Oral History of Herbert F. Mataré

Interviewed by:
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Michael Riordan: This is Michael Riordan interviewing Herbert Mataré in Malibu, California. It's December 20, 2004.

<long silent gap in the recording> [Editor's Note (hereafter "EN"): This is probably material about Mataré's WWII silicon R&D work.]

Riordan: Tell me a little more about Mr. Engel. What was his discipline? [EN: From Mataré's notes, Engel was apparently a patent attorney who became valuable to Westinghouse when the question arose about whether to employ German specialists in semiconductors for postwar development work on diodes.]

Herbert Mataré: Very interesting fellow. He was, I think, originally from Alsace-Lorraine. So a German-speaking Frenchman.

Riordan: Was he from the Paris area?

Mataré: Yes, from Paris. He was Director at Westinghouse, and he was also patent lawyer.

Riordan: Oh, he was a lawyer!

Mataré: Yes, he also took care of patents.

Riordan: So he wasn't a scientist? Did he have any kind of a science background? Or a science and technology background?

Mataré: A kind of what?

Riordan: A background in science and technology?

Mataré: No.

Riordan: He was a manager.

Mataré: Yes, a manager. He gave a speech, which is printed in that booklet I gave you where Welker and I gave a talk at the University for the Association of the French Electrical Engineers. You have that paper. I gave you a copy. [EN: Heinrich Welker was the other principal figure, with Mataré, in the Paris semiconductor company he is discussing here. He subsequently went to Siemens, where he was a pioneer in III-V compound semiconductors, such as GaAs.)

Riordan: Okay, yes.

Mataré: You can see what he’s doing . . . .

Riordan: What was his first name?

Mataré: . . . organizing. What do they call that first name?

Riordan: A. Wilhelm, okay.

Mataré: Albert Wilhelm [Engel], I guess.

Riordan: Albert?

Mataré: With an A. Yes, he spoke German very fluently.

Riordan: And initially the thrust of this group was to make germanium diodes for the military, right?

Mataré: Yes, telephone companies wanted the Sylvania diodes. <inaudible> Welker had the problem that they didn’t accept our diodes because the purification works was too small.

Riordan: The silicon.

Mataré: No, germanium.

Riordan: Germanium, I know.

Mataré: Welker had the equipment only to make germanium crystals. He couldn’t make silicon. That had to be done too hermetically for him. So we made germanium and improved on the purification process by reverse. I told him to make several [successive] crystalizations. Then you get better crystals. But he only made crystals which were small like this. Like the inside of a pencil, you know? That was the kind of crystal he made. And I said that that cannot be good because its surface-to-bulk ratio is too high.

Riordan: Why is that important? I saw where you said that in one of your publications. Why does the surface-to-bulk ratio of the crystals matter?

Mataré: Obviously because the impurities come from the surface. The impurities are at the surface. That’s where you have to contact to the outer environment, which is not 100 percent pure.

Riordan: You mean just because it's influenced by the external environment?

Mataré: Also because we did not have the [necessary] hyper-pure hydrogen, and we couldn't make an absolute vacuum. We couldn't make hyper-pure hydrogen. So all that happened was the bigger the crystal, the better was the purity inside the crystal.

Riordan: Inside, but you really didn't have access to that, did you?

Mataré: Well, it was all molten. Of course, we remelted it. We took a boule, which was pick-up. And the germanium, which was inside the boule, was much purer.

Riordan: But when you're contacting this germanium with point contacts, you're still only dealing with surface effects. You're not really...

Mataré: Oh, no, no, no. We cut it out from the inside. From the inside of the boule.

Riordan: Oh, from the inside. Okay. So you made...

Mataré: These big crystals here were not very good on the surface. But inside the crystals, it was good.

Riordan: Okay!

<overlapping conversation>

Riordan: From the way it was described before, it seemed like you were just...

Mataré: Oh, we made like...

Riordan: Contacting outside of these pencil...

Mataré: Oh, no. Is that what you understood? But from what Welker has written, yes.

Riordan: No, I didn't really spend too much time with what he wrote. But you actually would make pencil-thin samples of germanium, and then cut samples out from inside of it.

Mataré: Yes, he made these pencils. And then he cut the crystals here. And these little crystals he put into the holder and put the needle on. But that was a bad crystal.

Riordan: He actually made it too small?

Mataré: Well, you could also make the inside small. But the point was that there was a big surface.

Riordan: I'm losing you here.

Mataré: You see, when you make a crystal like this in a graphite boat, then the whole crystal is surface.

Riordan: Okay, so it's...

Mataré: The whole crystal is contaminated.

Riordan: So you can't find much, if any...

Mataré: You have no chance that this thing gets purified. But the idea would be to make a sphere — that you enclose a sphere in graphite. And then you heat it up. And then the impurities go to the outsides. And you can cut out an excellent piece out of the center.

Riordan: Okay, that's not at all clear from what you've written. I thought you were using the entire sample for contacting...

Mataré: No, no, no. What was meant was the melting process, and how much surface we had in the melting process.

Riordan: Okay, it begins to make a little bit more sense.

Mataré: Yes, because these already existed when I told him this; he did already have something that was very close to the boule or sphere.

Riordan: Yes, I noticed that in your description. It was this melting and recrystallization. That was a technique that was known to physical chemists before William Pfann began doing it at Bell Labs. William Pfann systematized it. But the fact that you could use melting and recrystallization to purify materials was known for most of the 20th century, at least.

Mataré: Yes.

Riordan: Well, what I still find intriguing is that Welker, a theoretical physicist, was doing what is really physical chemistry.

Mataré: Yes, yes.

Riordan: After the war, right?

Mataré: Yes, I know. He was doing this; I'll tell you why, It was because this was the only way he got free from military service.

Riordan: Ah! Okay!

Mataré: Otherwise, he would have been drafted [EN: during World War II].

Riordan: Yes, and especially after he got done with the production, it gave him the freedom...

Mataré: . . . to do superconductivity research; he could not be freed from military service [during the war].

Riordan: It was a purely theoretical activity in the 1940s.

Mataré: He did something for radar [EN: making germanium diodes for radar in Munich] . And then he could be freed [from military service.]

Riordan: But then after the war, there was no longer such a need. We're talking 1947-48 now, and he's still refining germanium.

Mataré: Yes, 1947-48, he's still doing germanium. He did not touch silicon. Because he was [a theorist at heart]. A man who wanted his quiet life. He did it as a hobby [EN: theory]. He worked continuously on the theory of superconductivity. I had the whole production of germanium diodes on my neck.

Riordan: But the focus of the Paris group was almost entirely, if not entirely, on germanium. Is that correct?

Mataré: Yes.

Riordan: And this was, in part, the choice of management.

Mataré: Yes.

Riordan: They wanted to duplicate Sylvania germanium diodes.

Mataré: Well, that was the point while I was there.

[audio ends abruptly]

END OF SIDE A / BEGINNING OF SIDE B

Riordan: This is side two of the interview with Herbert Mataré on December 20th, 2004. Go ahead.

Mataré: That was the time when I started to look into duo-diodes again, which I remembered from [my war-time work in] Leubus. [EN: As part of a letter to Riordan dated June 18, 2011, Mataré provided a drawing of the use of such a duo-diode in a push-pull mixer.]

Riordan: Can you give me an actual year?

Mataré: It was 1947, the beginning of 1947.

Riordan: Was this because you had succeeded in getting the diodes into production?

Mataré: I thought that maybe I was more lucky that this is germanium, which we used here because I wanted to separate those diodes out and make a duo-diode. And while doing this, of course, then I had the reaction, "What is happening here?" because I got interference. So I couldn't equalize them. I couldn't get good duo-diodes. [EN: In his letter, Mataré wrote, "These tests were inconclusive at the time because of barrier interference. This was actual injection of minorities from one side to the other but did not give the desired equal characteristics for radar mixers."] But I said, "Well, the hell with it." I put a circuit on the input and I put a circuit on the output, and I put a positive voltage on this side and <inaudible>. I got 100 times amplification. I did it right because we got amplification here. That was certainly something that had to do with induction. Welker said no, that is a field effect.

Riordan: Now you're talking 1948, aren't you, when you started seeing amplification?

Mataré: Excuse me? I'm not so good at hearing what you're saying.

Riordan: From what I remember from what you've written, it was in early 1948 when you began to recognize that you had amplification.

Mataré: I couldn't discriminate whether it was the end of 1947 or beginning of 1948. But I was sure I got the effect and explained it somehow in 1948.

Riordan: At what frequency? Were these AC measurements or DC measurements?

Mataré: These were AC measurements. I was a typical high-frequency guy.

Riordan: At what frequency were you pulsing the sample?

Mataré: I published a paper later on. Let me see. That was a few megacycles.

Riordan: Megacycles? They didn't achieve that with the transistor until the mid-1950s.

Mataré: I think I gave you a copy of the paper, which I published later on, on the frequency measurements on our transistor. It was so good that they were not comparable to what Bell Labs did. They were much better. And I suppose it was because of the higher conductivity germanium. We had a trick of making the needles very close together and weld [ph?] the other side, the . . . EN: Here Mataré suggested, in handwriting on the draft transcript, that one take a look at “Bell Labs emitter capacity.”]

Riordan: There were a couple of factors that influenced the frequency response or the frequency cutoff, one of which is the most important: the narrowness of the base in a junction transistor, or the distance between the two points in a contact.

Mataré: At the base.

Riordan: As I recall properly, you needed to get to micron dimensions, one or two micron dimensions in order to get megacycle frequencies. The other factor was the capacitance.

Mataré: I have to look at the frequency. I published that in late 1949 or early 1950 in *Das Elektron*, which was the only journal at that time that appeared. Everything else was gone. It was even forbidden in Germany. The American occupation forces forbade any research activity in higher frequencies. You couldn't do any research in high-frequency [radar]. So I couldn't even publish it. I tried to publish it in a journal, which appeared under the title of “Das Elektron,” The Electron. I think I gave you--

Riordan: I think I have that one. I’ll check that but I find it unusual that you got megacycles.

Mataré: It was astonishingly high. I’m not sure about the frequency, though. It could be also a few thousand kilocycles.

Riordan: A thousand kilocycles is a megacycle.

Mataré: Or a few hundred.

Riordan: Bell Labs didn't get into the megacycles until the 1950s. [EN: Mataré here again mentions “Bardeen’s emitter capacity” in his handwritten notes on the draft transcript.]

Mataré: I have it somewhere.

Riordan: When did the PTT [EN: Postes, Telephone et Telegraph, I think] come into the picture? There was this Westinghouse Company.

Mataré: Yes. They took all the orders from Westinghouse: all diodes, all transistors.

Riordan: Was PTT the one that Westinghouse was producing diodes for?

Mataré: Yes. They paid for it. PTT paid for it and got the whole production.

Riordan: This is for telecommunications.

Mataré: Yes. They made lots of equipment with these diodes and transistors.

Riordan: They were perhaps the ones that were specifying that they wanted germanium.

Mataré: Well, they [EN: Westinghouse, I think.] made [point-contact] germanium transistors, repeaters for telephone amplification. And they showed Shockley in 1950 the models of repeaters with our transistors. It was by telephone. He was on the telephone with a colleague in Algeria who spoke English with him.

Riordan: I really want to focus in on the actual discovery event, and we've narrowed it down to either late 1947 or early 1948. You'd gone back to study what you call “interference,” which you had observed but could not really spend much time on during the war. You were now working with germanium duo-diodes, but in this case, I presume you were able to set up one point, which is forward biased and one point is reversed biased. And you were able to get amplification. This was a new word that you weren't using during World War II.

Mataré: No. That was the first time when I noticed that this effect was so strong that I attached a high-frequency circuit to the input and I measured the output.

Riordan: When you say 100 times amplification, is that 100 times power amplification?

Mataré: Yes. It was power amplification, yes. I measured even the steepness, “steilheit,” of the characteristic. That means how much the increment of current I gave into the input [versus how much] the incremental current was on the output, because it was an amplification effect due to the effect that you had a high voltage [times] gross current on the output side, on the receiver, and injected carriers came from the positive side. [EN: Mataré's "receiver" is what Bell Labs called the "collector."]

Riordan: What we call the emitter.

Mataré: Yes. You had to multiply that current with a higher voltage. And, of course, current [multiplied by voltage] was just the power. So you were interested in high voltage at the receiver side, or backward bias

Riordan: One of the benefits of germanium, at least that I saw in the Bell Labs sequence, was that you could put a high reverse voltage on it of 100 volts, because they were using what they called "high back voltage" germanium. You'd have 100 volts on that side, so multiply that by the current and you have the power.

Mataré: It gives a lot of power.

Riordan: If you could only have 5 or 10 volts, then you're not going to have much power.

Mataré: The current [gain is] a big thing. The current multiplied by that voltage gives you the power.

Riordan: So that, plus the fact that the region of the spreading resistance was much larger in germanium, made it the ideal kind of breakthrough material. I'd like to move on to try to conceptualize this amplification.

Mataré: You want to move on to what?

Riordan: To how you conceptualized this amplification. What was going on inside the semiconductor? On Hendel's account, it seems it's based more on the writings. [EN: Handel wrote an earlier, unpublished history of the invention of the transistron as a Ph.D dissertation, accessible only on his web site.]

Mataré: I compared it to a vacuum tube. I know this from a tube. I made the same thing as I did with normal high vacuum tubes. I had a small input to the grid and that allows change between cathode and anode. So here was the same situation. I had a small change at the emitter, at the one characteristic on the outside which was positive because there was a small increment of current and a small voltage. And I had a large incremental current at a high voltage on the other side. That's amplification like in a vacuum tube.

Riordan: I want to begin to understand how you conceptualized this process on the submicroscopic level. The idea of holes acting as the charge carriers, this was a very new conception that did not yet exist--that It was possible that holes could act as charge carriers. We knew they existed in the late 1930s. But the fact that holes were flowing in the presence of electrons was a new conception [EN: in 1948].

Mataré: I saw it. <HM changes the subject> I noticed at the same time that I could get my needle way out when I used a grain boundary. In measuring the surface conductance there, you could show that a grain boundary causes an N-P-N structure. [EN: In his responses to my early edits, HM puts the focue on grain boundaries in his polycrystalline germanium sample: "In particular the effects of grain boudaries showed that positive potential at one positive contact was carried loss-free to the end of the grain boundary." In this way, his interpretation of the observed transistor effect is very different from John Bardeen's and William Shockley's. But I believe the grain-boundary explanation came later, not in 1948.]

Riordan: You say [you perceived] this in early 1948?

Mataré: I saw an N-P-N structure. I saw a negative-positive-negative structure at the grain boundary. [EN: HM comments in his responses, "the n-p-n structure at grain boundaries was later used to produce grain-boundary transistors."

Riordan: So the grain boundary is acting as the P layer.

Mataré: The P layer into the junction of the reverse-biased [N layer?].

Riordan: I think Handel makes this case, and I think he's basing it mainly on how Welker conceptualized the flow.

Mataré: Welker drew two barrier layers close by. There was nothing else in the barrier-layer interference, but it was not an explanation for what was happening. He thought it was a field effect. He thought that that [an electric] field was interfering with this flow.

Riordan: What really puzzles me, after hearing what you said about Welker not understanding French, is that we have this drawing that's supposedly from Welker, but the labels are in French.

Mataré: Right. We talked in French. When he talked about something or gave an explanation, he talked in French because we were in a French environment.

Riordan: He learned French within the first two years?

Mataré: Not much, not much. He wasn't very good at it. No. Welker did not publish a paper in France.

Riordan: Handel talks about this manuscript that's in German, but the drawings within the manuscript, which neither of us has seen – at least I haven't seen – shows the labels in French.

Mataré: You mean Handel gives it in German?

Riordan: Here's some of the text from this paper. <shows HM Handel’s text>

Mataré: Handel can translate it into French.

Riordan: No. It says somewhere in there that it's actually written in German.

Mataré: <Inaudible>. Welker may have written that in his notebook for himself.

Riordan: No. This is a document, which I hope to obtain, a document that exists today and presumably is in the Welker papers, wherever they're kept.

Mataré: Yes. But he wrote this for himself.

Riordan: Do you think it's not incongruous that he would make the figures in French?

Mataré: No. It's not incongruous.

Riordan: But Welker's conceptualization of what was going on is that this one electrode, which he calls the “electrode de command” is setting up a field . . .

Mataré: But it's wrong because he has two barrier layers there. Both must be polarized in the same direction. And that was why he always talked about a field effect. Yes. A field effect gives you -- when you put a signal in -- a decrease in the signal on the other side, while the injection gives you an increase in the [current] on the other side. All this was not known. Welker never did a measurement. I must say, frankly, he was not interested. He wasn't interested. Too bad.

Riordan: He sounds like Shockley in a way.

Mataré: Yes. He wanted to do theory, more or less.

Riordan: Let me pull out that drawing from your patent application of August 21st. [EN: I think this is US patent No. 2,552,052, granted May 8, 1951, which can be found on p. 14 of Mataré’s article, “Von der Radartechnik zur modernen Kommuniikationstechnik,” in *Tele Kommunikation Aktuell*, Heft 9/10 (September/October 2002).] The trouble we're working with is the lack of any written record from this key period from late 1947 through mid-1948, other than this Welker document. We're now looking at this Figure 1 from the U.S. patent, based on the French application of August 13, 1948. I’m trying to understand what is going on. We see two points coming down to a surface but I see a number of zones. I see one zone that's cross hatched on the left and the other one is cross hatched to the right. What are we looking at here?

Mataré: That is a metal enclosure and this is the actual crystal.

Riordan: Okay. So this is metal. In fact, I think I'll write on this particular one. So this is metal and this, number?

Mataré: It must be indicated in the patent.

Riordan: Number 7 is metal and this would be germanium. Right?

Mataré: Yes.

Riordan: So this is what Bardeen and Brattain would call the base. What are these zones within this germanium? One is kind of a wedge.

Mataré: This is here due to the positive bias, a zone full of positive [charge carriers].

Riordan: This is what we'd call the emitter. This is what we now call electrons, although you didn't use those.

Mataré: And due to the injection from the emitter, we get an enhanced base current.

Riordan: What do these arrows represent? Are those electrons, holes, fields?

Mataré: In this case, they would be holes, which are flowing into the barrier.

Riordan: This is germanium?

Mataré: Yes.

Riordan: These arrows here indicate holes?

Mataré: Yes, holes which cause a so-called positive zone interfering with the negative bias on the [junctions].

Riordan: So it's the positive potential here that's creating a positive zone here.

Mataré: Yes.

Riordan: But it's separated. So the electrons would be taken up. This electrode is negatively biased. So do these arrows represent electrons?

Mataré: No. These are the result of the injection, the increased base current. When I put a positive potential on the emitter, I measure an increased current into the base.

Riordan: Why does this one spread asymmetrically? Why does the zone underneath this contact spread asymmetrically?

Mataré: <Inaudible>. It was mainly to discriminate the zone that was positive.

Riordan: But this is not a zone that's chemically formed.

Mataré: No.

Riordan: The actual shape of this zone would vary depending on the potential.

Mataré: It's only schematic.

Riordan: This kind of semi-circular zone underneath the collector is the shape that would exist in the absence of any potential This is not really modified that much. That's done by biasing

Mataré: No.

Riordan: This is the normal barrier layer that would exist under a negatively biased . . .

Mataré: Just that it has a leakage current due to the injection.

Riordan: These are actually electron flows here.

Mataré: Yes.

Riordan: That helps me to understand a little bit better. This is all I had until today.

Mataré: Oh, you had only one page.

Riordan: You just gave me one page and it cuts off. This actually continues and probably describes what all these labels are.

Mataré: But you have the complete patent now.

Riordan: Now I have the complete patent for the whole thing, both in French and in English. So this is what you would mean when you're saying injection.

Mataré: Yes.

Riordan: But this is more akin to what Bardeen was talking about, that the holes are actually flowing in a P-type layer, what he called an inversion layer.

Mataré: Yes, yes. I tried that, but it did not work because of the surface states. Here, we convert the whole zone into P-type in the box.

Riordan: But in this patent, the explanation of what's going on here says that P-type or hole entities are flowing at least in the vicinity of N-type or electron entities. Right?

Mataré: Yes.

Riordan: Okay. That's not 100% of the way to what Shockley meant when he talked about injection. What he eventually said and I think proved . . .

Mataré: He talks about individual holes.

Riordan: ...is that holes are flowing through the N-type part itself, not just in an inversion layer.

Mataré: Right. Holes convert in a part of the crystal.

Riordan: There's plenty of hole-electron . . .

Mataré: There's many holes around.

Riordan: ...recombination going on but some holes are actually going through the bulk germanium and reaching the zone . . .

Mataré: But you have to have a stream of charges. Otherwise, you don't get an effect. It cannot be a single hole which makes the difference.

Riordan: There's plenty of them, but I don't think anybody ever did detailed enough tests to say how much of the flow was going in this surface layer and how much of it was actually going through the bulk germanium. I think Bardeen and Brattain tried to do those kinds of measurements but nobody was interested anymore.

Mataré: I think the drawing . . . And Welker had added a drawing on selenium.

Riordan: Excuse me, had added the drawing on . . .

Mataré: Yes. You know that. The Welker story on selenium. You have the drawings there. This patent has other drawings.

Riordan: Selenium is P-type. Right?

Mataré: Yes. Selenium is P-type.

Riordan: Here there's also a small layer right underneath each of the contacts surrounded by four and -- I can't even read that -- maybe eight. In this zone here. What is that?

Mataré: No. I don't think we . . . So you mean the charges there?

Riordan: The tiny layer right here.

Mataré: I don't know.

Riordan: It's labeled. I should be able to find out what it is.

Mataré: But look at the patent. It's not complete.

Riordan: I’m leaving this document here.

Mataré: But that is nothing.

Riordan: But I’d like to see how Welker conceptualized it. If you could translate this paragraph.

Mataré: This doesn't mean anything. <translates> “This kind of arrangement is a switch in principle. Currents in a crystal can be steered or can be changed; [they] exist in a form that one has in a detector crystal, and two input points which are enabled on the surface.” It's what you heard from me. <Inaudible> The distance between the two points has to be chosen so that the point in the area of a barrier layer reaches into the barrier layer. So Welker thinks here it is necessary to reach with this point into the barrier layer of the other point, which is not the case. The manuscript is in German but French [is used in] the drawings. So he is thinking that you have to inject carriers from a needle into a barrier layer.

Riordan: He's actually thinking that the field . . .

Mataré: Again, it's a grain-boundary field. I told you that he is talking field effect, always.

Riordan: I’ll leave this with you. I have this at home.

Mataré: Oh, I think I have it in the other paper.

Riordan: If you could do that translation and send it to me, I’d appreciate it. Don't do it now.

Mataré: Welker only says that this needle has to be in the barrier layer of the other one, or at least come close. As you see, he makes a barrier layer here. He doesn't even think about injection. He makes two barrier layers that overlap. That's all.

Riordan: The resolution of this conundrum is that perhaps Handel was focusing too much on Welker's interpretation. Maybe he didn't read the patent, although he says there's a lot of similarity between this description and [Shockley’s field-effect idea].

Mataré: Welker didn't help at all. First of all, he had made no measurements, and then he did not interpret it correctly. It was really difficult.

Riordan: At this point, did you know that you were putting points down on the opposite sides of a dislocation? Or is that something that occurred to you later?

Mataré: No. That was later on. I gave you a write-up on that to make a field-effect transistor. This model is. And the funny thing was, you couldn't freeze it out. Any transistor which was cool [semiconducting] material was no good anymore. You couldn't get any current flowing [in this] material. And the grain-boundary transistor worked fine at [room temperature]. I have the [results] in my book.

Riordan: But that's more of a phenomenon of the 1950s. Right? [EN: I think that Mataré is constantly telescoping events in time. He did not realize much about “grain-boundary” effects in late 1947 or 1948.]

Mataré: Yes.

Riordan: That's another way of making an NPN transistor.

Mataré: Yes. That was the ideal interpretation for low temperature, which people were looking for. Welker was so involved in his superconductivity [research] that he had no time for this. But later on, when I came from London, I told him that there were transistors which were made from lead sulfide, and we had to look at the other combinations where you get eventually higher electron mobility. And that sparked him up because he said “Well, I want something to go to Siemens with.” So he was sitting there and thinking about it, and he did a good job by melting together some indium and some antimony. And he saw that it gave a semiconductor because he measured the Hall voltage. And he said he convinced Siemens to put some money into these III-V compound semiconductor measurements, which he did.

Riordan: He deserves a lot of credit for that. Exactly when did you hear about the Bell Labs transistor?

Mataré: Oh, about Bell Labs? Yes.

Riordan: And how did you get that information?

Mataré: We didn't have satellite phones [in those days]. We had nothing else and eventually it appeared in the *New York Times*, something came over quickly because it was brought over by ship or by airplane. But our information was through Westinghouse center, or Mr. Engel, so far as I know. And I think he said something like “They made an amplifier at Bell Labs with this thing.” And while I had already measured amplification, “We have the same thing here. We should apply for a patent.” And Welker was very reluctant. He said “I don't know anything about that, and we have to first see what they are doing.” And so I said “Well, I will make a measurement and see. I have already measured the amplification so it should be possible.”

Riordan: Had you thought of patenting it before you heard about the Bell Labs results?

Mataré: Yes. I had already this two-point germanium situation explored and found out that there was an amplification possibility. So I said to Welker that this is certainly true. We should make these things and [patent them] as a device. At first I met with resistance, that we shouldn't spend money on such a thing. This is more like a toy.

Riordan: He was trying to make an amplifier [by the field effect].

Mataré: I forgot about that. It was purely a continuation of the other patents that existed already.

Riordan: What I'm thinking is that he did have a kind of "device focus," just like Shockley, who was focused on making devices based on physics. It seems like Welker, since 1945, was trying to make a crystal amplifier.

Mataré: No. He hadn't even bothered to patent it. Only when he heard that I had amplification, he sent a patent [application] priority mail to the patent office in Munich.

Riordan: In Munich?

Mataré: For what?

Riordan: For Westinghouse?

Mataré: No, no, no. It wasn't going to Westinghouse. That patent was redeposited in Germany, in Munich.

Riordan: You're talking about the August 13th patent?

Mataré: I'm talking now about Welker's field-effect idea from 1945, which was not a patent at that time. And after I told him that the germanium can amplify, he thought it was [based on] his field-effect patent. And he sent it again to [the patent office by], how do you say, fast mail to Munich in order to get the patent for it. But it had no meaning, because Welker's patent was for the usual field-effect transistor. [EN: In his notes about the interview, Mataré states: "The discrepancy between Welker's and my interpretation stemmed from the fact that Welker did not take part in the electronic measurements."]

Riordan: Based on his original patent.

Mataré: Yes. It had no meaning. It was only an interpretation.

Riordan: There's a definite parallel between this interaction and Shockley. In fact, when Shockley saw the Bardeen and Brattain point-contact device, he thought it was a derivative of his field-effect idea.

Mataré: Welker told me it isn't worth applying for a patent, because I have tried everything. It does not work. He told me about the field-effect device. He could not get it to work because the surface was too hot. The surface had not been polished out and etched out, and so we worked later on the field effect. But that kind of field effect, where you put a rough surface, where you put a <inaudible> on a hot surface cannot work, for . . ..

<audio glitch>

Mataré: It was why Mr. Bosch [ph?] said "Why did Welker never talk about the transistor when he went to Siemens?" Siemens would have been very eager to get in on the transistor manufacturing in some form very early. Because Welker was disappointed. He was completely disappointed because he didn't make it. Very simple.

Riordan: Can you describe the Paris lab, the one in Aulnay-sous-Bois? For example, was it in a home or a commercial building?

Mataré: It was a private house, down in the cellar so that Welker could place his crystal-growing furnace in there. And I had to change his generator so that he could melt the germanium, because he didn't know how to make a high-frequency coil.

Riordan: How many stories was it? Was it made of brick or wood?

Mataré: It was a brick building, three stories. On the center floor, we had the girls and the measurement systems and on the lower floor was the workshop with some materials and a jeweller's lathe. And in the cellar was the crystal-growing furnace.

Riordan: Was this in a residential district?

Mataré: Pardon?

Riordan: Was the house in a residential district?

Mataré: The normal part, a suburb of Paris.

Riordan: It said Aulnay-sous-Bois, under the wood. Was it near a forest?

Mataré: No. It was in a suburb.

Riordan: Was it considered a wealthy district?

Mataré: Middle class.

Riordan: Was there any war-related damage?

Mataré: In 1947, 1946? No, no bomb-based damage. No. There was a problem only with our fumes. the gases and chemicals. Maybe some people in the neighborhood would have complained about that, that we had the chemical lab there. There were all kinds of etchings. We did etchings on the crystals and used them later on for the plastic melting material, these alcohol derivatives for plastic. And that wasn't very healthy for the girls. It went into the lungs. That is prohibited now. We cannot do that anymore.

Riordan: Was it out there because it was electromagnetically quiet in the suburb, away from vibrations and noise?

Mataré: No. They put the labs there because they didn't want us in the neighborhood of selenium. They had a huge selenium plant outside of Paris and originally they planned to put us with them. But then we said selenium is a big contaminant for germanium. It would mix selenium into the germanium. So they said "Well, I'll buy you a pavilion house and you make it completely separate in the suburb of Paris." And we said fine. We'll have no contamination there except for private people, <inaudible> contamination.

Riordan: Did you personally live nearby?

Mataré: We rented a house in Vaucresson. My family had the upper floor., But we slept at the lab during the week sometimes, to avoid the car rush through Paris, because my family was in the suburbs, but a fine suburb, very noble. [EN: In his responses, Mataré notes that Vaucresson was over an hour drive from Aulnay-sous-Bois. "Therefore we often camped in Aulnay overnight, when the work load was high."]

Riordan: This is your wife?

Mataré: Yes.

Riordan: Did you have any children at this time?

Mataré: Yes. I and my wife had a daughter, and she was very demanding. And we had a good house, a fine house, a villa with a garden. Welker had the lower portion and I had the upper portion, and we lived there together.

Riordan: Did you typically stay there [in Aulnay] for three or four days in a row, working?

Mataré: [EN: HM misunderstands, thinking I mean Vaucresson] Friday evening to Monday morning, yes. Then we would go over to Paris and stayed in the upper floors [of the Aulnay-sous-Bois house], each on a couch. There was a restroom and we could wash, take a shower.

Riordan: You were around each other pretty constantly.

Mataré: Pardon?

Riordan: You and Welker were around each other pretty constantly.

Mataré: Oh, yes, we were. He played some violin in the morning, which was very nice.

Riordan: And you played the piano?

Mataré: I generally played piano, but I had no piano in that small house. But I had my larger piano in the villa in [Vaucresson].

Riordan: On the Westinghouse Compagnie des Freins & Signaux. I looked at my French dictionary, and “freins” translated as “brakes.” Am I translating it wrong? Signaux is obviously “signals,” but “freins”? How would you translate that?

Mataré: Brakes

Riordan: Freins & Signaux. That was the name and I’m trying to translate “freins.”

Mataré: Freins & signaux – freins is brakes. “Freins” is “brakes”, and “signaux” is “signals.” Brakes and signals were two important things at the railroad. Westinghouse made brakes and signals.

Riordan: Signals like a semaphore.

Mataré: Signals, this thing, maybe for change in direction.

Riordan: What were they doing getting into semiconductors?

Mataré: Oh, signaux, it was a very big moneymaker. They were into all kinds of technical tools and gadgets.

Riordan: So it existed long before.

Mataré: Yes, but also since a long time before semiconductors, like selenium and copper-oxide rectifiers. They made rectifiers for battery chargers for years. We were planning to go to the semiconductor plant, to the signaux plant, but we said that cannot be done because we could get contamination. Also, Welker and I wanted to be alone.

Riordan: I take it Engel was the connection to Westinghouse.

Mataré: Oh. You have everything on the back of the tape. [EN: We discussed Engel at the outset.]

Riordan: On the tape, yes. Let's move ahead to Intermetall. It strikes me that Intermetall was remarkably successful at commercializing the point-contact transistor.

Mataré: Yes. Our idea was that, right from the beginning, if we are fast enough also making receivers with this material, we would get into the portable radio business. [EN: In his additional notes, HM writes: "We knew about the good frequency performance of the transistron and thus made small receivers. One was shown at the Radio Show in Dusseldorf in 1952-53. The whole reason for Mr. Jacob Michael to come to Paris to talk with me about production of transistrons in Germany was that he was looking for a sellable product, to transform his huge fortune in Germany into a product sellable in the USA. The German banks had a stop in their money-transfer system. This did not last beyond 1951-52 and thus led to the sale of Intermetall Corp. to the Cleavite Corp." Cleavite also eventually bought Shockely Semiconductor from Beckman Instruments, in 1960.]

Riordan: You saw radio as a potential product in 1949?

Mataré: But I had already started [working with] silicon. You have pictures of silicon rectifiers. I had started using III-V compounds already.

Riordan: In Intermetall?

Mataré: In Intermetall. That's why I called it Intermetall. I had hired five PhDs from Telefunken [to work] in Intermetall.

Riordan: When did Intermetall begin business?

Mataré: They started to sell products in 1951–52.

Riordan: When did you start spending money in building a plant and things like that?

Mataré: Oh, that was when I came over from Paris, yes. Let me see, that was started at the end of 1951, I guess. I was still working in Paris for awhile, while I ordered equipment for Intermetall. I joined Intermetall only after they had some equipment.

Riordan: As I understand it, Intermetall was a company set up because a certain Mr. Michael wanted to convert marks into dollars, which he couldn't do directly.

Mataré: He could not get the money out. His company was DeFaKa, which means it's like a Wal-Mart, something like Wal-Mart. His magazines or whatever you could call them, did very well. He made millions.

Riordan: Do you remember his first name?

Mataré: It was Jacob.Michael was his last name.

Riordan: So these were like department stores.

Mataré: Yes, yes. It was department stores that were named DeFaKa, ”Deutsche Familie Kaufhof” DeFaKa. It's the abbreviation. And he made millions and couldn't bring it over to the United States.

Riordan: So the idea was to make semiconductor devices.

Mataré: Yes. And he needed a guy who was in the forefront of something technical, which he could sell in the United States. And his lawyer said, “You have to go to Paris and talk to Mataré, who is now ready to leave.” And then he came over and made the offer.

Riordan: That reminds me, we should pick up on Shockley, but continue on that story.

Mataré: Shockley founded the transistor corporation in San Francisco.

Riordan: But when he was still at Bell Labs, it was either 1949 or 1950. Shockley and Brattain paid you a visit, right?

Mataré: Shockley visited us in 1950.

Riordan: What time of the year?

Mataré: It must have been summertime.

Riordan: At that point, you were still with Westinghouse.

Mataré: Yes.

Riordan: So he visited Aulnay-sous-Bois.

Mataré: He visited what?

Riordan: Did he visit at your laboratory?

Mataré: He visited the whole lab. He discussed things with Welker and me, and he looked at our transistors and then he talked to Sueur, who was the director of the PTT. Sueur said "I could show you what we do with these transistors." And he said "You can talk over the phone on repeaters made with these transistors here. Here's the phone. Talk." And Shockley talked over the phone with a guy who was English-speaking in Algiers.

Riordan: That's quite a few repeaters.

Mataré: There were a number of repeaters. They had made them all from our transistors.

Riordan: By then, you had achieved some control over the noise and the variability, which were the real problems with what Bell Labs called the Type-A transistors. This was inside a cylinder with the two points.

Mataré: But our transistors had a better frequency response. I don't know why that was. It may have been also that we used really higher mobility material leading to less transit time. [EN: In his notes, Mataré adds, "The transistron was also used as an optical amplifier, with a lens on the upper opening of the ceramic body.]

Riordan: Because of higher hole mobility?

Mataré: Yes, yes.

Riordan: You mentioned Mr. . . .

Mataré: Reshofsky?.

Riordan: At the PTT.

Mataré: No Reshofsky was Michael's attorney, Sueur, S-U-E-U-R [was head of the PTT.]

Riordan: Do you know his first name? [EN: In his notes, Mataré said he thinks it was René Reshofsky.]

Mataré: I don't know. But there's a publication out. He wrote a paper in the *Monde Electrique*.

Riordan: I can probably dig that up.

Mataré: I think Mr. Fandoma [ph?] has it.

Riordan: You met Shockley and Brattain in 1950?

Mataré: I met both, yes. In fact, Brattain invited me to his house in New Jersey.

Riordan: Was that the first time you met them?

Mataré: I met Shockley and Brattain the first time they visited us in Paris. And then I saw Shockley in 1950 at the conference in London [EN: where he spoke on holes and electrons in semiconductors].

Riordan: Later in 1950?

Mataré: Yes, and I've given you a paper which I gave in London, where Bardeen and Shockley were present.

Riordan: Shockley and Bardeen in London in 1950.

Mataré: You have a copy.

Riordan: Fall of 1950?

Mataré: It was in summer, in summer of 1950.

Riordan: You said in summer of 1950, Shockley and Brattain visited you.

Mataré: It must have been later.. It could be 1951. [EN: I believe that's when Shockley gave his paper.]

Riordan: Was there still some question when Shockley visited in 1950 as to who would get the patent rights to this device?

Mataré: I talked to Shockley about it, and I said one time, at lunch, "We both found out what is possible with germanium in 1948." "Oh, no," he said, "That's not what happened." He referred to the Bardeen-Brattain situation, while in principle, he conceived his idea of hole injection, of minority carriers in 1948.

Riordan: That's the basis of the junction transistor.

Mataré: That's what I meant when I . . .

Riordan: But by looking at the documents – and this is why documents are so valuable – they say they [EN: Bardeen and Brattain] had amplification on December 16, 1947 and then they demonstrated it to the Bell Labs managers on December 23rd.

Mataré: It's too bad that he didn't . . First of all, I had no chance of getting my notebooks from Leubus, in Silesia [EN: then occupied by the Soviet army]. Some remarked about the effect, and I did not think in Paris that we would do anything else and apply for a patent. We never thought about the notebooks.

Riordan: In Leubus, you were seeing some kind of strange effect and you didn't have time to look into it.

Mataré: We might have called it at that time the “schmutz effect.”

Riordan: “Interference” you called it, or “interaction.” Correct me if I'm wrong. The conceptualization of this amplification took place in early 1948, and you actually measured a power amplification of something over 100 times . . .

Mataré: Yes. It was much later. I did [not] know about amplification levels [in Leubus]. My lab was under enormous time pressure. All I had to do at the time was, can I make a duo-diode or not? No, it wasn't impossible. So I took silicon and that was the end of it.

Riordan: At Leubus, your focus was on silicon.

Mataré: And I had much more to do than just make a detector. I had to make a whole mixer. I had to make a whole [microwave] amplifier. I had to mix all microwave devices. I had to make an emitter to do the measurements. I have pictures here in the book, which I did later on in Paris, too. That wasn't easy. I did this in Paris in order to do the same, which I did in Germany. So here, at the end of the book, you can find all these things. I did the measurement of the power amplification, power changes first with these hollow tubes. And there's a picture also of some equipment which I used <points to book>. Here is a hollow tube. Here is a system that changes the power. And here is a receiver. This is the principle here. What you have to do is, you make changes in power in the neighborhood of 10^{-20} watts. Imagine.

Riordan: Can you measure that?

Mataré: Yes.

Riordan: 10^{-20} volts?

Mataré: Yes, 10^{-20} volts, yeah. I have whole lists of the number of kTs. The kT is the measurement unit you use for that purpose. [EN: Presumably this is Boltzmann's constant k times the absolute temperature T in kelvins; the product would be measured in energy units, probably ergs.] These measurements were almost at the limit of the sensitivity that one can make. It came very close to the end of it, here, and in kT. Here, you see, these are the values which had to be calculated as the optimum, and these are the measurements here. <points to book again> Look how close they are. This is almost the same decimal.

Riordan: I want to get back to Intermetall and finish up. I think at that point, you were selling Intermetall.

Mataré: Yes. You have the slides on your CD. I went with the slides to New York and to Minneapolis, Minnesota.

Riordan: But before that, there's this demonstration of the transistor radio, which was really the first transistor radio, although you weren't making these for production, were you?

Mataré: I had production in Paris. I had production in Dusseldorf. My technicians also made receivers.

Riordan: But the transistor radio, like the woman is holding, what fair was that at? The radio fair in . . .

Mataré: In Dusseldorf.

Riordan: That was 1953. Right?

Mataré: Yes.

Riordan: There may have been examples where Bell Labs used four or six transistors to make a transistor radio, but they never produced more than one or two models. Was this something on which you were waiting for production?

Mataré: Yes.

Riordan: Did the company get around to selling them?

[audio ends abruptly]

END OF INTERVIEW