible>. But they're too expensive <laughs> for some exposures, so to pay for that, <inaudible> cheap <laughs>, so usually, bit cost go down at the small dimension, but if we are using the EUV lithography tools, almost twice what <laughs>--

Doug Fairbairn: Twice the cost per bit?

Shozo Saito: Yeah. So, that is too difficult. If we can do that—some breakthrough the physical dimensions, but cost is not follow-- then we need much more reasonable cost of the lithography technologies or some etching technology. So, we have to develop new materials coming. So, that same things for the not only memories and the logic LSI, most of the same thing that some limited for the geometries. But for the memory side, one of good news: We can change to some material or device itself. But the logic guys are only almost the same for the MOSFET, so that idea different. So, we are looking for the new material that area. It's not flash memory-- the other material something.

Doug Fairbairn: I see.

Shozo Saito: Magnetic or the other material.

Doug Fairbairn: So, going forward, do you see the investment cost being a bigger challenge than the technology?

Shozo Saito: Yes. So, much more need for the breakthrough technologies compared to before that. It used to be we are going to the-- so to reduce for the geometry only depend on the lithography. But now it much more variety. We need all the much more solution. We need much more solution that, except for the--

Doug Fairbairn: Less expensive solutions. <laughs>

Shozo Saito: Less expensive, of course. So, that the challenge for the-- that is something to the-- some good challenge worldwide, the semiconductor industries. So, now is booming with China industries, but the other things is much more changeable, that area.

Doug Fairbairn: Are there breakthroughs that you can see that might come through? Do you have ideas about how to get beyond the current economic bottleneck?

Shozo Saito: We have some idea that, but we don't know that is a good solution or not. So, we are now just investigating which technologies, some good breakthrough for the futures. So, now is many idea.

Doug Fairbairn: How many bits are the largest flash memory now?

Shozo Saito: One chip is 256-- 64 gigabit.

Doug Fairbairn: 64 gigabit.

Shozo Saito: And also, we have the stack chip-- 16 stack <inaudible>. So, 256 gigabyte. <laughs> <inaudible>

Doug Fairbairn: And that's technology that you can make in volume today?

Shozo Saito: Yeah. So <inaudible> use of that, yeah. Some PC, SSD now is <inaudible>

Doug Fairbairn: Yeah, SSD. I need a bigger SSD in my computer. <laughs>

Shozo Saito: <laughs> To first every enjoy that. <laughs>

Doug Fairbairn: And your smartphone has 256 gigabyte in it also.

Shozo Saito: Gigabyte <inaudible>. Yeah, on one chip.

Doug Fairbairn: Just one chip <laughs>-- for those of us who remember the days of one kilobit <laughs> DRAM. <laughs>

Shozo Saito: I'm just started for the 1973 Intel to announced for the 1K -- 1024 bit. <laughs>

Doug Fairbairn: Bit! <laughs>

Shozo Saito: Bit! <laughs> That truly different <laughs>.

Doug Fairbairn: 40 years later, <laughs> amazing technology. So, are you still involved on a regular basis with these kinds of decisions with Toshiba? Are you asked as an advisor? What is your role today?

Shozo Saito: My role is now in the advisors. Not to direct.

Doug Fairbairn: No direct management.

Shozo Saito: No direct management, but advisors, but I'm going to the any places in the factories, I'm check to that <laughs> to the advisors <inaudible> advise that <laughs>.

Doug Fairbairn: So, you're still actively involved with things that are going on?

Shozo Saito: Yeah.

Doug Fairbairn: You visit different factories and review their progress and problems and make recommendations as to steps to take?

Shozo Saito: Yeah. So, that why I said the semiconductor company and the industry still going ahead, moving, so that myself also until I die. <laughs>

Doug Fairbairn: You keep moving right?

Shozo Saito: Keep moving. So, Toshiba, as you may know that area, Toshiba has some nuclear generation generators we call big electronics and semiconductors of course. This one in the whale to moving to the slow and the big ocean. The semiconductor - the tiny fish going around the small area. <laughs> So, big fish in the inside of the Toshiba <laughs> whale and the small fish.

Doug Fairbairn: <laughs> Which one has more investment?

Shozo Saito: Small. <laughs>

Doug Fairbairn: Small. <laughs> More money going into small than going into big. <laughs>

Shozo Saito: Small, yeah. But small still around, moving that. <laughs> That's my life. <laughs>

Doug Fairbairn: Is Toshiba also making investment in totally new areas-- biology or any of those-- or strictly electronics? What about bioelectronics?

Shozo Saito: Bio industry and the healthcare type of things or-- so, many type of <inaudible> so, used to be Toshiba is the only two categories: one is the electric generation or something-- infrastructure; we call infrastructures-- then the other is devices. Then we need for the third one, so that area now we are considering to the future areas-- in the future and some areas. So, bio is something or the other-- so, that a new challenge there.

Doug Fairbairn: Are you actively involved in making some of those decisions?

Shozo Saito: No, <laughs> but suggest otherwise. Also, I'm working now in some government for 5 or 10 years later. What kind of society is coming in Japan and worldwide? So, looking for that area in the 10 years later or we call just 2.0 or 3.0 types of things. What type of society's coming? Then that society need what kind of service or some hardware, software? So, one of solution is in the semiconductor industry, also some contribute from some areas. That the discussion-- areas from the government side. So, for example, US in the Industrial Internet Consortium IIC -- <inaudible>

Doug Fairbairn: IoT or IT--

Shozo Saito: It's a consortium for the—IIC Yeah. And also, Germany for the Industry 4.0 - no, no, industry 4.0 - that type of the government style. Then now, in Japan, they started for the society 5.0 So, that a new society is coming. So, used to be our information society, but 5.0 is the new-- to smart society. So, we are looking for that at that time. So, that why a consortium is coming.

Doug Fairbairn: So, do you travel to other countries and have discussions of this type also?

Shozo Saito: Yeah. So, I'm working for ... I'm a board member of the Global Semiconductor Association, GSA, so that is every time I visit the US for the GSA board meeting. So, they are also discussing that area, future of the industries, how to move that new industry. Not only global semiconductor areas; it's much more wider societies.

Doug Fairbairn: Many challenges, interesting opportunities. <laughs>

Shozo Saito: Yes. So, I'm a GSA board member, Japanese representative-- also JSIA, Japanese Semiconductor Industry Association, and the chairman. So, not only Toshiba and semiconductor industry-- all over the semiconductor industries to the areas, I'm working that position-- still moving that <laughs>.

Doug Fairbairn: So, you're very busy; you keep moving.

Shozo Saito: Yeah. Worldwide is visiting that. So, the I started the research and development for the R&D centers, and I'm going to engineers <laughs> and some marketing guy and management. Now, it is <laughs> some consulting for the worldwide <laughs>. So, that is my life. <laughs>

Doug Fairbairn: Well, good. So, the next time you come to Silicon Valley, you must come and visit us at the Computer History Museum. We also are not only looking at the past, but looking at the future, and we have a number of new things going on. So, I think you would find it very interesting to see and hear what's developing there. I strongly encourage you to come visit us next time you come to the United States.

Shozo Saito: Thank you very much.

Doug Fairbairn: Is there anything else that you would like to talk about or cover, or do you think we've sort of completed--

Shozo Saito: Nothing.

Doug Fairbairn: That's it?

Shozo Saito: I talked a lot. <laughs>

Doug Fairbairn: That's good. That's what we asked you to do. Thank you very much.

Shozo Saito: Thank you very much.

END OF INTERVIEW