Oral History of Shang-Yi Chiang

Interviewed by:
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Fairbairn: Okay. We're here at the Computer History Museum. It is March 15, 2022. My name is Doug Fairbairn and I'm here to interview Shang-Yi Chiang, right?

Chiang: Yes. <laughs>

Fairbairn: Is that right?

Chiang Yes. You did pretty well, yeah.

Fairbairn: And so we're looking forward to our oral history. Thank you very much for coming.

Chiang: Thank you, Doug. It's really a great honor. Thank you for the invitation.

Fairbairn: As I mentioned earlier, we'd like to start in the beginning. Where were you born? Tell me if you could a little bit about your family life, what your father and mother were doing at the time, any siblings? Tell me what kind of child you were growing up.

Chiang: I was born in China right after World War II in 1946. So I'm the early group of these Baby Boomers.

Fairbairn: Yes.

Chiang: I think it was pretty lucky; there are more opportunities when you grew up, I think.

Fairbairn: What part of China were you born in?

Chiang: In the city called Chongqing. Chongqing. It was during World War II, the Chinese government was pushed to move their headquarters to Chongqing because of the war. So my father at that time worked for the government. He was a civilian but he kind of worked for the-- His background, he was an aeronautic engineer. He was educated in his undergraduate in Shanghai, a university called Tongji University. And after that he fortunately got a government fellowship. He went to Germany for study, because that university was founded by Germans.

Fairbairn: Oh, I see.

Chiang: And there's some connections. So he studied aeronautic engineering, then the war, World War II, broke out. He got back, because I think at that time not many Chinese engineers in this field, so he was called back before he finished his study. Then he worked for the government. From what I can tell, it's at that time China was pretty-- a little bit behind in industry and also the military force. The airplane, for example, I think the airplane, it's far behind Japanese airplanes and so and the lack of parts. But basically, his job was, my impression was the airplane got damaged and they were trying to put a few airplanes together to make a new one and then go to fight again. And I heard my mother say they lived in the place with airplane pilots and my mother told us in the beginning there were about 100 of them, but at the end of the War there were only 2 left.

Fairbairn: Oh, my gosh, 100 to 2, huh?

Chiang: Yeah. And they were pretty young.

Fairbairn: Yeah.

Chiang: So of course my father didn't fly the airplane.

Fairbairn: Your father was an aeronautical engineer and basically designed airplanes?

Chiang: Yes. Manufacture, designing, in that area, yeah.

Fairbairn: So what did you mother do at the time? Was she--?

Chiang: My mother just, just a housewife.

Fairbairn: Housewife, homemaker.

Chiang: Yeah. I think she had some medical background. So at the end of the War, we moved back for to our own hometown which is about maybe 150 miles from Shanghai. So I was 2-months-old then.

Fairbairn: Two-months-old.

Chiang: We went back.

Fairbairn: And you were born in '46.

Chiang: Yes.

Fairbairn: Right after the War.

Chiang: Yes, right after the War, yeah. And my father began to look for a job and I heard he got three job offers. My grandparents -- I think they are not familiar with what my father did at all. But they are pretty devoted to Buddhism. So, my grandmother said that she would ask God as Buddha for a decision. And we didn't really know how she asked the Buddha, but she came back and said the Buddha said my father should go to the one furthest away from home, which was Taiwan.

Fairbairn: Oh.

<laughter>

Chiang: That's how--

Fairbairn: That's how you got to Taiwan, huh?

<laughter>

Chiang: I was quite impressed. My father listened to that. My father said, "Okay, we'll go to that one."

<laughter>

Chiang: So we went to Taiwan.

Fairbairn: So this was before the Communists took over--

Chiang: Yeah.

Fairbairn: And so you were in the right place to go forward then.

Chiang: Yeah, but my father went to Taiwan two years before the Communists took over. At that time, really nobody expected that would happen.

Fairbairn: Yes.

Chiang: But then, like, my mother, I had one brother, an elder brother, 3 years older than me. We, my mother and my brother and I, stayed at home. My father went to Taiwan by himself. But then a year later, the Communists began to win, and then my mother took my brother and I to Taiwan, so that was '48, 1948 when we went to Taiwan. So I didn't have any memory about my hometown at that time. So, I grew up in Taiwan. And my childhood was pretty boring, actually.

<laughter>

Chiang: That situation in Taiwan is all of a sudden there's a group of people I think like 2, 3 million people move from Mainland China to Taiwan. It got very crowded, so the resource is a problem. So that means the competition. So, we grew up in a situation that's quite competitive. So we start from elementary school. If you want to go to a good junior high, there's an entry exam. Go to senior high, there's an entry exam. Go to college, there's an entry exam. And all parents always say, well, you had to work and study hard and--

Fairbairn: Right. Jump over each hurdle.

Chiang: <laughs> Work hard-- Because the common sense is you don't start on the right track, it's difficult for you to catch up later. So that's my childhood from elementary school. Usually, you go into school and you get off at 2:00 PM. And then there's a special program my parents' arranged so another kind of private class until 5:00 PM. And at night, there is another kind of tutorial, kind of tutor. <laughs>

Fairbairn: So you were going to school all day long.

Chiang: <laughs> All day long.

<laughter>

Chiang: So far.

Fairbairn: Did you enjoy this or did you hate it or--?

Chiang: I hated it. I hated it.

Fairbairn: You hated it.

Chiang: Yeah.

Fairbairn: Is there any subject that you-- Were you good in math or what subjects did you find most interesting?

Chiang: Well, relatively speaking, I was much better in nature science, in math and chemistry, I feel. And in kind of literature, I am quite poor. So, until my college entrance exam, I remember my Chinese and English altogether on the base of 100, my Chinese and English altogether was 100 and my math and chemistry altogether was 180. There was a kind of gap.

<laughter>

Fairbairn: So you were learning-- you learned English throughout school, is that right?

Chiang: Started from junior high at that time.

Fairbairn: Junior high, okay.

Chiang: Yeah.

Chiang: But these days in Taiwan, start from kindergarten they begin to learn English.

Fairbairn: So, at what point did you decide to come to the U.S. for college? Is that something you always intended to do or something that was decided later?

Chiang: In my time, so I was fortunate enough to be able to get into National Taiwan University which was a top in Taiwan. And in EE almost every one of my classmates had in mind afterward they should get more education in U.S. So as a result, actually, we finished the college, we serve in military. We went into military the same day we discharge the same day. I get off in I think on July the 2nd and by the time the school started in late August, early September, so we-- I came to U.S. August 28th and at that time there are very few flights between Taiwan and the U.S. for the students had a charter flight.

Fairbairn: Oh. For all the students coming.

Chiang: For all the students.

Fairbairn: Mm-hmm.

Chiang: And on the charter flight I took, there are 18 of my classmates from National Taiwan University EE, 18 of us on the same flight.

Fairbairn: Oh, my God.

Chiang: And about 80 percent of my classmates come to U.S. that summer 2 months after we discharge from military.

Fairbairn: Wow. And what year was that? August?

Chiang: 1969.

Fairbairn: 1969.

Chiang: Yeah.

Fairbairn: So you got a Bachelor's degree in Taiwan.

Chiang: Taiwan, right.

Fairbairn: And then you served a year in the military?

Chiang: Right.

Fairbairn: And then you came to Princeton, is that right?

Chiang: Princeton, right.

Fairbairn: And how did you choose Princeton?

Chiang: At that time, we just apply from a long list.

<laughter>

Chiang: And I got accepted by Princeton with some scholarships from Princeton.

Fairbairn: Had you chosen a specialty in electrical engineering? Were you interested in semiconductors or what had you studied in Taiwan?

Chiang: I choose semiconductors because it happened that we had a system and some chaired professor, most come from U.S. universities, came to Taiwan for a year. And when I was a senior, we happened to have 2 of these chair professors in semiconductor area. So I took some semiconductor courses. At that time, our possible choices are control, power and communication, semiconductor. And computers just started, all those areas. So, I happened to because I think my own interest was more towards physics.

Fairbairn: Towards what?

Chiang: Physics.

Fairbairn: Mm-hmm. Physics, yeah.

Chiang: So, I chose semiconductor. Communication and information theory, I think more involved in mathematics. I went to Princeton. Princeton was very famous, of course, and I was very happy. But after I got there, I found Princeton was very, very academic, actually. At that time I think they are top in Physics, Mathematics and Philosophy. In EE, the first-year graduate student, they took advantage of this. If you were semiconductor major the first year, they send you to physics department to take courses. Then the second year you come back. For information theory, they send you to mathematics and that was the situation. So, I went to Princeton, and I was very shocked. It's very academic in most field. We lived in graduate student dormitory called Graduate College, which is in I think the South End of the campus at the side of the golf course, very beautiful, and the dormitory, the dining room is like a church, very high ceiling, it's stained--

Fairbairn: Big windows, stained glass windows, right.

Chiang: Stained glass windows.

Fairbairn: Yeah.

Chiang: Very beautiful. And by then, they still endured this British tradition. We, when we go to dinner, it's open at 6:30, you had to wear this black gown every night for dinner.

Fairbairn: Oh, wow.

Chiang: And you line up before 6:30 and they check your meal card and then you go in. There's a long table, I think about maybe 8 to 10 people each side on both sides. And when you, it's a high-- It's a pretty formal chair. You go in, you find a place. You stand behind the chair and when everybody was in position, they had a short prayer in Latin. And I never understood what they said. <laughs> And then you sit down. After you wear that black gown, you tend to be really formal, so you talk to people very politely. And then on the table there may be 2 milks and a 2 iced tea and if you want iced tea, it could be on the other end of the table. "Would you please pass the iced tea? Would you please pass that the iced tea…

Fairbairn: <laughs>

Chiang: "Would you please pass the iced tea?" Then you get the iced tea, so. I was very impressed. And the entire place just give you feel very, very academic.

Fairbairn: Yeah.

Chiang: And I thought if that's great if I want to be a scholar and I really don't want to be a scholar.

Fairbairn: Yeah.

Chiang: So, I decided I had to find another place.

Fairbairn: Besides the formal dinner, it must have been quite a shock moving to the United States from Taiwan. Had you ever been outside Taiwan?

Chiang: No. We-- At that time, we couldn't.

Fairbairn: Yeah.

Chiang: It's under martial law, so for males you cannot leave the country after you are 11-year-old until you finish the military service. Otherwise, people would sneak--

Fairbairn: Yeah. Right.

Chiang: So we cannot leave the island until we finish the service. So I'd never been abroad.

Fairbairn: So you must remember when you first landed in the United States?

Chiang: <laughs> Yeah. Also one thing was at that time in Taiwan, we worked 6 days a week and I was very impressed you have 2-day weekend.

Fairbairn: <laughs> So there were 18 students that came from your university. Did they all go to Princeton, or did they go to different colleges in the United States?

Chiang: Eighteen is only the same airplane with me.

Fairbairn: Right.

Chiang: So--

Fairbairn: And did they all go to Princeton?

Chiang: No.

Fairbairn: They went to--

Chiang: Yeah. Altogether, we I think there are about 50 of my classmates came just that summer. So about 80 percent of my classmates went on to the U.S. graduate school at that time. But these days they don't do that anymore. I think 2 of my classmates went to Harvard; 3 or 4 went to Berkeley; 3 to Yale; 2 to UPenn - just all over the place.

Fairbairn: It's remarkable you remember all of that.

<laughter>

Fairbairn: Who went where.

<laughter>

Fairbairn: So you were there for a year.

Chiang: Right.

Fairbairn: And you it sounds like you quickly decided that this was not your long-term home.

Chiang: Right.

Fairbairn: And you moved on to Stanford. How did you choose Stanford for your next--?

Chiang: I applied for the real engineering schools. MIT, Berkeley, Stanford, Caltech. And I was accepted by Berkeley and Stanford. I was not accepted by MIT and Caltech.

Fairbairn: I didn't get accepted by Caltech either.

<laughter>

Fairbairn: I lived in Pasadena. That's where I grew up.

Chiang: You did? <laughs>

Fairbairn: Yeah.

<laughter>

Fairbairn: My father wanted me to go but I said, "No, no. I don't want to--" Fortunately, I didn’t get in, so I didn't have to have that discussion.

Chiang: So you lived in Pasadena but you went to Stanford. Dr. Shockley live in Palo Alto but he went to Caltech.

Fairbairn: Yeah.

<laughter>

Chiang: And then I applied for these universities and I was fortunately accepted by Dr. Pearson. He was already 65 at that time.

Fairbairn: Who was that?

Chiang: Dr. Pearson.

Fairbairn: Uh-huh.

Chiang: And he was old timer from Bell Labs. Worked with Shockley and those people. So I went over to Stanford to work for him.

Fairbairn: You must have found Stanford quite different from Princeton.

Chiang: Oh, yes. Yes.

<laughter>

Chiang: I was shocked.

Fairbairn: No formal dinners. <laughs>

Chiang: I went over. I think I arrived Saturday and my advisor was very nice. He asked one of his graduate students to pick me up and send me to the dormitory. And Sunday morning I got up, it was a brunch. And a girl with pajamas come to brunch. <laughs> They look better than wearing the big gown.

Fairbairn: No black robes, just pajamas, huh?

<laughter>

Chiang: Look better than the black robe. <laughs> Yeah. And Stanford is very much an engineering school, so I really, really enjoyed it.

Fairbairn: Who was your advisor?

Chiang: Dr. Pearson.

Fairbairn: It was Pearson, okay.

Chiang: Yeah, it was Pearson. I worked for him. He unfortunately passed away. He was already 65 when I had my--

Fairbairn: So you were committed to study semiconductors. And what was your Ph.D. thesis on?

Chiang: On gallium arsenide material.

Fairbairn: Oh, gallium arsenide.

Chiang: Yeah. At that time it was the material of the future.

Fairbairn: Yes, it was. I remember that.

Chiang: <laughs>

Fairbairn: It was the fastest thing you could get your hands on.

Chiang: Right. The mobility is much higher.

Fairbairn: Yeah.

Chiang: Yeah. But then I began to work on silicon when I joined TI. And then--

Fairbairn: So who were the professors that had the biggest influence on you?

Chiang: Yeah, must be Professor Pearson. And later on, when I worked at Hewlett Packard, for quite a long time my boss was Dr. John Moll.

Fairbairn: Oh.

Chiang: Actually, he was my boss but he was much more like my advisor.

<laughter>

Chiang: He was very, very academic.

Fairbairn: Yeah.

Chiang: Very much like a scholar type of person.

Fairbairn: Yeah.

Chiang: And he was a Stanford professor but he left a year or two before I joined. I think I learned a lot from Dr. Moll actually when I worked for him at HP. And he was more like my thesis advisor. That's when I was very impressed with him because when we were at HP Labs, when you have a problem, I thought it was an engineering problem. But you sit down with him, he began to derive the problem from Newton's Law.

Fairbairn: <laughs>

Chiang: It was very impressive. Some really fundamental, very basics.

Fairbairn: Yeah.

Chiang: So I think that's the best way to resolve the problem.

Fairbairn: So upon graduation from Stanford you went to Hewlett-Packard, that was your first to HP Labs?

Chiang: When I graduated from Stanford, it happened that time was during the Recession, so my first job was a company called ITT.

Fairbairn: This is in 1974.

Chiang: '74, yeah. ITT, they make this GaAs laser, LED for the fiber optics communication. They had a fiber optics communication program, and they need a light source, so I got my first job was to work for them for this light source. A small group of 5, 6 people only.

Fairbairn: So this would build on your thesis in gallium arsenide.

Chiang: Right.

Fairbairn: That was directly applicable.

Chiang: Right, yeah. And so then later on, I worked there for about a year and a half, so I thought the first job I think more ideally, firstly that I think I should study a broader field in silicon. Also, I think the first job better to be in a place you can see more, not just such a small group and TI seems to be a good place so I worked for TI.

Fairbairn: Oh, so you went from ITT to Texas Instruments.

Chiang: To TI. Right, right.

Fairbairn: And how long-- You know, tell me about your career there. How long did you spend there?

Chiang: I worked there for about 5 years.

Fairbairn: From like '76 to--?

Chiang: '76 to '80.

Fairbairn: '80, '81.

Chiang: Yeah. About 4 years. Like early '76 to late '80, so 4-1/2. At that time, Morris Chang already was 10 levels <laughs> above me.

Fairbairn: Ten levels above you.

Chiang: Right.

<laughter>

Chiang: I didn't really know him.

Fairbairn: What did they hire you to do? What was your first job at TI?

Chiang: My first job was to make silicon solar cells.

Fairbairn: Oh.

Chiang: That time was the oil embargo was in '73.

Fairbairn: Yeah.

Chiang: So, U.S. government began to study to start a program to promote--

Fairbairn: Alternative energy and--

Chiang: Alternative energy.

Fairbairn: Right. Sun.

Chiang: Yeah. So, we made silicon solar cells. They set a very aggressive goal actually at that time and never reached it. And one interesting thing we found was that we make a solar cell at that time efficiency was about 10 to 12 percent only. These days, it's almost 20 percent. And we found that also we used that top grade silicon and with the traditional semiconductor process, use the same equipment we make MOS circuits. So we-- It doesn't matter the cost. Disregarding to the cost, but the energy we're spending on making these silicon solar cells, if you put these solar cells under the sun for 20 years, you cannot recover--

<laughter>

Fairbairn: You know, somebody told me that a long time ago and mentioned that the power to make it was more than the power it would ever generate.

Chiang: Right.

Fairbairn: That has changed, I presume?

Chiang: That has changed, yeah. I checked into that. It's not the case anymore. Today, I think there was a company called SunPower started by some Stanford professor. They made the highest efficiency solar cell by putting the junction in the back side of the silicon. Actually, I was the first one to put the active junction on the back. Because we studied silicon solar cell. At that time, all the junction is on the front side. One problem is your metal, your metal will block about 15 percent of the light.

Fairbairn: Right.

Chiang: And it's already there. But we started with the idea that what if we also put a junction on the back. So, we collect the power from both front junction and a back junction. So we make this solar cell. We found we can add about 10 percent of the collection, which is not very much. But when we studied that, I found if I disconnect the front junction, I only could measure the back junction, I can get about 90 percent of what I collect on the front junction. And the reason is the electron mean free path -- and even though the light penetration, most of the blue light was absorbed in the very narrow, very thin layer, the red light can penetrate longer. The absorption coefficient, or the penetration depth, is a function of wavelength.

Fairbairn: Right.

Chiang: So the solar cell, there’s a surface recombination, the older the traditional thought, the conventional thought, was because a lot of surface states and also when you make the junction, you damage the silicon, so the top layer usually has a lot of recombination center which is that would be a loss for your collection. That's why people never thought about putting it [on the] back, because the top surface will eat you alive. Even if you, even a lot of photons generated deeper and also your main free path was long enough for electron to reach the back surface, but the top surface will eat you alive.

Fairbairn: The top surface was what?

Chiang: Has many silicon crystals damaged.

Fairbairn: Oh, I see.

Chiang: And also the surface states--

Fairbairn: Yeah.

Chiang: it will trap your carriers. So if this carrier got trapped, they never reach, they'd never be collected.

Fairbairn: Right.

Chiang: So it's a loss.

Fairbairn: Right.

Chiang: But if we put a front junction and we leave it floating, actually, these it had a buildup energy which will push electron towards the back. So, if we leave the damaged front junction floating and you can collect from the back side. And if you make the solar cells thinner, so finally to the point, because with the thick solar cell, I can, if I leave the front junction floating and I only collect from the back side, I can get about 90 percent. I can get about 90-- Well, if I'm, the conventional solar cell had a front side collection, so if you, if I have a 10 percent efficiency. If I leave the front junction open and I collect from the back junction, I can get 9 percent. But if I-- The front side metal takes 15 percent. If I remove that front side metal so if I only collect from the back side, with the front junction floating, I can get 11-- 10.-- I can get 10.5 percent which is better than 10 percent.

Fairbairn: Mm-hmm.

Chiang: If I make it thinner then I can begin to get 11 percent, 13 percent. I believe I was the first one to propose we make the junction on the back side and then later on, this was about 20 years later, I think SunPower made the best efficiency commercial solar cell putting the junction on the back side. So, I think that was my major contribution in silicon solar cell.

Fairbairn: So did you work on solar cells the entire time you were at TI?

Chiang: No. Two years.

Fairbairn: Two years.

Chiang: Yeah.

Fairbairn: And what was the other projects?

Chiang: Then I began to work on NMOS and the CMOS. I worked for a person named Al Tasch. You probably have heard of him. Al Tasch.

Fairbairn: Al Cash?

Chiang: Ai Tasch, T-A-S-C-H .

Fairbairn: Oh, yeah.

Chiang: He later became a Professor at UT Austin. Yeah. I worked for him. And I learned a lot from him. He got his Ph.D. from Illinois under CT Sah (a few words were deleted) who worked his graduate students very, very hard. They were well-trained. Then when Al Tasch came to TI, he (words deleted) drove us very hard. <laughs> Don't take it seriously. He's a very good mentor--

Fairbairn: So you became familiar with both NMOS and CMOS.

Chiang: Right.

Fairbairn: During that time.

Chiang: At that time, CMOS just started.

Fairbairn: Yeah.

Chiang: Just began to get started.

Fairbairn: Were you developing it for a certain product? Or--?

Chiang: TI at that time, because CMOS just got started, we more like only trying to learn how to make CMOS. And interesting at that time was you can develop one entire technology with one engineer. I can run some SUPREM simulation to simulate and then I do the diffusion. I push my own wafer on a quartz boat into the furnace – pull it out, see what the timing…

Fairbairn: <laughs>

Chiang: Makes it is a 5 micron CMOS technology. We can do that. Later on I think when I left TI it was probably 1 micron CMOS technology. So I learned a lot from Al Tasch.

Fairbairn: So by this time you had gallium arsenide,--

Chiang: Silicon solar cells.

Fairbairn: Solar cells, solar-- silicon solar cells, NMOS and CMOS.

Chiang: CMOS.

Fairbairn: Information. So you in just a few years, you had developed a pretty broad understanding of semiconductor technology.

Chiang: Right. So, for all my career, I'd been working on more areas. Usually, we call it integration engineer. You are broad but you are not deep, so you know a little bit about many things but not, you know, somebody that works on the same field for 40 years, not that kind.

Fairbairn: You then moved back to California to go to Hewlett-Packard, is that right?

Chiang: Right. Yeah. Partly, it's my Asian background. It feels more comfortable in California.

Fairbairn: Mm-hmm. Where were you in Texas?

Chiang: Dallas.

Fairbairn: Dallas, uh-huh.

Chiang: Yeah. I think in Texas, especially, even though you come from Illinois, you are an outsider.

Fairbairn: <laughs> You are not from Texas, that makes you outsider, huh?

Chiang: Right, right. So we feel, just for Asian community, more convenient grocery shopping, go to restaurant. So, we moved back to California.

Fairbairn: So you were at TI until 1980?

Chiang: Yes, 1980.

Fairbairn: And then you moved back to Hewlett-Packard.

Chiang: Right. I moved to--

Fairbairn: Did you, had somebody approached you from Hewlett-Packard or were you--?

Chiang: I applied.

Fairbairn: Out looking-- I'm sorry?

Chiang: I applied.

Fairbairn: You applied.

Chiang: Right.

Fairbairn: And was this to HP Labs?

Chiang: Yes. I worked for Dr. John Moll.

Fairbairn: John Moll, yeah.

Chiang: Yeah.

Fairbairn: So tell me about, so you were at Hewlett-Packard for quite a while then, 15 years?

Chiang: Seventeen years.

Fairbairn: Seventeen years.

Chiang: Yes.

Fairbairn: And were you in HP Labs that whole time?

Chiang: HP Labs, you know. We reorganized the-- in the same organization, Hewlett-Packard started a circuit technology group. They decided that they wanted to make a semiconductors not a money loser, so they started a circuit technology group and then moved this IC lab from HP Labs to Semiconductor Group.

Fairbairn: I see.

Chiang: So we began to in the same organization change the name and the same location. So it became Circuit Technology Group on the—And later on, they moved back to HP Labs.

Fairbairn: So what was your first job at Hewlett-Packard? What did they hire you to work on?

Chiang: To develop some technology in different project, but it's all related to develop a CMOS technology. I worked on a CCD project. I worked on a CMOS project. And I also worked on a bipolar project. I was appointed the program manager to develop one generation of bipolar they call HP-25. I think they still use HP-25 in production right now. Mainly for the instruments. Instruments still use bipolar for its high speed. Not very large volume. In HP Labs, I happened to get caught in the time. This IC industry, you know very well, <laughs> it there's one period of time I think in the seventies, eighties, every company wants to have their own IC technology.

Fairbairn: Right.

Chiang: Build your own fab.

Fairbairn: Build your own fab, right.

Chiang: Yeah.

Fairbairn: Absolutely.

Chiang: <laughs>

Fairbairn: Hewlett-Packard had several fabs.

Chiang: Many, many, yeah.

Fairbairn: <laughs>

Chiang: So the time I was in Hewlett-Packard, especially the late stage, they began to realize it didn't make sense, so they began to consolidate all the IC technology. And actually, later on I realized HP already planned to phase out the IC. So the later part of my career at HP was always under the pressure to consolidate. Your budget got cut every year, and you would never hire on a new person. And later on, the lab was closed, all those kinds of things.

And if we think back, it's really also our own fault because we kind of joke at each other. Like we say we began to develop the .5 micron CMOS. And then we never finished it. Then we say, "Oh, no, .5 micron was too old. It's not advanced anymore, so let's work on .35." So we always want to work on the most leading edge technology but never complete anything. Now I think back, there was a problem of HP Labs IC Labs. We always work on the leading-edge technology but never complete any project and never transfer any technology to manufacture it. So, the end of the-- it began to be obvious that you can tell the company, you are not welcome in the company.

<laughter>

From the budget and from the hiring was just-- But the last--

Fairbairn: So you worked on CCDs and what other kinds of technology did you explore there?

Chiang: CCD, CMOS technology and the bipolar technology, mainly those three for different applications. Most of the CMOS. Bipolar we target on the instruments.

Fairbairn: Yeah.

Chiang: CMOS, target on the computer.

Fairbairn: Right.

Chiang: The customers for CMOS are in Cupertino and for the bipolar in Fort Collins, Colorado.

Fairbairn: Right. So, but you stayed for 17 years. It sounds like it was frustrating, things never going to completion. But--

Chiang: Yeah. Hewlett-Packard is a very, very good company to work for. The culture, I really love it. I really enjoyed it.

Fairbairn: Yeah.

Chiang: But now if I look back, for IC technology, you really need scale. You really need a large scale; so, the small scale, it just cannot survive. It cannot be competitive.

Fairbairn: Certainly, in semiconductor technology, where it's so expensive to do anything, right?

Chiang: Right.

Fairbairn: <laughs>

Chiang: Yeah, from the very basic. Because equipment is so expensive. If today you want to work on the 16-nanometer technology, for example, and you need 300 different equipment. And with 300 different equipment, every equipment has their own throughput. Some equipment you can make 300 wafers in an hour. Another equipment can only make 3 wafers in an hour.

Fairbairn: Oh. <laughs>

Chiang: Actually, it's true. Epiwafer, Epi, the deposition only makes 3 wafers in an hour.

Fairbairn: Oh, wow.

Chiang: And when you want to set up a line, an R&D line, you buy these 300 pieces of equipment and your throughput is 3 wafers an hour and that [equipment] with 300 wafers an hour, sit there for 90 percent of the time.

Fairbairn: Right.

Chiang: Idle.

Fairbairn: Right.

Chiang: So at that time, your equipment cost, your depreciation, your equipment efficiency becomes very, very low, so your cost very high. And for the 3 wafers an hour, you buy another equipment then all of a sudden, your throughput went up to 6 wafers an hour. So if you look at the capital cost per 1,0000 wafers vs total capacity curve. It comes down like that. In the beginning, it's very, very high because many equipment are idle. When your capacity becomes bigger and bigger, it will drop. So, this when it comes to the knee, this knee point is about 15,000 to 20,000 wafers per month. So, these days people who want to make a new technology, leading edge technology wafer fab, you need to be about at least 30,000 wafers per month to be competitive. Because even as that time, your entire fab cost of 55 percent was the depreciation even though you reached the plateau.

Fairbairn: Yeah.

Chiang: So if the fab's capacity is much smaller than 30,000 wafers a month, you can see you're not competitive at all. Your costs will be much higher than your competitors. And in addition, if your company has small capacity, when you buy equipment from Applied Materials, from Lam Research, you pay much higher price. We know that the gap could be 15 percent or more. When Samsung or TSMC pay for the same equipment, their cost can be 15 or 20 percent lower than a small wafer fab. So in all these things, it is the economy of scale that really plays a pretty key role. On top of that, these days if you want to develop the leading-edge technology, your cost, you need to have at least about $2 billion dollars in the budget to be able to develop the most leading-edge technology. Then if you have $2 billion dollars, your revenue needs to be about $40 billion dollars revenue.

Fairbairn: $40 billion dollars?

Chiang: $40 billion dollars, yeah. That's fine today. It's only TSMC, Intel and Samsung who can afford developing more leading-edge technology because they're all $40 billion dollar above. And number four is less than $10 billion dollar, so they cannot afford that.

Fairbairn: Is there anything notable or important that you wanted to mention about Hewlett-Packard before we move on to TSMC? You've sort of alluded to some of the costs and production characteristics of TSMC but from a technology point of view or from, you know, from later impact on your career, were there other important things that happened at Hewlett-Packard?

Chiang: Hewlett-Packard later on, I think they realized this problem so the Circuit Technology Group, they have to be responsible for their own profit and loss, so they also began to do foundry business in order to expand their capacity.

Fairbairn: Yeah.

Chiang: They build capacity, yeah.

Fairbairn: Right.

Chiang: But it's just not enough. So, we began to realize, we tried pretty hard to get into the foundry business, but didn't do so well. At HP we did some benchmark at that time, like with TSMC. Because HP was one of the potential customers TSMC targeted. So, we sent some team to look at the TSMC fab. And they came back, they said, they actually went to count how many steppers TSMC has in this fab and how many we had and what's their capacity and what is our capacity.

Fairbairn: Right.

Chiang: And there was a very large gap. It's about 50 percent gap. So that in Taiwan, you can use fewer equipment, you can produce more wafers. So, at that time, actually, Hewlett-Packard began to realize all these things but it's a little bit too late. Also, I enjoyed HP's culture. I learned if we start a project, everybody has different, their own, opinion. "I want to do it this way. I want to do it that way."

<laughter>

Chiang: And HP is quite democratic. "Let's talk about it." So, you have 10 different opinions and the people just fight and people argue. But then HP management are trained to have a way they will begin to converge. So finally, they all agree on one approach. Everybody had opinion to express their own way, but finally agree on that, so everybody supported that. And that was a strength at HP. I found that very, very effective. Later in my career, I tried to do it that way.

Fairbairn: So, then you moved on to TSMC. Is that right? The next step was TSMC?

Chiang: Yes.

Fairbairn: And did Morris Chang come looking for you?

Chiang: <laughs> I didn't really know him at all. At that time, Morris Chang was Chairman and there was a General Manager, Dr. F. C. Tseng. I didn't really know him very well. I met him at a conference a couple times and that's about it. And one afternoon, I came back from work because the 5:00 PM here is 8:00 AM in Taiwan.

Fairbairn: Right.

Chiang: So I just got home from work and got a phone call from a person. And interesting, I didn’t really know him well and he said, "We have an opening for VP of R&D. You come to work with us. Here, this is the salary, and this is your responsibility, and this is a signing bonus. I don't need to go to interview. That was a job offer.

Fairbairn: <laughs> Did he tell you what you were to work on? What did they want you to work on, to do?

Chiang: VP of R&D.

Fairbairn: VP of R&D, I see.

Chiang: Yeah. It was that simple.

Fairbairn: <laughs> So how old was-- This was 1997?

Chiang: This was 1996, actually.

Fairbairn: Six.

Chiang: Yeah.

Fairbairn: And when had TSMC started?

Chiang: '87.

Fairbairn: So, it was 10 years old at the time?

Chiang: Ten-years-old. So at that time, I got this phone call, I said, "Oh, no, thank you very much, but I never thought about going to Taiwan."

Fairbairn: Yeah.

Chiang: And it was '96. I was 50-year-old. And I saw that because TSMC was very small company and may not be very stable and of course, I have my mortgage to pay and my children's tuition to pay. If I work for TSMC, if something happened, it would be difficult for me to find a job in reality. So I said, "Thank you. Well, my children all grow up here, so." So my first reaction was no. And later on, we actually talked about half a year before I finally joined the company.

Fairbairn: So that required you move you and your family to Taiwan? Or were the children older?

Chiang: I was in Taiwan all alone by myself for all these years.

Fairbairn: Oh, my gosh.

Chiang: And my family, they're all in here. Yeah.

Fairbairn: How old were your children when you moved to Taiwan?

Chiang: Oh, actually, my younger one just got into college. So the time I moved to Taiwan, my daughter just graduated from high school. And she was accepted by Stanford, so they kind of grew up. Well, finally, it's pretty from the more realistic way, it's unfortunately, it's this job, you're somebody work for fun; and somebody work for food, right? <laughs> And you've got to consider the realistic part, the job security of these things. I did feel insecure for the job in the TSMC at that time.

Fairbairn: Right.

Chiang: That's why I didn't take it. HP was very different. It had a good job security. So finally, I realized that you know, the person contact me, he told me this will be your signing bonus in terms of how many TSMC shares.

Fairbairn: Shares, uh-huh.

Chiang: It's free. And one day he told me, he said, "You know how much TSMC's stock price was?" I don't know and he told me. And I did a simple calculation and this stock will be granted the day I join the company. There's no--

Fairbairn: No vesting.

Chiang: No vesting period. So we give to you just the sum.

Fairbairn: Yeah.

Chiang: And I just so did it, "Oh, I didn't realize the--" According to the market price for the stock and the shares they give to me, if I work for HP until 65, based on my salary at that time, the HP salary, TSMC stock was more.

Fairbairn: Right.

Chiang: So then I thought from the financial point of view I really have no risk, so I joined it. <laughs>

Fairbairn: Yeah, it's salary guaranteed--

Chiang: <laughs> But later on, actually, the financial compensation was much, much better and--

Fairbairn: Yeah.

Chiang: At TSMC.

Fairbairn: So going from the kind of environment you describe at Hewlett-Packard, which was more R&D-oriented and you know, the projects didn't finish and so forth, you were moving to a very different environment--

Chiang: Right.

Fairbairn: At TSMC. Plus, you're moving, Taiwan had changed a lot since you left there--

Chiang: Right.

<laughter>

Fairbairn: I presume you've gone back and forth? You visited many times family or other things there during-- you were in the U.S. from '68 to--?

Chiang: '69 to '97.

Fairbairn: '97.

Chiang: Yeah.

Fairbairn: So almost 30 years in the U.S.

Chiang: Right.

Fairbairn: And did you go to Taiwan many times?

Chiang: Not many times.

Fairbairn: Not many times.

Chiang: A couple times. Yeah. Two, three times only. So, I did go through this reverse culture shock.

Fairbairn: Yeah.

(several lines were removed)

Chiang: I reported to Dr. Morris Chang who set very high expectations to his staff. After I worked for him for several years, I began to realize because I began to think during the time I worked for TSMC, I worked very long hours. Typically, I'd go home maybe 9:00, 10:00 p.m. because I had no family.

Fairbairn: No family. Yeah.

Chiang: Yeah.

<laughter>

Chiang: Then I began to realize he went home 6:00 every day.

Fairbairn: <laughs>

Chiang: And he has a lot more responsibility than I did.

Fairbairn: Yeah.

Chiang: I only take care of R&D and you take care of the manufacturing, sales, marketing, government relationship, press and customer, need to take care of all this. And how come he can go home at 6:00 every day?

Fairbairn: Right.

Chiang: Then I began to learn his secret. If he asked you to give a presentation, he had very high expectation. He expected you will tell him the most important thing in your area and this thing is something he didn't know. That's his expectation. You probably have 30 minutes. So you began to in my-- as an engineer, I was trained when I give a paper, I began to talk about it, "Here is a problem and this is my experiment. This is my approach."

Fairbairn: Right, yeah.

Chiang: "And this is my data. And this is my interpretation and here is my conclusion."

Fairbairn: Right.

Chiang: If you make a presentation to him in that way, you're in big, big trouble.

<laughter>

Chiang: He totally has no patience for this sort of thing. So, you have to go reverse direction. You tell him, "This is the result." Then he says, "Oh." Then he thinks, "My 30 minutes already paid off." Then he will be very patient to listen to you on the details.

Fairbairn: I see. <laughs>

Chiang: And even very nice to you.

<laughter>

Chiang: And very, very patient. Because his 30 minutes already paid off. He already got what he wanted.

Fairbairn: Right.

Chiang: But if you start it the other way, he got lost in 5 minutes then the other 25 minutes, you really have a hard time. He will tear you apart. He will blame you. He will criticize all this, and he will tear up your paper and tell you to get out. <laughs>

Fairbairn: So how long did it take you to figure this out?

Chiang: <laughs> Probably about four, five years.

Fairbairn: Four or five years.

<laughter>

Chiang: But I shared with many colleagues.

Fairbairn: Did you then tell other people the secret of how you work with Morris?

Chiang: Yes. Yes, I did.

<laughter>

Chiang: I make the little troubles go away.

Fairbairn: So when you joined TSMC, TSMC was not a leader in technology. Right? When you left TSMC--

Chiang: Yeah.

Fairbairn: The whole world looked to TSMC as the most advanced semiconductor technology in the world.

Chiang: Yeah.

Fairbairn: What did you do?

Chiang: When I joined TSMC, when we sent a paper to IEDM, people don't even look at that. "From TSMC? Oh." <laughs>

Fairbairn: Yeah.

Chiang: But the difference is that when I-- I think when I left TSMC, "If this paper is from TSMC, it will be accepted." <laughs>

Fairbairn: No matter what. It doesn't matter what it says.

Chiang: Right. <laughs> That's the only difference. No, when I start at TSMC, R&D only has 120 people, a very small group.

Fairbairn: In the whole company or in R&D?

Chiang: R&D.

Fairbairn: R&D.

Chiang: Only 120 people. And people are very-- have very little experience. So my title was VP of R&D. Actually, I was like a project manager. I got into all the details how to design a transistor, all these things. When I remember at that time, we had a transistor designer who… When you design a transistor, you decided what is the doping profile, what oxide thickness for the dimension, give you the threshold voltage, give you the best performance. When you design a transistor, he only tried to pick up a random spot. "Oh, okay. This meet all my requirements to do that." He never check the neighborhood around that. Because you had to have a process window. "If this spot will work, what if you deviate a little bit you fall into a cliff, then you shouldn't choose that spot." This was one example. They didn't have enough experience.

I joined the company I think on June-- July 6th, and I worked all day, all night, every weekend, Saturday and Sunday. I live in the dormitory in the Science Park about a couple hundred meters from the office. I seldom left the Science Park except go to get a haircut, buy some groceries. I worked days, nights, weekends, holidays. The first time I went hiking with my friends was October 25th. It was a national holiday at that time, so for 3-1/2 months I worked every day and every night. Because at that time, they were developing .25 micron technology. And during the .25 micron technology development, they changed four R&D VP's. I was number four. And they changed three program managers and I was the last one to clean up. We had identified five major technical problems which needed to be resolved. And honestly, I did take some advantage of the knowledge I already learned to help solve some technical problems.

Fairbairn: That you had learned at Hewlett-Packard? Or--?

Chiang: Yes. I learned at Hewlett-Packard. Yes. I didn't steal any company documents there and the secrets--

Fairbairn: Right.

Chiang: But I went through that, so I--

Fairbairn: You knew, yeah.

Chiang: I knew that. So that was my-- the first--

Fairbairn: Now were the people that were working for you, were they working these hours also?

Chiang: Pretty much.

Fairbairn: <laughs> Everybody. <laughs>

Chiang: Pretty much. One night because I was alone by myself, I remember one of the Friday nights at, like, 1:30 AM my telephone rings. And I couldn’t believe anybody would call me at 1:30 AM.

Fairbairn: Right.

Chiang: But I still decided to pick up. It was my wife calling from the U.S.

Fairbairn: <laughs>

Chiang: And she was very impressed I still work. And she--

Fairbairn: She wanted to make sure you were behaving yourself, huh? <laughs>

Chiang: After I got home-- Okay, she was very nice. After I got home, my phone recorder got a message with a very nasty. "1:30 AM? Where are you?" <laughs>

Fairbairn: Yeah, "Where are you?"

<laughter>

Fairbairn: Thought you were out partying, right?

<laughter>

Chiang: Yeah.

Fairbairn: Just call me at work.

<laughter>

Chiang: And I was so lucky. At that time, there was no cell phones like now.

Fairbairn: Yeah.

Chiang: If I happened to have gone to the bathroom or driving home, I didn't get that--

Fairbairn: You would have missed the phone.

Chiang: Missed the phone. I couldn't explain--

<laughter>

Fairbairn: So getting the quarter micron, technology turned around, it sounded like it was in trouble.

Chiang: So we released the .25 micron, still not in a very graceful way because still a lot of all kind of problems. But we struggled. We got it released anyway. And until the next generation is the .18. And .18, we run into some interesting problem. In the metal interconnect, you have the metal, you have dielectric; you isolate your metal lines with dielectric. And at that time, people began to have that. Used to be all the dielectric are silicon dioxide. It's a very good insulator. Then people began to realize, I want to reduce the capacitance, so I have to reduce the K-value of the--

Fairbairn: K. Yeah. You need low K.

Chiang: Need low K, right, right, right. At that time, low K already began to be the idea. Well, the first generation low K called FSG, they put some flourine in the SIO2, and the K-value would drop a little bit. So we used FSG for .25u. And at .18u, somebody had a clever idea. We will make something very similar to FSG but use a spin-on technique. You do not have to go through the chemical vapor deposition. And spin-on has two advantages. One is lower cost. And the idea for the spin-on… If they dissolve this silicon dioxide in some kind of solvent, so you allow you to spin-on, it's cheaper. And then later on, you bake it, you evaporate this solvent in the SiO2, it will leave the SiO2 on the wafer. Another advantage is it will be more planarized. Because spin-on

Fairbairn: Flatter then, yeah.

Chiang: …surface is flatter.

Fairbairn: Right.

Chiang: So they have this new material come out of spin-on glass called HSQ-- HSQ. We tested it and everything was great. So we use HSQ to replace FSG. It was great. Then we-- In R&D, we had to do some reliability qualification.

Fairbairn: Yeah, sure.

Chiang: It passed all the criteria when the production. But when you have a large volume, we began to have a reliability problem. And we found at the last moment, after we already went to production. And then it was around the Christmas time and we immediately we tried to put the FSG back, so again we worked days and at night, no break for Christmas, no break for New Year, no break for Chinese New Year. All the way and under very high pressure, and we finally get it, it's out, and it's already late, but good. And then later on, we found that TI had exactly the same experience we had. They also used HSQ and was okay with R&D after getting the production they had a problem, exactly what we had. So, we were not alone. So, that was .18.

Fairbairn: What was the problem with the HSQ? Why did it fail in production?

Chiang: I think this spin-on material, it just, the stress will be different. Because in one way you deposit chemical vapor deposit on the wafer, you did have a stress problem, because you deposit at a high temperature and you want to go to low temperature, the silicon, and oxide, their thermal expansion coefficients were somewhat different, so you would have some stress. But people learn how to manage that because people use that for a long time. But the spin-on has a different characteristic. Instead of the temperature difference, you heat up to a lower temperature than CVD oxide, you drive the solvent off. But this material will shrink in a different way. So, you have some reliability problem later. I really cannot explain beyond that point.

Fairbairn: So, you went back to the FSG you know?

Chiang: FSG is a chemical vapor deposit fluorine doped glass.

Fairbairn: I see.

Chiang: So, we, again, we were late, but we solved the problem. But later on, because of that, we were very lucky for the next generation. I should say the next, next generation, because we added a .15 node. Many other companies didn't have that. But that's not important. So, when we went to .13u, .13u the people began to change from aluminum to copper. And IBM was the leader for the copper metal. They had the longest history of developing copper technology. They worked for more than ten years on copper. TSMC didn't have any experience in copper at all. So, when we decided we need to adopt copper, okay. So, the copper is one story and low-k material is another one. IBM decided kind of low-k material is a spin-on material called SILK. IBM had a Research Consortium that IBM-- Samsung joined them, I think, ST Micro joined them. Several companies joined the Consortium.

Fairbairn: Yeah.

Chiang: And UMC joined them. But we didn't join them. They all used that spin-on low-K material. But we decided to use CVD - instead of flourine-doped it's a carbon-doped made by Applied Materials. They're called Black Diamond. So, we choose Black Diamond. The reason we chose Black Diamond was very simple, because I suffer at .18 with a spin-on. I wouldn't touch spin-on again. <laughter> But they didn't go through that. So, we were very, very lucky. TSMC became the first company in the world which was able to ship a manufacturing wafers with the copper and low-k, because IBM failed. And that--

Fairbairn: Because their spin-on

Chiang: Their spin-on. Later on they found reliability the problem.

Fairbairn: So, did you-- this is a few years in. You started at a quarter [micron]. You were working your way down to .18u and .15u and then .13u, right?

Chiang: Right.

Fairbairn: Did you change the culture? Did you bring in new people? What allowed you to get TSMC on a different trajectory.

Chiang: .13u was actually the very important node for TSMC. Because we became the first one in the world to deliver manufacturing wafer of copper and low-K. I remember going, "Wow! This company did something." So, that was the time people began to notice TSMC. That was a kind of turning point at TSMC. One thing was -- you remember Sematech?

Fairbairn: Yeah.

Chiang: TSMC was a member of Sematech. And I represented TSMC on their board. And we have all these board members from TI, from IBM.

Fairbairn: Intel and--

Chiang: Intel, Motorola, National, HP. And they're all my customers.

Fairbairn: Right.

Chiang: And the board member they sent to Sematech for many companies happen to be the person also in charge of the supply chain. Well, they are my major customer, but on the Sematech board we kind of sit together, we can discuss things on equal base. Not like my customer. <laughs> And so, in that platform we are able to-- some time we are able to more freely exchange some information. So, one time at a dinner, they asked me, they said that, "We all take two years to develop one generation, how come you guys can do it in one or one-and-a-half year?" And they asked if some of your customer transfer technology to you or what not? And I told him, "No," I told him that, "That's not true." I think he probably implied we steal technology from customer, the way he talk.

And I say, "I'll tell you why." I said that, "When we develop one node, basically you have some learning cycles. First, you do some simulation. And you have some idea, then you run wafers to prove that. So, you run a group of wafers according to simulation and you have some splits. The wafer runs through the fab, they come out and you measure them, you analyze them, and you try to improve and you run this again. This again, you run. So, this is learning cycle." At that time, "It takes about six learning cycle , roughly, to complete one generation." Of course, you had some short loops and not just one. I said that, "My R&D wafer in the fab run much faster than yours, because my R&D engineer works three shifts and you only work one shift. So, your R&D wafer move eight hours a day, my work/move 24-hours a day. So, my wafers go three times faster, even if you are twice smarter than me, I still beat you up." <laughter>

Fairbairn: That's what everybody says. Faster learning cycle, right?

Chiang: Faster learning cycle. And three to one is kind of a little bit exaggerated, because it's usually night shift it's not very effective. Just the idea. But because I knew at HP, TSMC R&D wafer did move much, much faster than HP. But HP is not a good benchmark.

Fairbairn: Not a good bench-- yeah.

Chiang: And then they ask me, "How can you make your R&D engineer work night shift?" And I kind of joke with them -- and I can share with you the real reason what I think. But at that time, I told them, I said, "In Taiwan, we all have to serve the military." I said, "I did. When you're in service, you-- especially in the basic training-- you take a duty for the security guard."

Fairbairn: Mm hm, stand watch.

Chiang: Stand watch, right. "It may be my turn from 2 a.m. to 3 a.m. Then the guy would wake me up at 1:45. Then I got up, I change my clothes, I got my helmet, got my rifle, then I went over at 2 o'clock, and 2:45 I wake up another guy. And so, all my engineers have been through that. So, I tell him to, you know, it's your turn to do that! <laughs> Don’t complain!" <laughter>

And what interesting at that time, the board member from Motorola, I just remember, his name was Bill Walker-- I don't know if you know him or not?

Fairbairn: No, I don't think I know him.

Chiang: Bill Walker. He's a big, big guy. Later on, I found he used to be a Marine. I knew that later.

Fairbairn: Yeah.

Chiang: Because he was one of my very large customers, I usually visit him once a year.

Fairbairn: Mm hm.

Chiang: I went over with our sales manager and the two of us usually went to his office. And he had one of his Supply Chain Manager - four of us sit-down. Usually Bill would give us a lecture telling us what we did wrong and how bad we behaved. I took notes. The meeting lasts an hour. Next time I visit him, they took me to a different room. I found it a little bit different. When they opened the door, there were about 20 people around the table. He was in charge of R&D and the manufacturing for Motorola Semiconductor Worldwide. He said, "These are my R&D and the fab managers in the entire world. I got them together. I want you to tell the same story to them." <laughter> So, that was what I always told them but they didn’t listen.

Fairbairn: So, what was the real answer about <laughter>?

Chiang: The real answer is I, honestly, I just share with you, I think the culture. Asians are more hungry, because we had a tougher life. So, to make money is more important to us. People are willing to sacrifice their own privacy, their private life in order to have financial security.

Fairbairn: That's what you did. You moved to Taiwan without your wife or your family, right?

Chiang: Right. Just to make a living.

Fairbairn: And work 22 hours a day.

Chiang: <laughs> But not later. So, I firmly believe this is one of the really important reasons why TSMC succeeded. It's culture. If equipment went down, because equipment depreciation cost was so high, you really want to run your equipment 24 hours a day. In United States, if equipment went down, wait until next morning. The people come in at eight o'clock and probably go to fix it, nine o'clock. Yeah. But if at two o'clock in the morning, we just called the equipment engineer, "You come right away," he won't complain. And his wife won't complain. And that's the way it is.

Fairbairn: Right.

Chiang: And that help a lot.

Fairbairn: Mm hm.

Chiang: I went through one experience. I was very shocked. I share with you, it's an interesting story. In 1999, TSMC at that time tried to start this wafer fab in Oregon called WaferTech. And the performance was very poor. Was far behind TSMC fab. Had given them all kinds of headaches. So, finally they decided one morning the VP in charge of manufacture, he got a list of 20 people, and he called one by one to his office. Everyone go to his office for ten minutes. And early ones didn't know, because they never talked to this VP--

Fairbairn: Right.

Chiang: -- you know, what he wants? And then later on, these guys come out, "Oh, why did he call you in the office?" "TSMC want to send you to Wafer Tech, for assignment for two years. You go back to start to apply for visa, get your passport. And be ready in three weeks."

Fairbairn: And go back to Taiwan?

Chiang: From Taiwan to U.S.

Fairbairn: Oh, Taiwan to the U.S. Oh, I-- move the people from there. Okay.

Chiang: Right. So, they moved 20 people, including the fab manager, and in every area, all the engineering area and manufacturing area, Manufacture Supervisor, QRA, sent the entire team, 20 people.

Fairbairn: Mm hm, somebody from each group.

Chiang: Right. That's the way they did it. I look at that, wow. And three weeks later, 20 people on the same airplane to U.S. And they live in the same place. They told me every morning, these people they all carpool, they had ten cars, just drive to work <laughs> and go home. And they fixed that fab. And then during this time, I was shocked, because in U.S. that's not the way they do it. If you're in HP, if we have an assignment in France and some people look at people profile, "Oh, this may be a candidate." His boss will probe him. "Oh, we have the job there. It's very interesting. And it's very important for the company."

Fairbairn: Right. Try to convince him.

Chiang: Try to convince him.

Fairbairn: Right.

Chiang: "And just think about it," two weeks later, "Oh, have you thought about that? Well, good. Go talk to your family and see how it works." And a month later, "Oh, it looks good," you go there to interview. And come back, oh, everything seems to go on, and you talk about your package. Oh, later on, go with your wife to house-hunting. They wait until summer, your kids out of school, you go there six months later. At TSMC, it's three weeks.

Fairbairn: It's 20 people, boom.

Chiang: Twenty people.

Fairbairn: How long did they stay there in Oregon?

Chiang: Two years.

Fairbairn: Two years?

Chiang: Mm hm. And some of them didn't, I think, come back. They decide to stay. And this time, I knew two examples. One was-- one guy come back, and told his peer, he said, "Company want to send me to--," and he had two kids. He said he really had no idea what kind of life there is. Never been in the U.S. And he said he really didn't know he can come back two years later or not. And he had his house, and it's no mortgage, it's all paid for. And he said he had no time to take care of that. And here is a signed deed of trust, please help me to take care of that. Just a couple months earlier, Taiwan had a very big earthquake.

Fairbairn: Oh, yeah.

Chiang: About, it was two- three-thousand people casualty. He said, "You sell that house. All the money go to donate to this charity," he said, "Company wanted me to do that. That's more important. And everything else is not important." And the other example, the fab manager, I happen to know him pretty well, and he also come back to tell his secretary, he said, "We will go to U.S. for a two-year assignment." He live in Taipei and he rent a place in Hsinchu during the weekdays. He go back in Taipei, he own that place in Taipei. And he said to his secretary he had no time to take care of all these things. He said, "Please take care of disconnect the water, disconnect the gas, the electricity, negotiate with landlord for the penalty."

Fairbairn: Because he was moving to the U.S.

Chiang: Right, right.

Fairbairn: Yeah.

Chiang: He said he had no time to take care of that. Asked his secretary to do that. He said, "Also, you have been working for me for five years, and now they really have--," he said, "If you--," he said, "I will miss you. You also probably will miss me. When every time your birthday, New Year, Christmas, I'd like to send you a present. And when you feel frustrated, you go to get a nice dinner or buy yourself a present." And in Taiwan, we have a bank account, usually it's a booklet, and you-- at that time, your signature not important go by stamp.

Fairbairn: Yeah, yeah.

Chiang: "And here is my account book and here's a stamp. And there are a couple million Taiwan dollars in the account." He asked his secretary to take care of that. And also--

Fairbairn: And she can just go buy a dinner or whatever.

Chiang: A gift for herself. Yeah. It's just the way when company wants you to do something, just go for it. Everything else not important, just do that. And that kind of spirit nobody can beat. That is really the-- in my mind, I was very, very shocked that-- but TSMC doesn't have that spirit anymore.

Fairbairn: Doesn't have that feeling anymore?

Chiang: No.

Fairbairn: Yeah.

Chiang: The older generation employee has that kind of commitment, the young ones didn't.

Fairbairn: Yeah, that-- <laughs>

Chiang: And the young ones didn't work as hard anymore.

Fairbairn: Right. So, along the same lines, you know, TSMC made huge progress and is now the leader. Intel has stumbled and has really struggled, and I suspect it was more difference than just a cultural issue. That there must have been some technical direction or equipment choices or whatever that Intel made that didn't work out and set them back a significant period of time, right?

Chiang: Yeah, in my own opinion, especially from the R&D side, I mean, we didn't really do anything special, anything great. But we didn't make any major mistake. And I think when we started, UMC was TSMC's really strong competitor. These two companies were like that, and we compete, very severe. At .13u and after UMC made a mistake, and I think this time, Intel made some mistakes. Instead of TSMC really did anything great. Because TSMC didn't make any big mistakes.

Intel, not TSMC, had a couple different cultures. Intel decided they want to do everything, “copy exact”. This most important principle in their R&D and their manufacturing. And what it means it's great for them. What it means, they develop this technology in R&D, use this equipment, use this recipe. They check everything very thoroughly. Everything great. Go to manufacturing, you never change it. You just follow that. Don't do any change. It's great. You have much lower risk. But the one problem is a year later, the new equipment has a better efficiency. TSMC will adapt that, Intel would not. So, then TSMC would begin to have a lower cost than Intel. So, TSMC tried to be very flexible, which it adapted.

Fairbairn: Mm hm.

Chiang: And one reason is, obvious reason is Intel's system. They can sell the wafer for $20,000 a wafer, because their CPU chip's very high price. And TSMC cannot sell the wafer for $20,000. We can only sell for $4,000. And we have to try to cut the cost. Next thing is Intel-- I really respect Intel. I think they are most willing to take very high risks. In every generation, they are willing to take risk to do something new. And in many key areas, for example, like high-K metal gate, strained engineering, FinFET, etc., it was always Intel, the first one to adapt that. And then TSMC would adapt in the next following generation.

So, every node, Intel's performance was better than TSMC. When I was at TSMC, I keep telling people, "We are behind Intel." We were behind Intel. "Don't look at it that you can release your 10-nanometer before Intel, then you're very happy. you are definitely wrong. Number one, TSMC's 10-nanometer definition is more like Intel's 14-nanometer dimension

Fairbairn: Oh, I see.

Chiang: You just call it 10-nanometer.

Fairbairn: Right.

Chiang: Actually, look at the details, maybe not quite by one generation, but TSMC's 10-nanometer, performance-wise, is behind Intel's 10-nanometer. That is definitely the case. Number two, Intel always, like I just said, Intel always had the guts to adapt innovations.

Fairbairn: I'm sorry, had a what?

Chiang: Had the courage to--

Fairbairn: Had the courage to--

Chiang: -- to start a new innovation.

Fairbairn: Uh huh.

Chiang: TSMC usually will wait until Intel adapted, till do it at the next following generation. Number three, not only the design rule, TSMC was also behind in transistor performance. TSMC always behind Intel's transistor performance. And that's a good reason because Intel, their only product is CPU. And that is performance driven - they need that. TSMC doesn't need that. But usually if you try to judge who has a better technology, you go by performance. And you had to respect Intel had the better performance. When I was at TSMC, it was my last couple of years, I start an initiative. I say, "I want--" we called it

Advanced Transistor Leadership, "We want to catch up and beat Intel in transistor performance." And that project failed. That project failed. I think nobody outside of TSMC’s small group knew about that. So, one of my biggest regrets in my entire career is we didn't catch up with Intel. But in my mind, TSMC technology was behind Intel. While you look at it from the surface, TSMC now is able to do 5-nanometer production. Intel's still at 10-nanometer. But I think Intel did stumble somehow. Right now, I think, Intel really is a little bit behind.

Fairbairn: You think that Intel is what?

Chiang: Intel is really a little bit behind.

Fairbairn: A little bit behind, yeah.

Chiang: But if you look at the press, you look at the image. TSMC already claimed they were ahead of Intel three years ago. That was not the case.

Fairbairn: Mm hm.

Chiang: Because number one is that node definition was different. Number two, Intel transistor always performed better. So, that was my biggest regret. We didn't catch up with Intel in my career.

Fairbairn: So, during that time, there was-- Apple became-- you became the sole supplier for Apple's phone chipset, right?

Chiang: Yeah.

Fairbairn: So, what can you tell me about the relationship between TSMC and Apple? How did that develop and what role did you play in that, and--?

Chiang: Yeah, that's a little-- that's one of the key factors-- let me tell you from the technology side first. When Apple first approached TSMC, it was a kind of test water. They commit just one product, just tried. But later on, kind of fully commit to TSMC. Had to do with a thing called an Advanced Package Technology.

So, if I share with you this history. In 2009, I first retired in 2006, then Morris Chang, he retired in 2005 the first time. Then he decided to return to be CEO in 2009. So, I retired 2006, and then he called me back after he went back. So, shortly after he called me back, I told him I want to start two initiatives. One is transistor leadership. That was the one I just shared with you. "We want to catch up with Intel." And I told him, "We are behind Intel all this time. And never been close to Intel." And he agreed. So, he gave me some resource. Number two, "I want to start an Advanced Package." And he said that-- he said, "You joined TSMC too late." He said, "From Day 1, we talk a lot about it whether we should do package or not. And we decide not to do package, because that's a little technology content, very low profit margin." I told him, "No, what I mean package is not the kind of wire bonding." I said, "I'll call it Advanced Package. I really have no better name than to call it Advanced Package." And now Advanced Package was used as a common terminology now. <laughs> Everybody talking about Advanced Package. I said, "If you look at the technology map, on the silicon wafer, we follow Moore's Law, and the progress was so significant. But if you look at the package in a PC board, if you look at the PC board, the metal pitch is 110-micron. Has been that for almost 20 years. <laughter> It probably migrated from 150 to 110 in 20 years."

Fairbairn: Mm hm.

Chiang: They spend little in R&D. Also, they spend more of their effort in trying to cut cost. And because of the silicon-- the advances in silicon wafer, the entire industry was happy with that. Because it makes an advance after you use newly developed silicon technology. The package just doesn't matter. Now we begin to see that that package became bottleneck in some cases. And as Moore's Law is getting close to its limit, we need to resolve this bottleneck. For example, one graphics player was one of our most important customer, nVidia. We have a GPU drive 8 DRAM. And you send a lot of signal back and forth between GPU and DRAMs. If you look at this GPU and DRAMs, they are so far apart. Why they're so apart? They're so far apart because the metal lines were very wide. If you're too close, you cannot get all these metal line connected. Because of that, if you-- I did a simulation, I have somebody do the simulation. It costs you about 30 percent in speed and about 60 percent in power in this--

Fairbairn: Just driving those lines?

Chiang: Right, driving these lines, yeah. If I use the metal pitch on the PC board or substrate that is 110-micron, I can do that-- I can easily do 110-nanometer on silicon wafers. If I use a silicon wafer to replace a PC board, I can put GPU and DRAMs right next to each other. The performance will be very much like on the same wafer. And I did a simulation that benefited almost two generation of technology.

Fairbairn: Yeah. <laughs>

Chiang: But this is, honestly, this is only for graphic chips. Very few cases like that.

Fairbairn: Yeah, I understand the bottleneck there in terms of huge numbers of memory accesses and power is the problem there.

Chiang: Part of that because of the distance and width, part of that because standard. Because you have to drive so long, you had to set a very loose standard. You can cut the delta V much lower if you put them right next to each other. Said, "This is what I mean," huh. I said, "We use," said, "The package industry their technology is so far behind us that we use our technology to eat their lunch." Also in that case, I'd say, "We also solved this bottleneck going forward when Moore's Law began to approach its limit. We should look at the entire system to solve the system problem. Not just look at the wafers."

Fairbairn: Yep.

Chiang: And he appreciated it right away. He asked me how much resource I need. I said say I want to add 400 engineers. I want a hundred million equipment.

Fairbairn: Four hundred engineers?

Chiang: Four hundred engineers and $100 million equipment. He said yes right away. He's that kind of guy. And that next day I began to hire people. And a year later, I asked a guy named Doug Yu to run the program, and he's a very, very good technologist. So, a year later, we develop this technology. So I just simply told him I want to replace PC board with silicon. It's called silicon interposer.

Fairbairn: So you're bonding the chips to a silicon substrate.

Chiang: Right, use a solder bump, instead of wire bond, and use the interconnect from CPU to DRAM are made on silicon, and we don't even have to use the very advanced silicon technology. We use a three generation older technologies and it worked very well. The interesting thing was, when we develop technology to manufacture that, we begin to look for customer. I told Nvidia. Oh, it was great! But, they never used it. Even though one day, their foundry, outsourcing VP told me-- she was a lady, Barbara. I forgot her last name. She says, "You didn't know how we work with you, and we work with package company, with OSAT [Offshore Assembly and Test]." I said, "We can make OSAT do anything, but you guys are so nonflexible, and you guys ask for 30% margin. They only ask for five percent margin." "I never work with you on package, unless you transfer your technology to OSAT, and I work with them." She said "With OSAT, I can tell them to hold an inventory because I have my budget issue, and I can tell them when to hold it, when to release it. They'll listen to me. You guys never did that." Say, "Oh, I don't want to work with you on package," and also later on, I begin to realize it's a high risk for any customer to use a brand-new technology. What if it doesn't work? The entire company will fail, and he would definitely be fired. So we couldn't find a customer. I tried very hard to get Xilinx to use it, and the way Xilinx use it not anywhere close to my expectation. The way I developed technology because I think will solve the performance bottleneck. Xilinx just want to connect four dies together as one, so they can sell it as the next generation product, and they can sell it for a very, very good price. So they use that, only want to package 4 dies together making it a very big die. In my mind, my good innovation was not used in a good way.

Fairbairn: So getting back to Nvidia, so even though you could demonstrate this performance advantage, they still didn't want to use it.

Chiang: They didn't want to use it for these two reasons.

Fairbairn: Because they wanted it-- your margins were too high and they wanted you to charge the same margins as their current packaging people.

Chiang: And being as flexible as the package people.

Fairbairn: And be as flexible.

Chiang: Yeah. They wouldn't work with us. And also, it's a risk; too risky for them.

Fairbairn: So did Apple adopt any of this either?

Chiang: No. That was the first generation. Xilinx worked with TSMC on CoWoS. Their codename was CoWoS. It's a funny name for TSMC's silicon interposer. That was a first-generation advanced package technology. So I only had one customer Xilinx and they order 50 wafers a month, so I became a joke in the company. I really became a joke, and there was so much pressure on me, and I went over-- Qualcomm was our biggest customer.

Fairbairn: Qualcomm. Uh-huh.

Chiang: I talked to one of their VP. I talked to them many, many times, until one time, I had dinner with one of their VP, and he just very casually told me, he said, you know, "If you want to sell that to me, I would only pay one cent per millimeter square." One cent per millimeter square. He said, "That's the only cost I will pay for it." I said, "How come you didn't tell me earlier?" He said, "You should know that. Why I should tell you? You should know that." But, I didn't know that.

That was a very good example of something that R&D trying to drive a product makes that kind of mistake. So I went back. I told Doug Yu. I said, "Please go to figure out how much that CoWoS costs us." Seven cents per millimeter square. So that's why we couldn't sell it. I said, "Let's develop something that costs one cent, and you can relax the performance, and you sacrifice performance." Our second generation called InFO meet that criteria and it was sell like a hotcake. So that one word saved my life and the InFO was why Apple was hooked by TSMC. Earlier, why TSMC couldn't get Apple business, early stage, because Samsung offer them a package solution by wire bond DRAM on top of CPU, on top of the AP, and TSMC couldn't do that.

Fairbairn: On top of AP?

Chiang: AP, yeah. The wire bond it. They put a DRAM on top of AP and use wire bond to connect them together.

Fairbairn: AP is what?

Chiang: Application processor, the CPU sort of. Apple's chips, two most important chips is a modem and AP. Modem is more to the communication side, and AP is more to the control side. And later on, TSMC InFO outperform Samsung's, and also, their relationship with Samsung is very strange. They're competitors.

Fairbairn: Yeah. Because they're a competitor, as well as a vendor.

Chiang: Yeah. They like to find other reason to use TSMC. Previously, they couldn't do that because-- and now they-- and InFO outperform their package solution, so they began to commit so much to TSMC. And also, now-- so what I didn't know at that time, when I first proposed this advanced package, I had in mind to solve the performance bottleneck for GPU. At that time, we don't have any CPU customers, so CPU doesn't mean much to us. But these days, the AI becomes so popular and AI can take full advantage of that as well.

Fairbairn: Yeah, absolutely.

Fairbairn: So that become more popular, so advanced package become so popular these days. Then another reason was-- also, we didn't realize at that time. Later on, we found our general wisdom was, if you can integrate two chips into one, you win. Integrate three chips into two, into one, you win. But after we have this advanced package technology, we began to realize many chips, if you take them apart, you're much better off, because the chip become-- its function is so complicated. Some function, you cannot take advantage of the leading-edge technology, like analog part, and you're much better off and lower cost, stay at older technology, and then we began to take it apart. So, it came with the concept of chiplets these days. You try to-- pretty much that you make an IP a chiplet and then you advanced package to connect them together, like a Lego type of concept. So, an advanced package become more and more popular these days. That's really what I expected at that time, but we did something and all these-- the result was beyond our original expectation. By luck, sometime.

Fairbairn: Okay, well, that was a pretty interesting story. Thank you. So you had left. You came back to TSMC in 2009 and you stayed until 2015 or when?

Chiang: I stayed until 2013.

Fairbairn: Thirteen?

Chiang: My boss asked me to continue work as his advisor for two years, until 2015. So it was part time.

Fairbairn: And then you joined the board of…

Chiang: SMIC.

Fairbairn: SMIC.

Chiang: Yeah.

Fairbairn: How did that happen?

Chiang: That happened actually, for two reasons, and one reason is, in my entire life, I was quite passive. Usually, I feel myself was driven by this-- when everybody say you should work harder, so you can go to a better junior high, go to a better college, and kind of years of study, I just thought of that. And EE was-- in the Taiwan’s college entrance exam, EE was on the top, so I studied EE. So I decided to retire. In ‘06 I retire, and Morris asked me to go back. ’09, I went back, and in 2016, late 2016, the CEO of SMIC happened to be my old colleague at TSMC. He was a fab manager at TSMC, and personally, we are pretty close because we come from the same hometown in China. And his father and my father were friends, so we were pretty close. And he asked me to help him out because they had some-- he was blamed for lag in R&D. His name is TY Chu. He did very, very well. SMIC always lose money before he became CEO.

But from day one, after he took over, in a short time, he made it profitable and profitable for every quarter. But he was blamed for lag behind in R&D. He asked me if I can help him and I told him, frankly, I think it's pretty sensitive. I think I can't help because a competitor. I may be able to help you more in the-- not in a direct way, in more remote, I think. So we come up with idea to be his board member. Board member only go there once a quarter and just make some general comments, and it's not really that bad. So that's how it started. One is a friend, and one is just my own-- usually, I never-- unfortunately, I never tried to decide my own path. I just driven by happenstance.

Fairbairn: Somebody asks you to do something, and you do it.

Chiang: I just do it. Yeah. So, I went to SMIC, and before that, before I made a commitment, I made a special trip to tell Morris Chang. I said, "They invited me," and he said, "Okay." He said, okay. Then I told him, okay. But when they appoint a new director, they have to have call a special board meeting. So the rumor leak out before the announcement and made a big news in Taiwan. I didn't expect that. But for some reason, Morris Chang approved. So later on, was I got a bad image. Before that, I had a pretty good image in Taiwan. That really hurt my image a lot. I didn't expect that. People thought political.

Fairbairn: So you first came in as board, and then you actually joined the company to head the R&D, or to…

Chiang: Later on, I joined the company. It was a mistake. Yeah. You did something right. You do something foolish in your life. It was one of the foolish things I've done.

Fairbairn: That was one of the foolish ones, huh? So tell me about the company. One of the challenges they had, they were under embargo or whatever. So they could not buy the latest R&D equipment, right, the manufacturing equipment.

Chiang: Right. They cannot buy any equipment to do the technology for ten nanometer or below. They cannot do seven nanometer, specifically.

Fairbairn: But when you joined, did you understand that that was a limitation or did…?

Chiang: The sanction happened three days after I joined.

Fairbairn: Three days.

Chiang: I joined on December 15th. The announcement was made on the 18th. Because I am U.S. citizen, it did bother me a lot. So I didn't feel comfortable. Also, because of that, get me into some problems. But that government did have a lot of influence on that and they didn't trust me. Because this guy's not only Taiwanese, he's also U.S. citizen.

Fairbairn: So subsequently, you were there for about a year and then retired again. Is that right?

Chiang: Right. Yeah.

Fairbairn: And so now are you retired?

Chiang: I retired a third time.

Fairbairn: Third time.

Chiang: I have no plan to go back to work at this moment. That's enough. I'm 76. On my coming birthday, I'll be 76.

Fairbairn: So do you have a home here? I mean, where do you…

Chiang: I live here.

Fairbairn: Yeah, and you may travel back to Taiwan or to China but you're…

Chiang: I'm based here.

Fairbairn: You're based here.

Chiang: All my family are here.

Fairbairn: This is your home.

Chiang: This is my home.

Fairbairn: So tell me about your children. What?

Chiang: I have a son and a daughter. My son graduated from UC Berkeley. He studied bioengineering and the bioengineering happened to be a trap. This happened worldwide, every place. Because in 1990s, bioengineering was very hot. People think that will be the future of the electronics industry. It didn't happen. So, a lot of kids studied bioengineering because of that. His classmate at UC Berkeley, also he went to U Penn for his master degree. He told me over all his classmate still work in bioengineering, probably less than 20% because no job available. So right now, he ended to be doing-- he worked for an equipment company in Bay Area. It's nothing to do with bioengineering.

Fairbairn: What about your daughter?

Chiang: My daughter is a medical doctor. She settled down in San Diego. She likes San Diego. She was a gymnast as a kid. She got into U.S. National team when she was 12. The U.S. National team had a criteria. You had to be 12 in the year. For example, they select the National team member usually in May. So the criteria is that before the end of year, you will turn 12. Her birthday was December 27.

Fairbairn: So she was only 11 when they…

Chiang: Yeah, U.S. had a sports festival every year if there's no Olympics that year. It's a kind of replacement for the Olympic, substitute for Olympic. So, then she went to the sports festival, and she was identified as the youngest member in the entire competition, even though she didn't do very well, but relatively speaking, she got a lot of TV exposure because of being the youngest. Then she retired at the age of 14. So, she was in National team for three years. She decided she didn't want to do it anymore. As it happened, one day she told us she wanted to quit. You're sure you want to quit? Yes. Okay, you tell your coach. You tell your coach. And her coach say, "well, maybe just take a break for a month or two, and if you like, you can still come back to the gym to play whatever you want." And two months later, "Coach, I still want to quit," and then her coach has to report to the-- they have some organization, U.S. Gymnastic Federation or something. And then they sent her a very nice letter, so give her a lot of encouragement. At your age, you have a lot of accomplishment, but you're going further, dah, dah, dah, a very, very warm letter. For the end however, now you are out of the National team, and she cried. Then she was a straight A student. She never get anything below A, and when she graduated from high school, she took five SAT exams, two SAT, and three achievement test.

Fairbairn: Yeah, the AP test, advanced placement test.

Chiang: SAT, the two SAT, English, and math, and then physics, chemistry.

Fairbairn: Yeah, those are advanced placement tests, AP tests.

Chiang: AP test. Right. She got 800 for…

Fairbairn: Eight hundred on everything, huh?

Chiang: She got an early admission to Stanford.

Fairbairn: To Stanford.

Chiang: Well, she only applied for one school.

Fairbairn: So, she went to Stanford undergraduate and what about for her medical degree?

Chiang: She went to Washington University. At that time, I think they ranked two or three and the first one always Harvard. The second one is either Johns Hopkins or Washington University. She went to Washington University.

Fairbairn: I think I want her to be my doctor. She sounds very smart.

Chiang: First she wants to be a sports doctor because she suffered during competition, broke a bone, or something. And then she told me that's man's job because you need a lot of muscle.

Fairbairn: Oh, I see.

Chiang: Yeah, but I say she's pretty strong. She was gymnast. No, not enough.

Fairbairn: Not enough, huh?

Chiang: Now she's practicing in San Diego. She just became a mother 15 months ago, so I just visit my…

Fairbairn: So now she has a little baby, huh?

Chiang: Yeah. I just visit my grandson last month. I told you I was going to take a trip to out of town. That was why. Yeah.

Fairbairn: Yeah.

Chiang: I saw him the first time.

Fairbairn: Well, we spent three hours or something in this conversation. Did we miss anything important do you think? Anything that you want to tell us about?

Chiang: Yeah. One thing I can-- you sure you have some time?

Fairbairn: Yeah.

Chiang: One thing I can share with you is the industry, we do 12-inch wafer now. It was supposed to go 18 inch.

Fairbairn: We've been stuck at 12-inch for a long time.

Chiang: Right. Supposed to go 450 millimeter and this project was very hot in 2013. Intel drove that. I think in the history, going to six-- I don't remember very well. I think going to 6 inch is driven by IBM and the 8 and 12 inch driven by Intel. Intel want to drive 450 again. So they promoted [that idea]. Going to a bigger wafer on surface, people say it's because of productivity. It's not exactly true. More it's a game. It's a game for the big guy to take advantage on the small guy. It's pretty clear that is the case. Why? Right now, if you want to go to 18 inch the first thing happened is all the equipment vendors, all their new equipment will be 18-inch. They will not make the most advanced technology on 12-inch. They will not. So the small player who doesn't need 18-inch, they are automatically out of the competition. Number two, it's again, the small guy, they don't need such a large volume. They cannot afford it either. So it's a big guy to squeeze a small guy out. That's the number one reason for going to the large wafer.

So, Intel started and actually, Intel tried very hard to get TSMC and Samsung to join force. Intel already start spending a couple billion dollars in preparing for 450-millimeter wafers, and for some reason, TSMC, because in the past, TSMC was very-- TSMC was quite aggressive pushing 12 inch, 300 millimeter, and it worked out very well for them. And also again, TSMC began to be very aggressive. I think, at one of the investor conference, Morris Chang himself gave a roadmap for TSMC's 450 millimeter. And all of a sudden, because previously only Intel was kind of saying, and now TSMC join it. Samsung always kept quiet. They didn't say yes. They didn't say no. They just quiet, keep quiet. Now two of them began to speak up. All of a sudden, the industry became very hot for 450 millimeter wafers.

And one day in 2013, I think around March, I believe, about this time of the year, I went to Morris Chang's office. I told him. I said, "I don't think we should promote these 450-millimeter wafers." "Why?" I said, "In the past, our competitors are UMC, SMIC, and those guys are much smaller than we are. We promote 450 mm. We take advantage on them. But right now, we only have two competitors, Intel and Samsung. Both are bigger than we are. So that didn't help us at all. It actually will hurt us."

I'll give you one example. I don't know exactly how many R&D engineers Intel has. We had 6,000 R&D engineer. I know their R&D budget is much bigger than we are. I say they may have 8,000. Right now, we are eight to six to them. If we started 450-millimeter, it may tie up 3,000 engineers. Then what we have left to do the R&D? Three thousand. They still have 5,000. So, if I try to compete 3,000 with 5,000, my pressure is much, much higher. That didn't help us at all. And their revenue was much higher than we are, both Intel and Samsung. So we shouldn't have the old idea, which I supposed to take advantage on UMC. Now we don't care about UMC.

And Morris Chang got the point immediately, and he appreciate very much, and he say, "What can we do?" I said-- Mike Splinter, he was Applied Materials' CEO at the time. I said, "Mike is here today." I say, "You may like to talk to him." He say, "Yes," so I went over to get Mike because I'd just talked to Mike. Mike was not originally on Morris' schedule. But I went over. I took him to Morris' office, and of course, Mike speak against that, Intel, and all the negative thing about that because no equipment company like to do that And then he sent me and our procurement VP to visit KLA [Tencor], visit Lam [Research], and again, visit Applied Materials here, and also, I tried to make appointment to visit TEL.

Fairbairn: To visit…

Chiang: TEL, Tokyo Electronics.

Fairbairn: Yeah. Right.

Chiang: They refused to see me, so I didn't talk to them, and they're all against 450 millimeter. So Morris Chang began to realize that that's not right thing to do now. So, he himself called at least ten meetings to discuss this topic in the company. He was very, very careful to try to look from all the aspect, and finally, he decided we should not support that. And then he tried very hard to think about the reason. If you just say directly, TSMC will not do that, it's a negative image because you guys not looking at the future. You cannot. So finally, he decided. When we make the announcement, he said, TSMC's priority is advanced technology development, not 450 millimeter our top priority. That was the announcement. We also talk to

ASML because ASML didn't care. They said, "Wafer bigger or smaller, my scanner, the time is the same. We cannot save anything because I have to expose each one."

Fairbairn: You still have to expose each one, right?

Chiang: So ASML arrange meeting at 2013 SEMICON West in San Francisco. They made a reservation for a private room. So we've got Intel, Samsung, and TSMC in a room to discuss 450-millimeter wafers, and Intel, the presenter was Bill Holt. You know Bill Holt? He was in charge of Intel's technology, R&D, and the manufacturing altogether, anything to do with silicon wafer he was in charge, and their procurement VP, and TSMC. I went, and also Steve Tso, our procurement VP. Samsung had sent two VP, but they are lower-level VPs. In the entire meeting, Samsung didn't say anything, and Bill Holt just get up. Again, he said he promoted a 18-inch wafer. We should all chip in. We should be aggressive, and then I told him-- then I'm the next speaker and I told him our priority is advanced technology. He got that. He was very upset and walked away. (words deleted) In the following day, Intel made announcement their priority is advanced technology development, and that's the end of 450-millimeter wafer. Nobody talked about it then.

Fairbairn: Nobody talked about it since then.

Chiang: Nobody talk about it since then.

Fairbairn: I knew that it had been planned and then it went away.

Chiang: Yeah. It was all of a sudden.

Fairbairn: Yeah.

Chiang: In July of 2013. Very few people knew of that meeting in San Francisco.

Fairbairn: Interesting. Yeah. That's important information.

Chiang: ASML knew that. Martin van den Brink, ASML's president, yeah, he knew it very well.

Fairbairn: Well, I'm glad you brought up that story. What other good stories did I miss?

Chiang: Well, thank you for spending so much time. This interview is very boring stories.

Fairbairn: No. It's all very interesting.

Chiang: I think I made the right decision to go to Taiwan. I made the wrong decision to go to China.

Fairbairn: Well, you had a great run and you made a huge difference. What a contribution. What a contribution.

Chiang: This industry, it's many, many people's effort. Nobody should take credit on that. When I retired, Morris Chang gave me a retirement party. He was very nice. He invited everybody in the company, director level and above, and of course, I had an opportunity to say some word. But I thank him. I thank the one who hired me to TSMC. I say I thank all my R&D colleagues. I say, “That honestly speaking, my most value to the company probably is decisions I made. Probably Morris thought I made more right decisions than wrong decisions, because I didn't really do any real work.” I said, “But I wouldn’t tell him that the time I work here because I want the credit. But now I’m retiring, I’ll tell everybody the truth.” When you make a right decision, you've made a right decision or not depending on the result.

Fairbairn: Depending on the what?

Chiang: The result.

Fairbairn: Oh.

Chiang: If the result is good, this was a good decision. If the results didn't work out, it was a bad decision. Very simple. I say, as long as I made an okay decision, I had a group of very capable people that will make it work, and then all is…

Fairbairn: Look like a good decision.

Chiang: Make a good decision. I say, as long as I don't make some terrible decision, they should all become good decisions. That was my conclusion.

Fairbairn: Well, thank you very much for spending the time. We really appreciate it and it’s a valuable contribution to our library of history of semiconductors. So thank you very much. I appreciate it.

Chiang: Thank you for the opportunity and thank you for listening.

Fairbairn: My pleasure.

Chiang: Thank you.

END OF THE INTERVIEW

