Oral History of Harry Sello

Interviewed by:
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Craig Addison: Thank you very much for joining us, Harry. Firstly, could you talk about your period at Shockley Labs; what was your job there and what the working atmosphere was like, for example?

Harry Sello: That was, of course, my introduction to the semiconductor industry as it existed at that time. William Shockley hired me in 1957, which was shortly after he had won the Nobel Prize for the discovery of the junction transistor. And I don't know quite the circumstances by which he found me in detail; my best guess is that he talked to people in a related industry, chemistry. I was in chemistry at the time, still am a physical chemist. But he did locate me and he asked me to come to the Shockley Semiconductor Laboratory, SSL then, in Mountain View, California, in early 1957 for an interview. The interview itself was colorful; I had never undergone such an interview. He spoke to me about my work and told me a little about his work. Mostly he asked questions, and I came back for a second interview over a weekend, and this was a very interesting one because it was a series of psychological tests. He said if I didn't mind, would I submit to psychological testing; he wanted to see my feelings, [and that] I shouldn't feel bent out of shape because he himself had taken these psychological tests. And in a moment of levity, I asked if he expected me to perform as well as he had on the tests. I was very self-conscious about that. And he sort of grunted; I don't remember Dr. Shockley ever laughing out loud, but it was friendly. And I went through Rorschach, I went through the Thematic Apperception Test, where they put diagrams or pictures in front of me and asked me to interpret those. There was some intelligence-type, IQ tests, and it took all of a Saturday for me to go through all of those tests. And I never really asked him, was that absolutely necessary, I was so overawed by the fact that this Nobel Prizewinner had thought to ask me to join his organization. He suggested that I come to the Shockley Semiconductor Laboratories and meet the people…and I met the crew at Shockley; that was Gordon Moore, Bob Noyce, Jay Last, Sheldon Roberts, Jean Hoerni, Julius Blank, Eugene Kleiner and Victor Grinich. They were the ones who later became the so-called "Traitorous Eight". In particular I met Gordon Moore and Bob Noyce. Bob had recently arrived at Shockley from Philco, where he had worked on semiconductors, and he was the only one that had had semiconductor experience.

Well, I met all these people…and Gordon Moore and Bob Noyce took me aside and said, look, we don't like to do this, but we do want to tell you that not everything is peaches and cream at this place; there are problems. Have you heard of any of these problems? And I said no, Dr. Shockley didn't tell me about anything, and of course my curiosity was aroused; I wondered, what are these problems? And they said, well, Shockley isn't the easiest guy to get along with. And in some of the problems, he takes a very dim view when somebody disagrees with him, he's pretty outspoken about it, and he creates hard feelings. There have been a number of these over the period of the last year and a half and we just wanted you to know so that you won't be surprised when you get into this. They were very honest and very frank about it. I got a little concerned, and I left that evening and talked to my wife about it, but I was so impressed with being hired by a Nobel Prizewinner that I joined.

Addison: What type of work did you do for Shockley?

Sello: He had a stable of very mixed technologies. Gordon Moore was a physical chemist. I am a physical chemist. Gordon Moore's work was mostly in infrared spectroscopy at the university where he had gone, CalTech. My work was more on the physical organic chemistry side. I had worked in kinetics of chemical reactions, organic chemical reactions, and I learned that it was because of that exposure to organic chemistry that Shockley was interested in me, because he wanted to get deeper into the field of chemistry. Bob Noyce was the only one that came with semiconductor experience, from Philco, albeit in germanium and not silicon. The others were metallurgists, engineers of one sort or another, a very mixed stable of technologies.

Addison: So what was the goal of Shockley? He wanted to build some kind of device?

Sello: Shockley wanted to work on silicon. Silicon had recently been not discovered but evaluated by the Bell Telephone Laboratories, where Shockley originated, as an ideal sort of a semiconductor material, over and above that of germanium. Silicon was more stable, easier to work with chemically for a variety of reasons, but mostly because it was the new, emerging semiconductor material, and Shockley's middle name was "new". Novelty was where he was headed; original work. He did not want to continue the work that he had done at the Bell Laboratories, necessarily, but he wanted to expand into silicon. And he wanted to make commercial devices from silicon as a semiconductor material. To my knowledge, at that time it was a first. As I learned subsequently, neither TI, nor Sprague, nor General Electric, nor even at some of the Bell Telephone/Western Electric installations had they done much, if any, work with silicon. So Shockley was clearly looking for a first, and we all felt that that was the case.

Addison: So at that stage, the raw silicon was a challenge?

Sello: The raw silicon was the problem. Shockley Laboratories had to start from scratch. We had brought in silicon material and were already working on devices from silicon, but therein was one of the basic difficulties of Shockley himself. He defined carefully the device he wanted to work on, the structure. And I felt he rammed it down the throat of everybody who was working there. He wanted to make the so-called four layer diode, in our parlance, PNPN diode. And these were so-called switching diodes, and the intention was to be the first ones made so he'd have the patents and the rights to those. These diodes, Shockley felt, would be eventually used to replace mechanical switching in telephone exchanges, where millions of switches occur during the course of operation. In principle, it was a very good selection for a new kind of field because electronic switches in telephone exchanges number in the many millions. So Shockley felt that he could supply this as a market. The basic problem, however, is that the silicon itself didn't quite agree with the making of the device; it was very difficult to repair, and a material which we knew very little about.

Addison: So the equipment and the materials used to build all these diodes, they were home made?

Sello: Largely, the chemical equipment was homemade. The furnaces, to a large part, were homemade. The electronic measuring equipment like Tektronix and Hewlett Packard oscilloscopes…those were commercially available as testers. However, they had to be cobbled together, what we call "rack and stack"; you stack up what you need and use that for measurements. As far as silicon furnaces were concerned, probably Motorola and TI might have had them, Bell Telephone had some silicon furnaces. The furnace equipment was not then available; we had a commercial-type furnace that was called a Burrell furnace which consisted of a quartz tube around which was wound a platinum resistor. And if you wound current around the platinum resistant material it would generate heat, heat the tube, and you could get up to the 1,400 degrees or so that you needed for silicon, and run diffusions. Unfortunately, the Burrell's had their own limitations; Gordon Moore is fond of telling the story that he didn't realize that platinum was volatile…one of the early ones he wound, the platinum evaporated; the furnace cured and he had to learn the hard way. When I came on board, one of the assignments I was given was to build a controllable long-quartz tube furnace for handling silicon diffusions. So that was one of my first projects: build a furnace that would maintain a long, constant temperature range, at that temperature, around 1,400 degrees or so, which you could run diffusions that would be something better than the Burrell furnace could do. And I had to start that one from scratch. Of course, you could buy [the tube] from quartz manufacturers at the time, but you couldn't get furnaces to operate that way, you had to build those, and I started on a lengthy project using a resistant material known as Kanthal to build a winding out of so it would retain the heat without melting and evaporating as Gordon had found out.

There was another interesting project that Shockley put me to work on; he wanted to make use of my organic chemistry exposure. I can best title the project as wax evaporation. In silicon etching, hydrofluoric acid will etch away silicon, so you can etch patterns. But you have to have a mask in order to etch patterns in only certain places. Well, it was difficult to make masks out of etch-resistant material. The material that was being used by and large was by Kodak and was called KPR: Kodak Photo Resist. And that worked. It had its limitations; it was difficult to handle. So Shockley said, we've got to find a better material, and we know you chemists know that wax resists hydrofluoric acid [because] it's kept in wax-coated bottles, so could you come up with a wax that would make an etch-resistant material. So I spent some weeks working on evaporating wax through various patterns to make the masks, or make the patterns through which we could then etch devices. The only problem is that in evaporating wax, the wax had to cooperate. And what would happen, invariably, you started off evaporating at a controllable weight and temperature, and as it went through and was continuously heated, the wax would change at different temperatures. It wasn't a very successful operation.

Besides the furnace project, I also worked on a couple of auxiliary device projects, [namely] PNP and NPN device structures to test what could be done with silicon. But the real problem was that Shockley wanted everybody to concentrate on this PNPN switch [the four-layer diode]. And he didn't want any other work going on in any other kind of a device. And of course, the publications coming out of Bell Laboratories and others at the time were concentrating on other structures…not three layers of diffusion, but two; PNP, or NPN transistors. Shockley wanted to put them both together. And that was a horrendous, difficult problem. I also worked on early packaging problems; if you had the device, how would you make contact to it, and how would you package the material? And that was not an easy chore. Up until the time I left, Shockley Labs continued to work on the PNPN switches, but they never really took hold because they were not reliable. And in telephone switching, you wanted something to switch at a certain voltage, you wanted it to switch always at that voltage and at no other voltage.

Addison: We've all heard the story about the Traitorous Eight leaving. Did they leave because of Shockley, or was it because they thought that the devices he was trying to build should not be built?

Sello: They felt that it was putting eggs into one basket and very early on, the devices showed a lack of reliability, even in early testing. And it was their feeling and mine too at the time, why concentrate on one device when the literature was announcing the existence of several others…a PNP or an NPN transistor. And we could make those, they'd be simpler, why not make those? But Shockley didn't like that because others were making those, and he didn't want to work in a field in which he used to say; "Other's had trampled already". And that was part of the problem, but what that engendered was a series of very difficult personality problems [with the technical staff]. It was the manner in which he spoke. Shockley had a tendency to ridicule the work of somebody who was not doing exactly the work that he wanted. Why were you stupid enough to do this? And you don't take sensitive egos of PhDs and tell them their work is stupid. It may be, but you've got to find other words. And that was sort of the problem, personality problems. Shockley would come into the laboratory and just criticize everything, then he'd disappear into his office and everybody was left hanging. What does the boss want us to do? Does he want us to find a better way? It would have been better if he just threw out his ideas, and asked people to sort them out and work on things that he thought would be better. It was not just the difficulty of the problems, which was enough; it was the personality which Shockley used to conduct his work. He offended most of us most of the time.

Addison: Can you recollect when Bob Noyce, Gordon Moore and the other six decided to leave; did that happen very quickly, or over time?

Sello: It happened quickly. I arrived in early 57, the group of eight left in late 57. So I got to overlap with them for a matter of months. They also asked me to leave with them if I wished. They thought enough of my limited background at that time, and I was flattered at the invitation, but I had only just arrived there. And Shockley was a Nobel prizewinner, and I felt, how can you just leave when I'd barely gotten started? That was why, for good or bad, I stayed on. And there were others of us. Dr. C.T. Sah, a famous man now in MOS transistor theory stayed on. A fellow by the name of Dr. Sam Fok stayed on, and a number of others of us who were technicians had similar feelings. Eventually, all of us left. I left two years later…I felt I had reached the saturation point with Shockley. I tried to talk to him about, you know, why couldn't we change, and by that time it was suggested that I'd better not try to carry on that conversation with Shockley. If you're unhappy about it, why don't you just resign and not bother to even talk to Dr. Shockley about it. I insisted that I wanted to say goodbye to him, but that was about all. He was very unhappy about all of this at the time.

Addison: Was there one particular individual in that group who led the resignations?

Sello: The unofficial leader of the group, relative to experience and personality, was Bob Noyce. And he sort of emerged as the spokesman. But you can't really say that he was the instigator. He was just sort of the guy who had had previous semiconductor experience in germanium, and he was bright enough and he had written papers together with Shockley, and had gotten along with him. But it was to him that the group sort of looked to; what do we do now, Bob, type of thing. He was an unofficially appointed leader. Gordon Moore got on very famously with Shockley, he wasn't really offended by him directly. Some of the others were more easily offended. I always thought that Gordon Moore and I had a special [situation] in that we were really not physicists, nor engineers, nor electronic engineers, nor even metallurgists; we were in chemistry. And Shockley was not at home in chemistry, so he could not beat on us like he could beat on the other guys.

Let me add one anecdote if I can, to illustrate Shockley's personality, which was the root of all the problems at the Shockley laboratory. As an example of Shockley's penetrating, and somewhat superior, philosophy, he liked to go swimming at the Stanford swimming pool during the day. I didn't know that, and I used to like to go over every once and again at lunchtime and take a dip in the pool. And he learned about that, and he said, I understand you go to the pool at Stanford. Well, I was a little bit worried. I said, should I have asked for permission? And he said, oh no, but next time you go, let me know, I'd like to go with you; I enjoy swimming. I told him I did too, so we [both] went the next time I went. And he said, so do you think you're a pretty good swimmer? And I said, well, I swam a little bit in high school competitively. I can handle myself in the water. And he said well, why don't we just go in and swim a few laps, and you can stop whenever you want, and I'll stop whenever I want, and we'll then leave, go back to the laboratory. I did not realize I was being put to the test. I of course wanted to impress the boss; this was not too long after I had joined the laboratory, so I went in and swam like hell for about 4 or 5 laps, I got a little tired, I lasted a couple more, and then I hauled myself out of the pool. No sense in showing off here, I had my swim. But that was not Shockley's intent. Shockley continued swimming. And he swam a total of 40 laps, at his pace. Ten times as much as I had swum. And when we got out, he said, wow, that wasn't bad, how do you feel? And I said good. And he said, I thought you were a swimmer. I said, well until I got into the pool, Dr. Shockley, I thought I was too, but you did very well. And he smiled, one of the few times I'd seen him smile, and we changed clothes and went back to the laboratory. When he learned that I went to the pool to swim, and I thought myself a swimmer, that was another place he could exhibit superiority. Shockley had to do that.

Addison: So Harry, how did you end up going to Fairchild? What were the circumstances?

Sello: Well, about a year later, I found that my contacts with Shockley were dropping off very rapidly, I couldn't get to see him, he was always too busy. I think he felt I had too much of the blight on me, having worked with the traitorous eight. So he probably didn't trust me as well; he never said so as much, but Maurice Hanafin [the new general manager] did. And one or two of the other guys who were there said, you know, Shockley doesn't talk to you very much, does that mean he doesn't like you? And I said, well, I haven't done anything to offend him. But then it was a little later that Mr. Hanafin pointed out that I was not getting the support I needed from Shockley and it might be better if I considered not continuing to stay here. Well, of course, I was at a loss. I had never been let go from anything, and it was quite an ego blow to think that, but as soon as the scuttlebutt got out that I was susceptible, the Fairchild guys jumped on me like a pot of locusts. They said, hey, you don't have to go anywhere, just come down the street and work with us, and you'll work with people you know. And I said well, you know, Tom [Sah] and I have decided that we're going to do a circuit, and go around and talk to other semiconductor companies on the east coast at that time. I did not want to talk to TI, I didn't quite like their atmosphere, but I did talk to several east coast companies. But Fairchild kept after me. In particular, Jay Last came up and said, why are you mucking around, talking to all of these companies that are never going to make it in silicon, we need you, come to Fairchild. That's all I needed to hear, I was needed. And I came to Fairchild in February, '59.

Addison: After you joined, what was the goal there? What were you trying to do?

Sello: It was an interesting point in time. Fairchild had been in existence just about two years…and Gordon Moore, who was really responsible for getting me on board, said I need you to come here because we have just had what I think is our first big defection. We lost Dave Weindorf, who was our head of pre-production engineering, and the group is foundering, has no leader, We need somebody to take over the device development conducted by that preproduction engineering group. And he said the work is just what it says, it's the engineering and development work needed to make a production line just prior to going into production. And I said, oh, that's fine, it's a hole already created. He said yes, Weindorf was pretty good, but he and a fellow by the name of Baldwin defected. He said that you might say they were sort of the “Traitorous Two”. Gordon was very outspoken, very honest, and they went to form a new company to make just the same products that we were making. And it was financed by Rheem, the water heater makers, and they went down the street and they’re building a plant. And he said we have reason to think that they took the plans for our plant with them, because as it turned out, they were carbon copies of what we had done here.

After I took over the group that was preproduction engineering -- it was maybe about 30 people -- I learned that the specifications that Fairchild was using to make the preproduction lines were missing. And these were later found, had been taken by Baldwin and Weindorf…stolen if you will, by Rheem to build their semiconductor lines. But I was lucky enough to drop into a much-needed kind of an operation; the pilot group to make mesa transistors, which was the device that they had been working on at Fairchild [when] they had started, and wanted to continue making for manufacturing production.

Addison: Talking about that particular time, what about the equipment that was used to make the transistors. Had it developed since the Shockley Labs days?

Sello: That was a serious problem. For one thing, you could not buy desirable production ovens, diffusion ovens, to both oxidize and diffuse impurities into silicon. And Fairchild had to make its own; I think the first year they made somewhere between 20 to 30 furnaces, or maybe more, that they used in their own preproduction lines, and later, production lines, for diffusion of silicon wafers. And Gordon [Moore] said, I know you were building a monster [furnace] at Shockley when I left there, whatever happened to it? And I said well, I turned it over to Sam Fok because Shockley wanted me to work on other things, but we never really got it built while I was there; we never got it finished. It was later finished; it turned out that it was not the design I was using [which was] a big furnace, very wide, maybe 3 feet wide by 3 feet tall. The design I was using was to make a furnace that was hot on the inside but had enough insulation on it [so] you could put your hand on the outside. The result was an enormous furnace. And [Fairchild] said we can’t use that because we don’t even have the room for the furnaces, we have to make small ones. And we can’t buy them. So they made furnaces on which you could roast your hand if you put it on the side because it was too small. But they had to make their own to fit the production lines, and we couldn’t buy those. Later, outfits like Thermco and others got in the business of making furnaces like that for semiconductors, and you could later buy them. But the first, I would say, few dozen furnaces we had to make ourselves. And I think this was true of the other companies, as well, at the time. We also did not have any mask-making equipment. That was totally unknown. So by and large, Bob Noyce, with the aid of Jay Last, had to invent a mask-making optical apparatus for making single masks of a pattern of transistors, and then allowing those masks to be stepped into repetitive patterns. And these were homemade devices. Later, you could buy some of this, maybe over a period of 2 or 3 years later, but we had to make the very first ones.

Electrical equipment was by and large available from Hewlett-Packard and Tektronix in the form of curve tracers. But we had to cobble them together in order to make devices that would measure the current/voltage relationships in these devices. And we couldn’t buy those, so we had to make jigs and equipment to go with these instruments. Later you could buy these from companies…once we placed an order for building them under our guidance, they would then build them. You could barely get quartz tubes; quartz was available because they were using it in the chemical industry and so forth. There were a number of others. For example, evaporation equipment, in order to evaporate metal…there were companies that were making such kinds of equipment, but we had to really cobble them together to make an existing vacuum apparatus that was used commercially for something else.

Addison: What about crystal growing?

Sello: Crystal growing is another fine example. Crystals were grown by the people that were making devices, TI and Motorola. They'd build their own crystal-growing furnaces, based on designs that they got from licenses purchased from Bell Telephone Laboratories. The origin of the crystal growing was at Bell Laboratories, and since all of us who were using that tool had to get the rights from Bell Laboratories, and they got a licensing fee for them, we had to buy the know-how and copy what Bell was doing, maybe improve on it. Even at Shockley Laboratories we started building our own crystal-puller. We never quite finished it while I was there, but later…[there was] an offshoot outfit that started building them and making them commercially for other semiconductor companies that were popping up.

Addison: Do you recall the details of that offshoot for the crystal pulling?

Sello: The crystal-pulling offshoot would have been something like early 1959.

Addison: Do you recall the people involved, the name of the company?

Sello: Dean Knapic; that was a key name. A gentleman by the name of Knapic who was assisting at the Shockley Laboratories went out on his own to try to create crystal growing furnaces, crystal-pulling furnaces. And he succeeded in building some and he sold them to us and to other semiconductor companies. His firm didn't last too long because it wasn't being done economically; it was a business failure rather than a technological failure. But he started doing that, and he had learned the skill at the Shockley Laboratories to begin with. TI was building furnaces, but they wouldn't sell them to a competitor, and neither would Motorola. So we had to learn the art of Czochralski crystal-pulling from furnaces we had to buy from Dean Knapic or somebody at Bell, or people who were building them for Bell.

Addison: Was the equipment used by the big guys, such as TI and Motorola, more productive than what you were using? Was there some sort of disadvantage to building your own?

Sello: We were at a disadvantage building our own, because we couldn't build them as fast as others could. We could build them economically. TI got into the business and became famous for building all its own equipment. It became an equipment-building company as well as a semiconductor-making company. To an extent, that slowed the development of TI, because we could contract for what we wanted on the outside. We could contract exactly what we needed from guys who were just starting up and were willing to risk themselves. In fact, I think privately several of the people working at Fairchild had invested in these kinds of businesses. Folks like Trevor Law went into crystal pulling….Galamar went into crystal pulling because they thought that it would be a profitable business. Fairchild not only spawned a lot of related business, but did a lot of their own construction. Not as much as TI or Motorola.

Addison: Do you recall any specific examples of Fairchild people who left to build their own equipment?

Sello: Well, I mentioned Galamar.

Addison: What about Art Lasch?

Sello: Art Lasch was one of the first super-technicians employed by Fairchild Semiconductor. [He] was a specialist in equipment bonders, wire bonders. And he got a start because in his garage at night, after hours, he made glass capillaries, which were very much like temperature tubes. Instead of mercury in them, they had gold wires running through them. And you fired a ball at the end of these, and the capillary was carefully made so that the gold ball could be used to bond onto a semiconductor. You heated that, and then, when you pressed that onto a bonder, you needed that capillary. So Art used to make them, and he was encouraged to even go into business for himself even though he was working for Fairchild at the time. Well, Art did, and it became Electroglas and went on to make other things like probes for measuring electrical characteristics of devices…wafer probers and device probers. Art used to refurbish [the capillaries] while he worked at Fairchild. He would take the broken capillaries and ground them down, polish them and put them back to work on the production line. We couldn't keep up with the rate of growth of trying to do this in situ, and Art thought, well I can do this at night, I'll work on my own time, but you know, could you pay me for them? Well, yeah, you can do that, but don't sacrifice your own work during the day. But he went further. It wasn't illegal, we knew about it, because Fairchild could make use of his sources of supply. Of course, when the bigger companies like TI and Motorola got wind of this, they wanted to buy also. They had to buy in larger quantities. So Art had to finally leave, because he wanted to start that business of his own. From that, it went into wafer probers, which is something that he was doing while he was working at Fairchild as well.

Addison: What was the relationship like between Art Lasch and Fairchild?

Sello: Art resigned. It was a friendly relationship. It was a synergistic relationship. Bob Noyce and Gordon Moore were the first to see that this was a growing business, and Art wanted to take a chance on his own like they had done. They encouraged it. I don't know if they helped him financially. They could have, but I rather don't think so, unless they did it privately.

Addison: If we could talk now about the integrated circuit, the equipment and the materials needed to build it. Was there any dramatic change in what you needed to build the integrated circuit?

Sello: Yes, there were two dramatic changes when it came to integrated circuits, the complexity being collections of large numbers of transistors in one square. I should precede this by what I think are the two most important developments in the semiconductor industry to this day. Number one was the development of diffusion under the oxide by Jean Hoerni, one of the Shockley originals. When you diffused and made a junction that was under the natural oxide of silicon, it made something that was impervious to the outside atmosphere. That was a milestone. There was a second such invention about a year later…credit given to Bob Noyce. That was the so-called "metal over oxide" patent in which you could connect one transistor on a chip to the next transistor by running an aluminum pathway over the oxide from one transistor to the next so that you didn't have to have the flying wires in between. TI never did develop that. They fought Fairchild on that patent all the way to the patent courts. We won, we prevailed. And those two developments led to the growth of the industry of integrated circuits because now, you could make a flip-flop, or an amplifier, composed of anywhere between half a dozen to a dozen transistors on one chip by using that technology. But now we had a problem; how are we going to test these things? So Fairchild formed a division of its own called Fairchild Semiconductor Testing Division, in which we made the electrical equipment and the probers and the testing boards necessary to test these complex integrated circuits, which up till then had never been made by anybody that way. Now Bob Noyce also did something which isn't generally recognized in the industry as often as it should be. He donated the word planar to the industry. We never got a nickel's worth of rights for the use of planar; they wouldn't do that today. But that, of course, expanded the industry… by leaps and bounds because now others could make that. Of course, if they made them by the techniques described by Fairchild, they had to license our patents. And Fairchild enjoyed, for many, many years after that, a very good licensing income based on the technology of integrated circuits which required this particular planar technology.

Addison: You said there were two developments…one was test. What was the other?

Sello: In order to make those devices, we had to have complex photolithographic equipment. Now, the early photolithographic equipment we used was homemade at Fairchild. But now we had to get people interested in making those things. And an optical industry grew from that in order to make masks that we could use as patterns. And there were a raft of little outfits that grew later into bigger outfits to make those masks. So those two developments led to rapid growth in the semiconductor equipment industry: testers and mask making.

Addison: But in the early days, Fairchild did that in-house?

Sello: We did that in house. We made our own testers, and we made our own micro lithographic equipment.

Addison: Gordon Moore tells the story of Bob Noyce going to a camera shop to buy three 16mm movie camera lenses for the lithography process.

Sello: Yes, he put together the lenses for the magnification of these devices. And the first of those mask-making equipments were built at Fairchild. You could buy magnification equipment. You could buy large equipment for magnifying a large pattern down to a tiny pattern, but you couldn't buy the repetitive equipment that was needed in order to step that across an integrated circuit wafer. And that gave birth to what we recognize as mask-making equipment. But Fairchild never got into the mask-making business, ever, as a commercial business, but encouraged others to do that. We got into the test equipment business because there weren't any that we could [find] at the time, and we felt that we had the electrical engineering know-how, largely started by Vic Grinich, one of the original Shockley guys, to make integrated circuit testers and transistor testers. And so the Fairchild testing company was born. It grew into Fairchild Sentry Systems later, but it had a hard time competing with the rapidly growing [competitors] that were coming along. We had a problem, because while we made the test equipment, we also made devices. Therefore, we were competitors to people who [would] buy our test equipment. They were worried that they would have to give up knowledge of their devices to buy our testers. So that was a difficulty in that area.

Addison: Do you recall, for example, Teradyne entering the market for testers?

Sello: That was an interesting case. Teradyne came along about that time and Teradyne had been making simple test equipment for individual devices and for certain amplifiers and certain controllers. But Teradyne recognized this need… if they could sell to the semiconductor industry they could compete with Fairchild, because Fairchild was having trouble selling to its competitors. Now, Teradyne was not a competitor elsewhere in the semiconductor industry, and that was largely responsible for the rapid growth of Teradyne. And they were smart enough, or lucky enough, to concentrate in linear integrated circuits. And that's where they got their start. So again, in that area, Fairchild made its own linear integrated circuit testers, but of course, people weren't comfortable buying the Fairchild series 4000, as they were called, because they would have to buy from a device competitor. But they could buy Teradyne, because Teradyne was not a device competitor. That was a very tough cross for us to bear in the instrument division. But it did last for a long time; Sentry Systems lasted all the way through Fairchild's history.

Addison: I would imagine that TI and Motorola built their own testers.

Sello: They built their own test equipment, but they didn't sell them. They would sell rudimentary equipment, but nothing of the advanced caliber that Fairchild was making.

Addison: In your interview with Rob Walker (for Silicon Genesis) you tell the story of how Bob Noyce invited you to go to Italy to work with SGS. When you got there, what did you have to do; did you have to build the factory from scratch?

Sello: In effect, yes. SGS was an interesting start typical of the advanced thinking of Bob Noyce and Gordon Moore. It was recognized early that we had to get into European market and the planar integrated circuit, and even the mesa transistors that we had started out making at Fairchild, were not being made in Europe to any reasonable extent. In order to penetrate the market in Europe, Bob Noyce, Gordon Moore, and the management came up with [the idea] that they should join up in a joint venture with Olivetti and another company called Telettra. And that was a combination called Societe Generale Semiconductore, SGS. And the purpose of that joint venture was to introduce silicon and planar devices into Europe. SGS existed in part, up to that point, without Fairchild, but they were making devices out of germanium, an old-fashioned material that was rapidly going out of style. So in order to get into silicon devices in Europe, they needed to get into silicon processes, and Noyce saw this as a very good opportunity. And I was the lucky Pierre who was assigned the job of converting the SGS factory, then in germanium, into a silicon transistor-manufacturing factory. That's a big mouthful, and it turned out to be a great big mouthful to implement, because I knew nothing about germanium, and none of the Fairchild guys, with the exception of Bob Noyce, recalled anything about germanium.

Well, it was a three-way venture, of which Fairchild, because of the technology, managed to own 40 percent…with 60 percent the other guys. And I was designated to be the operations manager with the chore of transferring them out of germanium and into silicon. Well, since I had never seen germanium, it was relatively easy for me to think, let's throw all this crap out, it doesn't have any reliability, and let's start right into silicon. The difficulty was that the partners refused to do that, because the germanium diodes were a source of income for the previously existing Societe, and my throwing it all out would reduce the income to essentially zero. So I begged, pleaded, and weaseled, and fought, and we started to convert one line at a time, keeping germanium going, reducing its production, but bringing in first the assembly for transistors made out of silicon, and then later the diffusion and assembly of making these transistors. I spent three years accomplishing that. There was still some germanium being run. Germanium is an unreliable device; it does not have the silicon oxide protection. So germanium devices in inventory tended to die, for leakage, for exposure to atmosphere, for whatever. So we couldn't maintain a large inventory. If you can't maintain an inventory, you can't ship from inventory, so it slowly died out; they finally, eventually converted all to silicon. By the time I left, it was about two-thirds converted. I was called back by Gordon Moore, asked to come back, because he had then just formed a new research and development division which hadn't existed before at Fairchild. He was the lead VP in research and development, I was to be department head in the R&D division to make new devices and new processes for Fairchild. Fairchild then, not too long after I came back [from Italy], elected to sell its portion [of SGS] to other partners. After I left, there was no one there who could see to the interests of Fairchild, so the other partners began taking over and building plants…they were building too many, it was too costly. The Italians operated in a manner which was not the Fairchild manner, so from a business point of view Fairchild finally sold its share back to the other partners, and SGS went on its own in its partnership.

Technically, the SGS people were quite good, and they were not too much at fault for the problems, but the word "teamwork" in the United States has a different meaning than it does in Italy. Teamwork in the United States means that you work together to solve a problem. And so the whole team gets the credit. In Italy, in general, among advanced-thinking engineers, they worry about who gets the credit for solving the problem, more than the team. So I had a difficult time trying to get the team to solve the problem without some engineer going out on his own and trying to do it without the benefit of the team. So it did not run under the control that I would have liked if I had stayed there. They wanted me to stay at SGS, but I felt that I belonged back in the United States, and when the offer came from Gordon Moore to join him in our R&D operation, I jumped on it.

Addison: Was it Bob Noyce or Gordon Moore who identified Italy and these partners?

Sello: It was more Bob Noyce than any other single person who identified the Italians, who managed, at the vice presidential level, the ongoing operations. In 1968, Noyce and Moore left Fairchild to form Intel. SGS started in about 1963-1965…they soon after left and formed Intel, so Fairchild was no longer interested, other than a licensee, to go along with SGS. They were a very good licensing target, and that's [how] I grew into the newly formed job of licensing the technology for Fairchild. I moved out of R&D to take over that directorship and vice presidency of Fairchild.

Addison: So there's another Bob Noyce legacy; SGS merged with Thomson and now it's No. 4 or 5 in device sales.

Sello: Yes, another legacy, a very good way of putting it. They became SGS, and then SGS Thomson. Now they call themselves ST, a combination. So that's another Bob Noyce legacy, I would say. He'd love to take credit for that, were he around.

Addison: When you came back from Italy, you said that you headed this new R&D facility at Fairchild.

Sello: That's right, got into this new department in R&D, and the department had, largely, two chores. One was to do materials processes development for making new devices, and device design itself. It's in the device design area that Rob Walker later joined in; this started before Rob joined Fairchild. R&D and material processes was the department to make the new processes, which would work together with the new devices, the more complex integrated circuits, both MOS circuits and bipolar circuits. Fairchild became very strong in the bipolar device making industry, and played a leading role in the world in that industry. But they did not develop MOS as fast as others did, and it was that opportunity to develop MOS devices that Noyce and Moore recognized that they wanted to do when they formed Intel.

Addison: Materials and processes. Today that's really the realm of the independent equipment makers. Back then, was there much contribution from outside the company?

Sello: There was contribution from the outside. For example, materials and processes also included mask making. We built and set up an enormous step and repeat camera…the first known to be built by a semiconductor company, in R&D. Unfortunately, the downside was that this needed to be production equipment and what we had built was what people would call an R&D monster. And it couldn't keep up with the production needs. And so we couldn't use it very much for production; we could use it only for making masks, for new device development. So people like David Mann, for example, came along, recognized the need, and began building cameras. So in my department, where Gordon asked me to take on this mask-making, I used to talk with him about, well, let's stop doing this, and let's buy a David Mann camera. Why do we have to build our own from scratch? Sure, there's nothing like it in the world, but this big hunk of granite, later called a granite tomb, was not a practical, cost-effective device for making masks. Intel, interestingly enough, never got into the business of making masks, but they encouraged people like Micromask to get into that, and thus got a preferred relationship with Micromask.

Addison: When you built this step-and-repeat camera, were Gordon Moore and Bob Noyce were still there?

Sello: They were still there, yes. I was asked to take it over when I came back from Italy. I looked at that, and I said, Gordon, we've never done anything like this. And he said, well, it ought to work; it was built on good principle. And it's since been called a "shoot on the fly camera". It was invented by Fairchild. The technology [of the day] was step, stop, and shoot, then repeat, but stop and shoot, then repeat, but stop and shoot. Our invention…was to keep the stage moving, but shoot on the fly. Just trigger the lenses to fly, trigger the lenses to go. And in principle it worked beautifully, but it wasn't a production piece of equipment; it was extremely expensive to build, and we couldn't build repetitive models. It was an R&D project that worked well in its time, but was not a commercial piece of equipment. Besides, the step and repeat was fast enough. And later, the shoot on the fly was built by the commercial guys anyway.

There was another parallel development. The Japanese like, Canon and Nikon, were extremely expert in building lenses. And because they had such a good source of lenses, and knew how to build matched lenses, which were wired half a dozen to a dozen at a time, they became mask makers. So they backed into mask making because of their skill in making lenses. Now, even in our granite original we bought lenses from the Japanese because we never got into the lens business. Even the camera that Bob Noyce built originally was built from commercial lenses, but he conceived of the idea of putting them together in a way that they could do step and repeat type of things. But they were Japanese lenses.

Addison: What about GCA and Perkin Elmer, they were once big in lithography. When did they come into the scene?

Sello: They came in later because they understood optics. You had to know device manufacturing, but you also had to know optics. Depth of field, and diameter of field, were critical. You had to have lenses that could refine that whole field. The Germans, Zeiss Optics, came in at that time. So the thing that Fairchild did not have was the ability to make lenses. We always had, as others did, to depend on commercial ones.

Addison: Maybe switching gears to the assembly and test process. I recall reading in Charlie Sporck's book that Fairchild was the leader in going offshore for the low labor cost, whereas TI and Motorola relied on automated machinery. And I think he made the argument that Fairchild was more competitive using the low-cost labor, as opposed to these big machines that were inflexible.

Sello: Yes, he certainly is right about that point. But that was true certainly at a transistor level, where the assembly is a rather simple type of operation. You only bond three leads to a chip, and two kinds of chips, two leads to a diode, and then the simple integrated circuits would have six to eight wire leads. And those all had to be done by operators working through microscopes and using Art Lasch's glass capillaries. But of course… as the integrated circuits got larger, and they went from several hundred into several thousand contacts, now the problem [was] in making multi-contacts, bonding to many, many leads. And one of the earliest ones to get into it…was Kulicke & Soffa, who could make automated bonders. And that, of course, broke open the need to go into automated machines, and TI was building automated machines early on to do that kind of bonding. It was more expensive because you had to amortize and this was expensive equipment. But if you had to make many thousands to tens of thousands of contacts on a chip, it didn't pay for hand labor to really carry that too far, even low-cost labor.

There's an interesting anecdote about the low-cost labor of Hong Kong devices. When Charlie Spork was running assembly, he was a great devotee of "work factor". That is, getting the operator to work with certain strokes and in a rapid manner. So work factor, implementing that, was an important job. Now, there were people in the American assembly lines who could work very fast, and they set the standards for work factor. When Charlie Spork and others went to look at Hong Kong, the standards for work factor flew out the window. Because the Chinese labor, the girls working there, were exceeding everything that was ever known with work factor. These people are going twice as fast as anything we've ever seen [in the U.S.], and we've got the highest standards in the world. So it just tore apart the whole work-factor end of things.

Addison: So did Fairchild try to develop any automated assembly equipment?

Sello: No, not really. Now, certain assembly equipment for particular devices were developed at Fairchild, but they never got to be developed to a commercial stage.

Addison: Maybe we can talk about the wafer sizes and the transitions there, and what headaches that caused. For example, when the IC was being developed, what size wafer was being used?

Sello: Oh dear, you're asking me to dig back into memory long gone. Let's put it this way; at Shockley, we had large wafers that were half-inch in diameter. And I remember them directly because at Shockley, the devices we were making had to be polished very carefully, planar polished on both sides. And the front side had to match, in parallel, with the backside. Now, that's a hard thing to do; how do you polish a wafer in order to make it simultaneously parallel and the same surface on both sides? So I remember standing in front of a lapping machine, which were commercial at the time because they were used in optical work and everything else, and I had a wafer under each finger, 10 wafers at a time. And I would stand there and work them by hand and try to polish them all simultaneously so I could do 10 at a time. And then we'd have to turn them over and do the other side and make them come out microscopically parallel. It was a pain in the butt. It just couldn't be done. Later, lapping devices, which were used in other industries, were purchased. And when we got to [wafers] that were an inch to 2 inches in diameter, we could no longer use the same sort of technique that was used to lap wafers. We didn't have enough fingers! But [lapping] was not a business that Fairchild ever got into, and I don't think it was a business any other semiconductor company got into; it was too highly developed already in the optical business.

Addison: The move to the larger wafers, was that really something that the device makers pushed? Did they say, okay, we need bigger wafers?

Sello: The device makers pushed it all the way. Fairchild pushed it as hard as anybody did. And I don't say that we were in the lead of making the largest wafers at the time, but we made wafers in-house. And of course, the industry went on to today's 12-inch diameter wafers. The investment in equipment was too large for a semiconductor company to develop on its own. You left that to the guys who knew how to grow the crystals. But let's see…4 inch wafers went into production, made by Fairchild, and from there on out, we relied just as much on the purchase of large diameter wafers as we did internally.

Addison: Were you involved at all with the standards work being done by SEMI to standardize these wafers?

Sello: Yes, I was involved in early days of standards. But I mostly got involved in standards for chemicals, because I was drawing upon my chemical background. And that also had the environmental factors involved. So the standards we were trying to work out involved what chemicals we work on that we need to have as a consequence of this work. So the committees that I attended, also run at the time by SEMI, were chemical-oriented, and the materials for doping. So I got involved in that, but it did not become a major part of my effort. But I did serve on some of those committees.

Addison: Talking about chemicals, when we had lunch today, you were telling some amusing stories about getting your hands on these chemicals. Can you recount some of the efforts you had to go through?

Sello: Yes. There's two things I can recall about chemicals. One thing was the safety factor involved in using the chemicals, and the second was the purity. Now we ran head-on into both of those factors at Shockley. When I came to work at Shockley, I was largely a physical chemist who was oriented toward organics, not toward inorganics. I knew what HF -- hydrofluoric acid -- was, as an example, but I never had a chance to use it much as an everyday working chemical. And of course it's a tremendously dangerous and corrosive thing. So I had to learn how to use HF. And my first mentor was Gordon Moore. He said let me show you about HF. And he says, the first thing you do when you use HF is put on a pair of safety gloves. Never go into the HF bin, into any of the bottles, without wearing safety gloves. And also for HF you wear a facemask, and if you like, I personally like to use safety goggles. And he gave me instructions [that] if I feel something itchy on my fingers, quick, whip off the mask, gloves, and everything, and get your hands under a shower. And so you could take care of the safety factor. Now, this was a terrible problem for engineers; I knew chemicals, so you didn't have to lecture me on the safety of HF once I learned. But engineers, who saw HF as they saw hydrochloric acid, or sulfuric acid, they were just nonplussed by this. And they had to etch samples to make their devices. So we had a hell of a time trying to keep them out of trouble. Because the engineer who saw CP on the bottle…didn't realize that CP meant chemically pure, which the HF had to be.

The other factor was the purity. We had a terrible time in the early days convincing people like Monsanto and Mallinckrodt -- those were the two big distributors of chemicals -- to make ultra pure material. What they called UHP, ultra-high purity, had too many metal contaminants down in the parts per million, parts per thousand and parts per million, which were too contaminated for semiconductor levels. And if we started with chemicals that already had too many of those in it, particularly things like copper, or sodium, we had a terrible time getting chemically pure materials. And I could not convince the engineers that there's two things you can't do; you can't contaminate them, so for God's sake use gloves. Not because I want to protect your hands; the hell with that. Don't contaminate the material. And of course we learned, in later work at Fairchild, that the major contaminant which destroyed MOS devices is the element sodium. Then, all hell broke loose, because how do you keep sodium out of chemically pure material? There's sodium in glass, and glass that contains the chemicals, and how do you convince Monsanto to use sodium-free glass? They wouldn't even make the chemically pure materials. And that persisted for quite a while, even after Fairchild stopped distilling their own materials. Sodium was discovered by Bruce Deal, at Fairchild, as being the major contaminant in making pure MOS devices. And when he discovered that…it was a revelation even to Bell Telephone Laboratories who never had heard of this as a contaminant in MOS devices.

Addison: At Fairchild, when you were doing fairly high volumes of production, how did you go about getting some of these special chemicals?

Sello: We had to order them specially, and in many cases, we even made small quantities by distilling pure water out of quartz in order to make these kinds of devices. We also learned, and from the literature became aware of, techniques on how to so-call "getter" the sodium out of the devices. And we applied the use of layers of phosphorous glass in order to purify, to getter, such impurities out of material. Now, we weren't the ones who invented the gettering process; the use of phosphorous glass to do that was picked up, I believe, by IBM. But we learned that it was the sodium that they were gettering. And so that was one of those things that came out when we licensed the processes. I can remember a special meeting we had with the fount of all knowledge, the Bell Telephone Laboratories, when we went there to explain why our MOS devices were so stable. And why our circuits would not drift. And Bell wanted to know, what's your secret? And we were cross-licensees of Bell's…[and they] wanted to buy a license from us for the planar device. And they wanted to know, as mutual licensees, how do you do this? And we said, well, the answer is sodium. And they looked at us askance; there were guys at the other end of the table that I'd known for years, and that Gordon Moore and Bruce Deal and Bob Noyce had known for years, and they said sodium, what do you mean; sodium is in everything! I mean salt, all over the place, are you guys trying to pull our leg or something? Come on, tell us the truth, what is your magic trick for getting driftless MOS capacitors? And I remember Bruce Deal, with his natural straight face, saying right out there, I'm telling you, keep the sodium out of it. They did not want to accept that; they would accept the recipe, in the course of which we said we used very highly pure water, because they knew water contained contaminants, even distilled water; but they never really bought off on the sodium theory. And this was mighty Bell Laboratories.

END OF INTERVIEW

