Oral History of Shunichi Iwasaki

Interviewed by:
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Recorded July 29, 2016
Sendai, Japan

CHM Reference number: X7914.2017

Tanaka: Dr. Iwasaki, thank you very much for joining the interview today.
One of the most significant recent technology developments has been the commercialization of Perpendicular Magnetic Recording, or PMR. Starting in 2005, adoption of PMR facilitated a tenfold increase in the data capacity of Hard Disk Drives (HDDs). HDD capacities up to 10 TB are the norm today. Professor Shunichi Iwasaki, of Tohoku University, was the most important champion of PMR. He also made key PMR inventions. This oral history records the contributions Professor Iwasaki made to the success of PMR.

Dr. Iwasaki, let me start the interview. First, I would like to ask about you, your birthplace and background.

Iwasaki: I am Shunichi Iwasaki. I was born in Fukushima prefecture in Tohoku region. In 1946, after World War II, I visited Tohoku University and met Professor Nagai. His expertise was in magnetic audio recording. He was a very famous professor who had discovered AC bias. When I enrolled in Tohoku University and became his student, it was natural that I began the research of magnetic audio recording or magnetic recording.

Tanaka: Thank you very much. You entered Tohoku University and became a professor later. Could you tell us about your academic history?

Iwasaki: History？

Tanaka: You became a professor at Tohoku University and later served as a Director of the Research Institute of Electronic Communication. Then,..

Iwasaki: Academic history? I should have not skipped that.
After I graduated from Tohoku University in 1949, I worked for Sony for a short time. Then in 1951, I joined the Research Institute of Electronic Communication at Tohoku University as a research assistant, then as an associate professor, and then was appointed to a professorship in 1959. Is that right?

Tanaka: In 1964.

Iwasaki: Yes, 1964. Since I graduated in 1949, it took about 10 years to become a professor. Then, what next?

Tanaka: You became the director of the Research Institute of Electronic Communication at Tohoku University, and later became the president of Tohoku Institute of Technology. It was 1989.

Iwasaki: Yes, it was 1989.

Tanaka: During those years, you received a number of academic awards including the Japan Academy Prize as well as Person of Cultural Merit in 1987, IEEE Cleo Brunetti Award in 1989, IEEE Magnetic Society Achievement Award in 2002, Japan's the Order of the Sacred Treasure, Gold and Silver Star 2003, Japan Prize in 2010, Japan's the Order of Cultural Merit in 2013, and United State's Benjamin Franklin Medal in 2014. Could you tell us who had the most important influence on your early days of magnetic recording research at the university?

Iwasaki: Surely, that is Professor Kenzo Nagai. I think, I was a junior working on my graduation research. He said something to me like, "you are really something". I still remember that. I took him at his word and soon enough started working with him.

Tanaka: Thank you very much. After your graduation, you worked for a short time for Tokyo Tsushin Kogyo Ltd., later known as Sony. That was soon after Sony was founded. Could you speak about your experiences with Sony's founders?

Iwasaki: At that time, Mr. Ibuka was the president and Mr. Morita was the vice president. I had a lot of opportunities to speak with them, and I have many memories. Mr. Ibuka complimented me after I moved back to Tohoku University. He said, "You may be a top-notch research scientist, but I also see you as a competent businessman." That was when I was an assistant professor at Tohoku University. This was one of many interactions with them.

Tanaka: Thank you very much. With his words, I think, he predicted what you would achieve in the future.

Iwasaki: Mr. Ibuka was a man of great insight. When he actively started his transistor development work, I was working on magnetic recording. I remember he frequently invited me to come back to work for Sony.

Tanaka: Thank you very much.
Next, I would like to ask you about magnetic recording research.
In the early days, when you had just entered Tohoku University, what kinds of technology subjects were you interested in? What was your thinking behind entering the university?

Iwasaki: I decided to choose Professor Nagai as an advisor, because he was one of two processors, Professor Nagai and Professor Uda, who also graduated from Tohoku University and later became professors there. Professor Nagai specialized in the technology of magnetic audio recording.
From there, I spent long hours learning about Professor Nagai's past research, such as AC bias recording and Sendai Alloy.
However, at that time, around 1946, 47, 48, after WW2, the industry was already using iron oxide tapes developed by 3M, Minnesota Mining and Manufacturing, for magnetic audio recording. That's how things were back then.

But, since I had thoroughly studied Professor Nagai's prior research, I had a firm understanding of how it all started. So, I figured out that things were going to change and made the reasonable prediction that tapes would be metal-based materials other than iron oxide.
Thus, audio tape made of metallic magnetic material, that is "Metal Tape", became my first research work.

Tanaka: From a very early stage, you were interested in magnetic audio recording and studied that in the university.

Iwasaki: Luckily, I was able to track the transition from a broader perspective. I had Professor Nagai's past works, not only the iron oxide tape, but how things actually got there. Then looking forward, I predicted where they would go next?
That is what research is all about.

Tanaka: In that sense, meeting with Professor Nagai brought a significant impact to your work.
When you were working on your doctoral research and thesis, how did you organize your theme? Did you experience any difficulties?

Iwasaki: I don't remember very well.
What I was thinking at that time was, magnetic recording is inherently non-linear but AC bias makes magnetic recording linear. AC bias involves linear characteristics. I thought, well then, let's look into those characteristics. That was the beginning and became my first work. I would say, that was something new.
Later, however, I learned that magnetic recording can be conducted by not only a linear circuit but also a delay circuit with the flexibility of selecting a time delay.
Of course, that was not all, but I did not have an idea where this would take me.

Tanaka: You started your research in a methodical manner.
Considering such a background, the history of magnetic recording research at the Research Institute of Electrical Communication, Tohoku University also had a significant impact on your work.

Iwasaki: Yes, professor Nagai started the research and his students did a lot of the work. He discovered AC bias recording in 1938. I think his team started the research about 10 years before that. That is when Professor Nagai was in his 20s. He launched the research in his younger days.

Tanaka: I think AC bias recording was a ground-breaking invention in the history of magnetic recording and a highly significant development in our knowledge. What was your thought process that lead from AC bias recording to the metal tape invention?

Iwasaki: Our original assumption was that AC bias recording was a very important technology to compensate the nonlinearity of magnetic materials, meaning that AC bias covers the initial magnetization region of the magnetic hysteresis loops.

After studying various aspects, we realized that our assumption was wrong because the distortion got better and better with larger amplitudes of AC bias. This phenomenon was completely different from the distortion that can be observed with DC bias.
The characteristics of AC bias were discovered when a large amplitude AC magnetic field was added. We started to think that this would be useful with materials with a large hysteresis loop area; specifically with permanent magnetic materials. In a sense, the metal tape was a leap to permanent magnetic.

Tanaka: By increasing BH product,

Iwasaki: Media could be thinner, which improves the recording performance.

Tanaka: Increasing energy input became one of the important keystones in the evolution of magnetic recording.

Iwasaki: At the same time, however, I came to understand in my mind that it would hit a threshold we cannot go beyond.

Tanaka: Professor Iwasaki, you extended your research to vector magnetization analysis and pursued the idea of action and reaction. Could you tell us about this thought?

Iwasaki: About that thought. At last, I had invented the Metal Tape, but no one wanted to put it into practical use right away, of course. So, for about the next 10 years, I followed up my invention with theoretical studies and worked really hard to develop practical applications.
However, I realized that studying the longitudinal component of magnetization is one-dimensional, but the magnetic head fields are arc-shaped and can be described in a vector space. We needed to include the idea of the “vector of material being magnetized”.
Then, we took a fresh look at the demagnetization effect. We simply interpreted that a medium is demagnetized when a magnetic field is applied to the negative area of the second quadrant on hysteresis loops, but we wondered, maybe what we are looking at is actually the effect of the “counter reaction” to magnetization. In magnetic recording, a magnetic field is continuously applied, which should be causing continuous action and reaction. Therefore, our interpretation of demagnetization was wrong. It was the effect of the magnetic field reaction. This is a very important point.
When I published and presented the results at the Intermag Conference in 1968, I received overwhelming feedback. “Dynamical Interpretation of Magnetic Recording Process”, this “Dynamical” was indeed a good expression. It is dynamic, not static. Since that paper, people started to recognize my name. That, along with the metal tape invention, all contributed to the interpretation of the self-consistent magnetic recording process. That was a significant achievement and now established as a classical theory.

Tanaka: Thank you very much.

Now, I would like to ask you about the perpendicular magnetic recording research. Could you explain how your process of invention evolved from the metal tape, to the vector magnetization analysis, to the self-consistent magnetization, and finally to the perpendicular magnetic recording?

Iwasaki: As my prospective advanced to non-linearity, self-consistent magnetization, and then to vector magnetization, it was very natural for me to think of perpendicular magnetization. I had a fundamental idea in my head that, in the nature of things, there should be "perpendicular" magnetization in addition to longitudinal and in-plane. Then, I asked myself, what would be the first requisite for proving perpendicular magnetization? As if the idea fell from the sky, I answered myself: that would be a medium, a perpendicular magnetic medium.

In conjunction with magnetic recording research, we were also studying optical magnetic recording, where we anticipated that adding chromium to cobalt reduces Curie temperature, making recording easier with optical magnetic recording. So, we prepared a sputtered thin film with cobalt and chromium, but we observed unexpected characteristics, an extremely narrow in-plane hysteresis loop. We wondered if this film would be able to support perpendicular magnetization, and then identified that the cobalt-chromium alloy does support perpendicular magnetization. That was a discovery, a real discovery indeed. We realized that the film in front of us was a perpendicular magnetization medium.

From there, we stepped up efforts focusing on perpendicular magnetic recording. Then, we developed a perpendicular head, of course. After numerous experiments surrounding film material characteristics, we identified fantastic results in a double-layered film whose output was almost the same as ones from traditional longitudinal recording, which carries the perpendicular magnetization characteristics as well. That was a real discovery.

Tanaka: That means that discovery of cobalt-chromium alloy was the breakthrough moment for perpendicular magnetic recording, and then…

Iwasaki: …perpendicular magnetization film, and heads, perpendicular heads and single-magnetic-pole heads.

Tanaka: These three important innovations were discovered and invented in a very short period of time. You faced great challenges and great opportunity, and you had great timing.

Iwasaki: At that time, I seriously tried to understand the fundamental nature of the difference in characteristics between perpendicular head and longitudinal head, perpendicular medium and longitudinal head, one is similar to analogue and the other is similar to digital, and so on. They are complemental to each other. I called this "complementarity". It was really exciting but it was also an important aspect that needed serious consideration.

Tanaka: You noticed the complemental relationship there and looked at the whole picture. How then, did you figure out the superiority of perpendicular magnetic recording over in-plane recording?

Iwasaki: I was thinking in my head why the first quadrant and the second have completely different characteristics. For instance, a medium can be thick for perpendicular recording, but not for in-plane, which has to be thin, or the saturation point can be high (for perpendicular) but it has to be low for in-plane. They appear to have opposite characteristics, just like the difference between the first quadrant and the second or the fourth, plus and minus. I built a map intuitively. At one point, that was my research.

Tanaka: I think the discovery of the complimentary relationship was a very important milestone and you have provided us a strong roadmap to go further. What do you think?

Iwasaki: One was analogue and the other was digital. That was a significant discovery. Don't you think so?

Tanaka: Regarding the complementary relationship, you followed the example of Bohr's complementarity principle, correct?

Iwasaki: Yes, Bohr's complementarity principle refers to properties of light, the particle and wave aspects of physical objects, which can be applied to magnetic recording comparatively because true physical phenomena all have complementarity. I learned that making things perpendicularly is not as simple as placing a block on top of each other. That would be just a matter of technique, if you trivialize your idea. Studying magnetic recording was just like studying philosophy, as if it was the source of all things.

Tanaka: Do you think, with that philosophy, your idea of magnetic recording was gradually but firmly accepted in the field of science?

Iwasaki: Yes, I think so, but no one referred to the word, "complementarity". I wondered why. Probably, people were scared of using such a philosophical word.

Tanaka: I think, in fact, it was the most important point, wasn't it?

Iwasaki: Yes. People would simply describe everything using much more trivialized expressions, such as making things perpendicular results in a stronger head field.

Tanaka: From that point of view, complementarity was the keyword for the world of science to open up to your specific idea.

Iwasaki: Yes, please do a good job translating that part to English.

Tanaka: Now, regarding the 144th Committee on Magnetic Recording at the Japan Society for the Promotion of Science, which you established, please tell us about its initial background and its significance.

Iwasaki: The Japan Society for the Promotion of Science (JSPS) is an open community. Research should be open rather than closed to everybody. Changing recording from longitudinal to perpendicular meant changing everything, head, medium, system and so on. That is a huge challenge and requires all kinds of support at a large scale. For that reason, we needed to make our research public rather than private. JSPS was a public organization under the Ministry of Education. In that sense, JSPS has contributed to our effort significantly.

Tanaka: So, the Committee promoted a very early version of open research?

Iwasaki: Yes, it did.

Tanaka: Although the perpendicular magnetic recording research was started, some years later, the number of papers on this subject had declined, which was referred as the "Death Valley" period.

Iwasaki: It became famous.

Tanaka: Yes, but in order to keep your idea alive, you launched the PMRC (Perpendicular Magnetic Recording Conference), and at the end, your idea survived because of it. Please tell us about what you were thinking back then, and the roles of PMRC as a leader.

Iwasaki: That was not a countermeasure against the decline. My intent was to show that there were so many research themes in this subject. That was it, but looking at the collected data, I was really surprised, the papers for PMRC indeed filled the Valley at all points. It turned out that way, but originally, I just wanted to positively encourage people in many ways by showing various themes to pursue. My 40-year rule and 20-year rule are also encouraged. I noticed that, in general, it takes about 20 years for technologies to be recognized, so, don't give up.
The 40-year rule was something I thought about a lot, and then I figured it out. For example, vacuum tube, triode vacuum tube, transistor, and optical integrated circuit, which were all new and fundamental to the evolution of electrical devices, occurred every 40 years. This 40-year rule is also true for wireless communication, starting from Marconi, microwave, and then fiber-optics. I was convinced, and to me, it was a discovery. I understood why people studied microwave persistently in 1940's. It sits right in the middle of Marconi and fiber optics. Well then, for recording it was wire, tape, and then perpendicular. That made sense to me. I believed that, despite the engineering challenges at the time, perpendicular recording was a sure thing. The 20-year rule refers to "improvement". Everybody knows that it usually takes 20 years to find a practical use of the technology. I wrote in my paper back then that perpendicular recording is around the corner.

Tanaka: You laid out your philosophy and guiding principles for us to diligently follow.

Iwasaki: It was rather encouragement than a guideline. I looked ahead, but we also received some disturbing criticism, such as Mr. Mallinson's paper. My idea did not make sense to some experts.

Tanaka: Professor Iwasaki, in the early days of PMRC, you challenged the group to expand the research both in depth and variety.

Iwasaki: Yes, I worked very hard to let people know the unprecedented significance of the research.

Tanaka: At the end, your effort led to a large number of papers that filled the Valley…

Iwasaki: Oh yes, I didn't realize at the time, but it did. I was so surprised.

Tanaka: Yes, and that led you to continue…

Iwasaki: At PMRC, I wanted to show that there were many more untapped ideas out there.

Tanaka: You made it happen, indeed.

Iwasaki: It filled the Death Valley as a result.

Tanaka: As the perpendicular magnetic recording research moved forward, I think, collaborations with industries for a national project was a very important point for practical science. How did the collaboration come together?

Iwasaki: In terms of "support" from the government, we received nothing other than Grant-in-Aid for Scientific Research. I think the manufacturers received the funds directly from the government. The 144th Committee didn't ask for much of anything.

Tanaka: Do you mean you created an open research platform and industries, I mean the manufacturers, joined you on their own accord?

Iwasaki: That is the way it should be, isn't it?

Tanaka: Yes, indeed, that is a role model for open research.

Iwasaki: I would say, open innovation, yes?

Tanaka: In 2005, the first commercially-available hard disk drive was produced using perpendicular magnetic recording technology. Could you tell us your thoughts, as the inventor of perpendicular magnetic recording, about this first instance of commercialization?

Iwasaki: From 2005 to 2010, almost everything has shifted to perpendicular disk, and has become fully commercialized. But come to think of it, the perpendicular magnetic recording was my idea, not something that society asked for or that was recognized as a good research idea. The metal tape research also followed the same path. I think, in the end, society understood and followed my ideas. As a researcher, I couldn't be happier because my ideas were accepted by society. Don't you think so? In addition to that, my ideas were adapted in both longitudinal and perpendicular recordings, and became a complete technology, where complementarity comes into play as solid science leading to great technology. That is invaluable. I believe that all of these were also meaningful contributions to the history of science and technology. All moved forward from my ideas and approach. That was something special.
I wondered and realized that my research followed a unique path. Generally, researchers talk about the subject, identify the gap, and find the solution. As an example, for LED, they identified the large energy gap, which makes it worth it to take on the challenge. So everybody tackles this widely known problem. On the contrary, metal tape and perpendicular magnetic recording were not the research challenges society was asking scientists to solve. That is something I have been thinking.
But I didn't think my ideas were the only contributions to this success. The perpendicular disks were already everywhere when the 3.11 earthquake occurred. People watched and shared everything from all over the world via the internet. Then, I remembered that, 10 years prior to the earthquake, at the Science Council of Japan, using a cyclical model, I presented my logic that our science and technology must be utilized by and for the benefit of our society. I realized everything was set up for a moment like this. A few years later, Dr. Nakanishi and I were awarded the Order of Cultural Merit. We used to discuss such things passionately. I couldn't be happier as a researcher but I wondered if I was sent out to be a researcher for only that reason.

Tanaka: I think that is true.

Iwasaki: Yes, indeed. Otherwise, things would not happen just at the right moment. Now I understand why it took such a long time to get here.

Tanaka: Toward a compelling conclusion…

Iwasaki: Yes, now I can say to people that I am happy because I created something of real value. If I cannot say that, this would just be an empty success story.

Tanaka: Yes, thank you very much. I understand your meaning quite well.

Iwasaki: Do you?

Tanaka: Professor Iwasaki, I would like to ask you about the significance of perpendicular magnetic recording and its contribution to our civilization. In the past, there was criticism, such as Japan is enjoying free ride on basic research conducted in the west. In response to that, I think that perpendicular magnetic recording research demonstrated a significant step forward. What are your thoughts on this?

Iwasaki: In the early 1980s, when the research reached the most interesting phase, the west frequently raised a concern about a free ride on basic research, saying that Japanese scientists are enjoying a free ride. At that time, Dr. Clark Johnson started a venture business “Vertimag”. When I visited his company, he said to me that Japan took advantage of America for cars and semiconductors. Now it is time for America to take advantage of Japan for perpendicular magnetic recording and export products from American industries to Japan. I remember his words, “This is a true Give & Take relationship”. With regard to the free ride on basic research, he said that we should apply the same principle to basic research as well, and give and take basic ideas. That became a reality. The perpendicular magnetic recording created the world of big data and contributed to revolutionary change. America now utilizes the technology in big data very effectively. Japan is now behind and delayed. From that experience, I think, and I said it at some point in the past, that it is important to nurture a relationship based on mutual respect in the fields of science and technology. I think that still holds true today.

Tanaka: Yes, thank you very much. Looking at the tremendous flow of technological innovation from a historical viewpoint, you have proposed the 40-year rule. Could you tell us what that is?

Iwasaki: As I mentioned earlier, it took 40 years to go from triode vacuum tube to transistor, and from transistor to integrated circuit. From Marconi to optical communication, it took 80 years. What was in between? The microwave, at 40 years, fits right in between. In the field of electronics, this 40-year cycle holds true. I wondered why and eventually realized it is generational. It takes 40 years for a technology to mature. After 40 years, we reach the limit where we have nowhere else to go. Longitudinal recording reached the limit where it couldn’t handle high density recording efficiently; disk drives and video tape recorders. Then perpendicular recording was introduced, 40 years after 1956 when longitudinal recording was introduced. I remember telling everybody that we were on the right track.

Tanaka: Now perpendicular magnetic recording has spread around the world and has created a platform to store and utilize a huge amount of information. I think perpendicular magnetic recording is going to have a significant role as the “Rosetta Stone” of our age. What do you think?

Iwasaki: The Rosetta Stone of our age. That involves, for instance, the mystery of how the pyramids were built and it has been a popular topic to date. We would have the answer if we had the images stored from back then, but we don’t have any so it remains as a mystery. The same notion applies to us. But today we can leave our images for

future generations. I recently came to recognize that we live in a new "century of images." The previous "century of images" refers to images taken by professionals that document what we were like in the past. The images of our current century are being taken by individuals and will be left as data for coming generations.
Images hold much more information than texts. With this abundance of information and images, we are leaving our history of each of us. That is what I have been thinking about.

Tanaka: Professor, as a process of research, you proposed the cyclical model of research, "Creation, Development and Integration". I think this is an important way of thinking. Could you tell us about this model?

Iwasaki: I believe that science and technology should make a positive difference in the world. One could chase, simply and purely, after the universal truth, but we should also be able to help people's lives. The traditional model has been linear; creation, application, and development, but instead, I think the process should follow a cycle through creation, development and integration. As a process for science and technology, I proposed this cyclical model at the Science Council of Japan about 10 years ago, around the year 2000. We should now place perpendicular magnetic recording into the cycle of creation, development and integration in order to best utilize it for our society.

Tanaka: Perpendicular magnetic recording has greatly contributed to information technology, to civilization and to improve the quality of life in our society. What are your thoughts about this?

Iwasaki: Yes, you are right. At the end of the day, it is all about "Quality of Society", and that is what we are aiming for through science and technology. The idea of "Quality of Life" came to Japan, from the US and Europe, after World War II. This is a good idea. However, before that, we must have "Quality of Society". This is what I have proposed along with the cyclical model. After all these elements came together, the perpendicular magnetic recording was successfully placed into practical use. I am proud of this. Without taking all of these steps, it would just be a boring success story, just like many that are out there these days, don't you think?

Tanaka: Professor, now looking at the principle of science and technology, you once said "Science is the mother of technology, and technology is the father of science". This message also aligns with the concept of the cyclical model. Could you tell us about this?

Iwasaki: That's true. Science should be a means to make our dreams come true. However, in order to ensure our dreams come true, we need to have solid technologies. Otherwise, science will lose its way. After all, science and technology are continuously cycling.

Tanaka: Thank you very much.

Iwasaki: When we reach the point that we can say these sorts of things, perpendicular magnetic recording will have truly reached the point of completion. This is the story.

Tanaka: Thank you very much.

Iwasaki: I am happy and proud of it.

Tanaka: Professor, lastly, what message would you send to younger generations who are working on storage technologies?

Iwasaki: Storage technology made big data possible. Build civilizations that utilize big data at their foundation. That would be a mission for the next generation, wouldn't it? Build civilizations that utilize big data as their foundation. Big data can be images, or how can I say it, just the other day, the Go grandmaster was defeated by artificial intelligence software. I think, the AI played its hand by intuitively recognizing data sets from images. This is again big data. This is the way of thinking derived from big data.

Tanaka: The next generation should keep that in mind.

Iwasaki: Yes.

Tanaka: Thank you very much.

Iwasaki: That last conclusion is very important.

Tanaka: Yes, it is. Professor, thank you very much for your time. We learned valuable lessons from your point of view and way of thinking. Again, thank you very much for everything.

Iwasaki: You understand my Japanese very well. I expect your English translation will be very good.

Tanaka: I hope so. I will work on it.

Iwasaki: That was a complete study of my research.

Tanaka: We just have to finalize my research on the history of your research. Thank you very much.

Iwasaki: Well done.

END OF THE INTERVIEW

