Oral History of Igor V. Grekhov

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Rosemary Remacle: This is 15 of May 2012 and I am Rosemary Remacle from the Computer History Museum and I am here to interview Dr. Grekhov, and first of all I will tell you how excited and pleased we are to have you contributing to the Museum's oral history program. So, thank you so much. <laughs> It's very exciting for us. So let me start the interview and ask you to tell me your name, where you were born, where you went to school how did you get interested in semiconductors and computing and in your whole field of science—big question!

Igor Grekhov: Yes, first, my name Igor Grekhov and now I am a Head of Solid state electronics Division in Ioffe Institute, Russian Academy of Science. I was born in 1934 in Smolensk-city, Russia. My mother and father both were schoolteachers. My father in 1939 was killed during USSR-Finland war. I grew up in Simferopol-city—it's Crimea, Ukraine now.

Remacle: The names are changed over time.

Grekhov: <laughs> Yes, change… It's a very good place, Simferopol, yes. I went to school there, and then went to Moscow Technical University named after Bauman. It's a famous place, yes, you know. And graduated from this University in 1959… 58. Yes, 1958.

Remacle: Why did you decide to go there? Did *you* decide, or did somebody else decide for you to go to that University.

Grekhov: Oh. I decide to go to Bauman Institute personally. But… Some problem… I tell you about… may be… Later…

Remacle: Ok.

Grekhov: It's very interesting problem, but in general… I have graduated from this University, and was sent… was sent to Saransk. It's Mordovia, 600 km to the East from Moscow, to work at the Electro-rectifier factory.

Remacle: Electric?

Grekhov: Electro-rectifier, it's the name of factory, rectifier….

Remacle: Ok.

Grekhov: I work there four years, and in 1962 I was invited to Ioffe Institute, Academy of Science, and worked here 50 years.

Remacle: Oh! That is very…

Grekhov: Exactly 50 years, tomorrow.

Remacle: Tomorrow? Oh, one day early for the party! <laughs> Congratulations!

Grekhov: I got PhD in 1974 from... oh, in 1967 from Ioffe, and next degree, doctor degree—it's Russian specialty, Doctor Degree in 1974. In 1991 I was elected as a correspondent-member of Russian Academy of Science, and in 2008 as a full-member of Russian Academy of Science. This is…

Remacle: … very important.

Grekhov: Yes. It's typical career for Russian.

Remacle: Can I ask you more personal question? When you were nominated and elected as an associate-member of Academy of Sciences and then you were made a full-member of the Academy of Sciences, how did you feel and… what did your family think? What was your family's reaction to the fact that…

Grekhov: Family? My mother...?

INTERPRETER: Как ваша семья отреагировала на то, что вы стали членом-корреспондентом Академии наук и потом, когда вас уже выбрали действительным членом Академии наук?

Grekhov: My mother died in 1985, so—no reaction.

Remacle: <laughs> She did not know.

Grekhov: And my wife and my son was happy.

Remacle: They were proud of you, I'm sure.

Grekhov: Yes.

Remacle: And your colleagues here, at Ioffe? Your colleagues here, were they excited for you?

Grekhov: You excuse me?

INTERPRETER: Ваши коллеги по институту, они обрадовались, когда… Для них это было большой новостью?

Grekhov: Er… Probably, yes. It is not some extraordinary situation. It's normal for Ioffe Institute.

Remacle: There are a lot of people.

Grekhov: Yeah.

Remacle: Can we go back a little bit, and talk about… How did you get interested in things scientific as a young boy? How did you become interested in science in physics?

Grekhov: Давайте поговорим, да. Это было совершенно случайно. Абсолютно.

INTERPRETER: It was just by chance. An accident.

Grekhov: Absolutely accidently.

Remacle: How did the accident occur?

Grekhov: Yes. I graduated from school with Gold Medal. So, I have a possibility to go to any University, any faculty of University without any examination. So, I sent my document to Bauman Institute and went to sport completion in Novocherkassk. And suddenly I got a telegram in Novocherkassk that I should come to Moscow as fast as possible. The faculty at Bauman University which seems to be good for me of cause was Rocket faculty. But when I come to Moscow, I got the information that no free position in the faculty. Ну, потому что я провел порядочно времени на соревнованиях по волейболу.

INTERPRETER: Because he was away too long, as doing sports <laughs>

Grekhov: И поэтому я мог поступить только на механико-технологический факультет.

INTERPRETER: That's why the only opportunity, the only free places they had was to enter the mechanical-technical Department.

Grekhov: И окончил я как инженер-механик.

INTERPRETER: And I graduated the University as an Engineer-Mechanic.

Grekhov: И должен был поехать в Саранск, работать на заводе, который, производил электрические лампочки.

INTERPRETER: And after the graduation I was assigned to go to Saransk to the factory that produced electric lamps.

Grekhov: но чиновник, который писал мои документы, ошибся, и вместо «Электролампового завода» написал «Электровыпрямитель».

INTERPRETER: And the bureaucrat who was filling down my papers had made a mistake and instead *electric lamps* he had put down *er… electric…*

Grekhov:*Electro-rectifiers*

INTERPRETER: *Rectifiers.*

Remacle: So, mistake… and then mistake…

Grekhov: Yes… И на этом заводе как раз начиналось производство мощных полупроводниковых приборов.

INTERPRETER: This exactly was the factory that had started the development and mass-production of the large and very powerful semiconductors.

Grekhov: Я не имел выбора, я должен был войти в производство полупроводников—semiconductors

INTERPRETER: And as I didn't have any choice, I just had to start researching that field.

Remacle: Was this is the first time when you have been exposed in any depth to semiconductor and science associated with semiconductors?

Grekhov: Excuse me?

INTERPRETER: Это был первый раз, когда вы начали изучать полупроводники?

Grekhov: Да.

INTERPRETER: Yes, it was the first time.

Remacle: So, this is learning the hard way… So, what describe how it was for you when you worked at this rectifier's facility? You didn't know very much about semiconductors. How did you learn, what did you do, and what kinds of projects did you work on?

Grekhov: My first work in the semiconductors was very unusual also. That time… You know, power semiconductor industry in Russia start from this point, from Ioffe Institute in 1954. And young researcher Zhores Alferov, and his colleagues

Remacle: I'm going to talk to him

Grekhov: Yes, elaborated power Germanium diode. This one, yes. Very heavy!

Remacle: Can I see? Ho-ho! This is like twenty pounds or more….

Grekhov: It is special diode for atomic submarine.

Remacle: Wow. I have never held a diode for atomic submarine.

Grekhov: Yeah, it's first one. I should organize the mass production of this diode in Saransk. It was my first work. I go to Ioffe Institute. We discuss with Alferov several steps of it work, and I go work to Saransk and tried to reproduce such diode here.

Remacle: How many did you produce in mass production?

Grekhov: Mm?

Remacle: How many did you produce in mass production?

Grekhov: How many?

Remacle: How many. Hundreds, or thousands…

Grekhov: No… No, no, no!

Remacle: Tens?

Grekhov: It should be… May be ten or twenty diodes per one submarine. So it's not very large production. But we made diodes for the other application. Not such a heavy. More simple, but in more scale.

Remacle: This is what year when you did the diodes?

Grekhov: Excuse me?

INTERPRETER: В каком году вы начали заниматься этим?

Remacle: The date.

INTERPRETER: в пятьдесят восьмом.

Grekhov: Yeah, right after I arrived to Saransk

INTERPRETER: 1958.

Grekhov: But my это только начальный эпизод, в общем.

INTERPRETER: This is only the beginning of the whole story.

Grekhov: Потому что к тому времени уже наступала эра кремния.

INTERPRETER: Because by that time that was the time when we started to use silicon.

Grekhov: И мы должны были в Саранске делать силовые кремниевые приборы

INTERPRETER: And in Saransk we started to design… produce…

Grekhov: Power semiconducting diode, thyristors…

INTERPRETER: With silicon

Grekhov: И это было очень интересное время в Советском Союзе, конец 50-начало 60-х годов—тогда начинала организовываться электроника в России.

INTERPRETER: The end of 1950s—beginning of 1960s. It was very interesting and exciting time in the Soviet Union. That's when Electronic Science had started to be developed.

Grekhov: Строились заводы, НИИ, заводы по производству современного по тем временам технологического оборудования.

INTERPRETER: There were many plants and factories work founded, factories that produced contemporary electronic devices, contemporary for those days, and research institutions were started as well.

Remacle: Which people were the most influential in the birth of microelectronics or semiconductor electronics in the Soviet Union?

Grekhov: That time I have absolutely no information. In Saransk. You understand?

Remacle: Yes... and the things were really second…

Grekhov: In Saransk, I have absolutely no information from microelectronic institutes, but I have seen the general moving of Russian industry to semiconductors. But… It was only in ministry of Electronics.

Remacle: So… the Ministry of electronics prescribed the development basically.

Grekhov: Yes. Но на уровне правительства было принято решение, что вся силовая электроника должна быть не в электронной промышленности, а в электротехнической, которая никогда не имела дела с полупроводниками

INTERPRETER: But on the level of the Ministry the decision was made that the power electronics were supposed to be assigned not to electronic department in electronic Ministry, but electro-technical one, that had never had anything to do with it before.

Grekhov: И результат этого решения я увидел сразу, как только приехал в Саранск

INTERPRETER: And the result of this decision I had a chance to see right after I had come in Saransk

Grekhov: Не было никакого технологического оборудования, ни чистых помещений, которые необходимы для производства полупроводников.

INTERPRETER: There was almost no equipment and almost no clean rooms that were necessary for the semiconductor's production.

Remacle: What was the rationale… Why did people decide to separate and put power electronics into the electro-technical ministry instead of the other.

Grekhov: Совет Министров

INTERPRETER: It is the Soviet of Ministers, the Counsel of Ministry Heads means had made the decision.

Remacle: So it was very high level of government

Grekhov: Yes it was at high level and very big mistake.

Remacle: Was it because they didn't have very good technical basis?

Grekhov: Yes… И реально в Саранске мы ничего не имели, и все нужно было делать самим.

INTERPRETER: We didn't have anything in Saransk, any equipment, so we had to start to make it our own.

Grekhov: Поэтому когда мы должны были быстро организовать производство мощных полупроводниковых приборов, мы должны были придумать такие технологические операции, которые не требовали бы вот этого современного оборудования

INTERPRETER: And that's why when we had to start the mass-production process in Saransk, of the powerful semiconductors, manufacturing them, we have to create a certain kind of equipment or technological process that would not require this very modern equipment to be installed.

Remacle: So, you were kind of backward - you were forced to be more backward …

Grekhov: Yes. И мы вообще-то имели очень серьезное постановление Правительства, мы должны были это сделать.

INTERPRETER: And we were assigned to do it, so we didn't have a choice.

Remacle: How did that feel as a scientist, somebody who knew there would a better ways to do something… How did it feel to be told "this is the way you will do it", and it's kind of a backward way? How did you feel emotionally? What did you think?

Grekhov: Мы были воспитаны тогда в духе преданности советской власти, и если нам приказали, мы должны сделать.

INTERPRETER: We were brought up in a different way, we didn't have a lot of thought about it, if we were told to do that then we would just go and do that.

Grekhov: И мы сделали!

INTERPRETER: And we did!

Grekhov: Yes <laughs> I can explain you how we can make…

Remacle: I want to step back a little bit. You said that you change from Germanium to Silicon. Can you talk about that period of time when people started to say, "Our silicon is getting good enough to use it in mass-production," and why did people decide to move silicon, how did that happen, what kinds of discussions went on about that decision?

Grekhov: Это я не могу сказать, потому что уровень в то время мой не позволял знать все эти тонкости. Я знал только то, что я должен сделать, а кто это… мне было приказано.

INTERPRETER: Unfortunately, I don't know much about that, because at that time the level of my work did not allow me to participate in any of these decisions and discussions and I just was told to do it this way, and I did it this way.

Grekhov: Мы понимали, что нужно изобрести что-то необычное, чтобы это все выполнить, мы тогда… в конечном счете, нам удалось найти технологические приемы… Может, я тогда расскажу о них немножко?

INTERPRETER: So we realized we had to come out with something unusual, something extraordinary and we had managed to find a certain technological decisions that were new, and may be you would like for me to tell about this?

Remacle: Absolutely. Please.

Grekhov: Обычно p-n-переходы делаются путем диффузии примесей в полупроводниковую пластину… термодиффузии..

INTERPRETER: Traditionally, p-n-junction is made with diffusion into the Silicon wafer.

Grekhov: И это нужно делать в очень чистых условиях, чтобы всякие загрязнения не могли сюда проникнуть.

INTERPRETER: And you should do it in very clean room, absolutely clean,

Remacle: Let me explain to her this a little bit. You have the wafers covered with metal, and the p-n-junction is a particular kind of joint within the wafer.

INTERPRETER: Розмари объяснила мне процесс технологически.

Grekhov: Есть только она примесь, которая может диффундировать в кремний, опережая прочие загрязнения—это алюминий.

INTERPRETER: And there is the only one impurity that can diffuse into silicon…

Grekhov: Very fast

INTERPRETER: Very fast, that can go through silicon and that's aluminum.

Grekhov: Это делается обычно в ампулах, откачанных ампулах, потому что алюминий очень агрессивен и на воздухе он окисляется

INTERPRETER: And usually this done with vacuum tubes, because otherwise Aluminum reacts very aggressively, and oxidizes in the air

Grekhov: Но ампулы на заводе—это было неприемлемо, и вот в результате наших поисков мы нашли метод, который позволял производить диффузию алюминия прямо на воздухе.

INTERPRETER: And we couldn't use vacuum tubes in the plant, and so, we came up with a method of diffusion of aluminum right in the air.

Grekhov: Оказалось, что если на сильно нарушенную шлифовкой поверхность кремния нанести раствор алюминия, каких-нибудь солей, то в таких условиях, даже если нагреть на воздухе все это дело, то алюминий восстанавливается из его окислов кремнием, и начинает диффундировать в кремний в самом начале процесса, но этот процесс прерывается сразу, как только пластины окислятся, но та часть, небольшая, количество алюминия, которая успевает зайти в кремний до этого окисления, продолжает диффундировать дальше и получается великолепный p-n- переход с очень хорошими характеристиками.

INTERPRETER: Я, возможно, попрошу еще раз повторить, но я начну переводить. So, we use a very rough surface of silicon wafer with aluminum nitrates solution placed on this surface. While being heated in the open tube, aluminum is recovered from it's oxides by silicon and diffuse into silicon wafer. This process is interrupted very fast due to silicon dioxide formation, but a small amount of aluminum continues to diffuse forming the very high quality p-n junction in silicon wafer.

Remacle: It's p-n-junction, like the letters…

Grekhov: Yes, p-n-junction with very good characteristics. So, it was an invention. И после того, как это было найдено, все остальное—это было уже инженерия, чисто инженерная техника. Мы очень быстро наладили технология массового производства полупроводниковых переводов очень высокого качества, дешевых, и в больших количествах практически без всякого оборудования полупроводникового.

INTERPRETER: And as soon as we had made this invention, then the rest after this invention was a technical part, the technical details. We managed with this a new method to start the mass-production of very high quality semiconductor devices, and in a very fast way without creating any new complicated equipment.

Grekhov: And very cheap, very cheap technology, very effective, and we start the mass-production of power semiconductor devices.

Remacle: In the similar time frame a lot of work has been done in Bell Labs, and in AT&T Bell Labs in New-Jersey

INTERPRETER: Вы слышали о том, что одновременно почти такая же технология использовалась в лабораториях Бэла ATNT в Америке?

Grekhov: No.

INTERPRETER: He didn't hear about this.

Remacle: Because they were doing a lot of the similar work in the same time

Grekhov: Namely aluminum?

Remacle: I believe so. They were working with p-n—junctions and there is materials including silicon, but not only silicon. Trying to figure out how to make cheaper, faster…

Grekhov: Yes, yes… Very interesting, I have no information.

Remacle: So that raises a good question—how, did you, besides doing your own research, doing your own work? Did you collaborate with your colleagues and friends in other locations? Or did you consult with technical journals? Or did you just work in your own lab?

Grekhov: Mainly technical journals. American journals.

Remacle: Which American scientists did you have conversation with, go to conferences?

Grekhov: During that time there were no conversation and practically no direct contact, absolutely… only printed information…

Remacle: I understand what I have read, I don't know… It was very difficult for Soviet scientists to get their hands… to get possession of American technical journal in English, it was difficult, was it true?

Grekhov: For me absolutely impossible.. not difficult, but impossible. But may be only for me in Saransk. Probably the situation in the microelectronics industry and electronics ministry was some different, may be.

Remacle: So, some people may be in Moscow, or Leningrad, perhaps, had access to this journals, but they were not available to you.

Grekhov: But our condition in Saransk was more complicated.

Remacle: I interrupted your story a little bit. So we go ahead and finish talking about the work in Saransk.

Grekhov: We had a good contact with Ioffe Institute. I've told you about Alferov and Director of semiconductor lab, Professor Tuchkevich, come to Saransk and we have a very good contact. And after this we organized the mass-production of semiconductor powers silicon diodes in Saransk. Then we start to elaborate thyristor. It's more complicated device, and it's very difficult to make this device in Saransk. Professor Tuchkevich invite me and two or three my colleagues from Saransk to his lab. We continue this work at Ioffe Institute, but we have direct contact with Saransk fab, and mass-production of thyristors started approximately in 1963. Only one year for research, development and start of production: it's not ordinary situation.

Remacle: Can you talk to me a little bit, explain a little bit about this the soviet system. There were, as I understand it, there were research centers such as Ioffe, there were design bureaus, and they were more closely associated with the factories, the organizations… How did we research and development and design, move things into mass-production and meeting customer requirements… that progression… How you did it work?

Grekhov: Now it's very complicated work, of course. But that time… Non-formal, non-formal contacts with our lab here and my old lab in Saransk, and Chief Engineer of Saransk and Director were my friends... not formal contact—therefore we worked very fast. <laughs> Non official…!

Remacle: Sometimes it helps not to be official.

Grekhov: So… Practically we organize the industry of power semiconductor device in Russia for several years. Five factories…

Remacle: Where were those five factories located?

Grekhov: One in Tallinn, the other in Zaporozhe, and Saransk, and Molodechno [Ukraine], and one in countryside in Kirgizia. Because the technology was very simple. We can start in any places.

Remacle: But production is not so simple.

Grekhov: Production?

INTERPRETER: Процесс производства, он не очень простой. Сам процесс…

Grekhov:Не понял.

INTERPRETER: Розмари говорит, что сам процесс производства, он же достаточно сложный—трудоемкий такой, высокоточный.

Grekhov: Нет, дело в том, что, я же говорил—мы изобрели ключевые операции, которые были очень простые и в то же время давали хороший результат. И они не требовали современного по тем временам оборудования, сложного и дорого. Потому что сам процесс изготовления p-n-переходов был аномально прост, и поэтому мы могли организовать его где угодно. А вот дальше остальные операции—они, конечно, все такие же, как делаются сейчас, на серьезных предприятиях, но это уже инженерная работа. Она не требовала открытий.

INTERPRETER: Well… as I mentioned, we had invented the major key-process, in creating new powerful semiconductors and p-n-junctions, and that's why it was extremely simple, cheap and easy to start. But of course, the rest of operations to create… it was engineering work and it was made, just as everywhere else in the country, as in the other functioning factories.

Remacle: When did clean rooms start to be… I don't know how to say this in English even… Clean room's evolved. They started out kind of clean… then they got cleaner… and then they got very clean and they got *clean* and then there was class one... So at what point now in the 50s, early 60s… how would you classify the clean room situation in Saransk, and in other production areas?

Grekhov:Сейчас, конечно, ситуация изменилась. И эти все заводы, они оснащены современным оборудованием, ведь прошло уже много времени. Но вот эта операция, которую мы тогда изобрели, она осталась на всех заводах. Более того, она в электронной промышленности тоже применяется.

INTERPRETER: Well.. of course the situation had changed now, and level of equipment is very high, in all the enterprises in the country, but in that time, when we were just designing new method, it was easy to use everywhere in country… Не подскажете, вот чистые комнаты—их уровень—вы их вообще не использовали?

Grekhov: Тогда—вообще не использовали, а сейчас используют, но это невысокого класса чистоты, там, 1000…

INTERPRETER: So, in that moment we didn't use any clean rooms at all, and now we do use clean rooms, but they are not very high level of clean, about thousand.

Remacle: Ok

Grekhov: At the end of 60s and beginning of 70s we stop our work in this area and change the area of our interest, because very many people work in power semiconductor production. We changed the area and we start the work in pulsed-power… make some new invention… some invention in this area also.

Remacle: Can I step back and ask more question about power semiconductors you were working with…what were the applications…where did they go primarily—in submarines, airplanes, rockets, spaceships, so were they in industrial control? What were the end uses of them?

Grekhov: Это очень важно… Вот последнюю часть мне переведите, пожалуйста.

INTERPRETER: Где использовались, в основном, в какой области применения вот эти высокомощные диоды, которые вы производили, какое было их применение в итоге.

Grekhov: I told you that. The first diode, first power diode was used in navy. And we got money from navy. Yes… it was small area of application, but the first one. The next was normal application in industry. Это, ну, скажем, так это электрифицированный транспорт. Железные дороги вот, электровозы.

INTERPRETER: Mainly used for instance in railway transport, electric transport, like electro-locomotives.

Grekhov: Производство алюминия.

Remacle: Excuse me, this like small control computing situations or some other application?

INTERPRETER: То есть, они использовались в основном для небольших компьютерных операций?

Grekhov: No, no, no. It's power device.

Remacle: Just power device? Simple power?

Grekhov: Simple power device for electro-motors etc., very powerful device. No computers…

Remacle: Nothing like that.

Grekhov: Yes. Ну вот, производство алюминия, там, меди… металлургия.

INTERPRETER: In the production of aluminum, copper and many other the metal production.

Grekhov:А вот в области импульсной техники, так мне рассказать немножко?

INTERPRETER: In the sphere of pulse power… would you like…

Remacle: Yes, yes.

Grekhov: первое, с чего мы начали—это создание приборов, которые могли бы переключать большие мощности очень быстро—за сотни пикосекунд.

INTERPRETER: In the pulse power the first thing we started with, our first task was to create a certain device that can turn on and turn off a very high electric power…

Grekhov: And very fast… for one nanosecond or less.

Remacle: at least one nanosecond

Grekhov: Several tens of picoseconds…

Remacle: Picoseconds, yes

Grekhov:в то время таких приборов в мире не было

INTERPRETER: They didn't exist in the world at that time, such devices

Grekhov: Идея была такая: обычный мощный прибор переключается таким образом: область объемного заряда p-n-перехода, обратно смещенного, блокирует приложенное напряжение. Мне перевести? Yeah, ok.

INTERPRETER: Вы не поможете мне, Владимир Иванович?

Владимир Иванович: The region of the charge blocked by reverse voltage.

Remacle: Ok.

Grekhov: And for switching we should introduce high density electron-hole plasma, into this region very fast. But the limited velocity of electrons and holes motion in semiconductors is not high enough.

Remacle: It was a big problem.

Grekhov: And so it's impossible to make fast switch on the basis of usual injection electrons and holes into the device. It's very clear that we should organize the plasma generation into the device directly. There are two ways. One is plasma generation by very high power pulse of light. It is very expensive way. The other is plasma generation by avalanche breakdown in high electric field. The idea looked like following. If reverse voltage, applied to the pn-junction, increases very fast, we could get electric field much higher than avalanche breakdown field under static conditions and causing tunnel emission of electrons. There electrons initiate fast avalanche breakdown at pn-junction and produce high density electron-hole plasma layer. Electric field drops down here but increase in nearby region causing breakdown etc. So formed front of breakdown moves in the device with the velocity ten time higher, than saturated velocity of electrons in silicon. It is the physical basis of superfast switches.

Remacle: You have moved from being mechanical engineer to being a device physicist.

Grekhov: I was forced <laughs>.

Remacle: That was a very big transition.

Grekhov: And very fast…

Remacle: Very fast transition for somebody to make… you were forced to do it, but your interest must have also drawn you to it. And your talent also most of all drawn you to it.

Grekhov: It was very interesting for me.

Remacle: It's your interest.

Grekhov: Yeah. We made this experiment with Alexey Kardo-Sysoev in 1979 and published in Russian literature in 1981 then in Electronic Letters. In 1987 experiment was reproduced in a Livermore National Lab. This is the only way to produce high power sub-nanosecond semiconductor switches.

Remacle: It sounded if I followed the dates correctly that you just mentioned the publishing of the paper. It sounded like it took about six years to get from Russian, the first publication, to Laurence Livermore where it was published in English. Why did it take so long and what was the response once got published in English from Americans or Europeans, or people who read it in English?

Grekhov: There is a special documents about what we can publish, what we cannot

Remacle: that would be secret..

Grekhov: Yes. And this level was moved… It depends on..

Remacle: So, may be secret, and may be very secret in 1980th by 1982 was less secret, in 1994 declassified. Is that correct?

Grekhov: Yes <laughs> But generally speaking when we invite this effect nobody knows about this possibility, so, no secret. And we published. After this… now… it may be partly secret.

Remacle: Officially partly secret.

Grekhov: Yeah! <laughs>

Remacle: But within scientific semiconductor community… It is not so secret…

Grekhov: Of course, yes… It's the first step, we have another

Remacle: I am still interested in the topic of how Russian scientists, semiconductor scientists especially, how they were able to become aware of what was going on outside the Soviet Union in fields that were close to what they were doing and how they shared their own discoveries and research in accomplishments outside the Soviet Union if they were able to do that at all.

Grekhov: Oh… Этот вопрос…

INTERPRETER: Она просит вас рассказать немножко о том, как ваши исследования становились известны в области полупроводников не только в Советском Союзе, но и в мире, и в то же время, как вы узнавали информацию, может быть, из-за границы—в области исследования полупроводников?

Grekhov: Вы знаете, ну вот к тому времени, о котором мы сейчас рассказываем, это же начало 80-х годов, ситуация—лично для меня —изменилась резко. Мы имеем—ну, вот в литературе—всю литературу, которая в мире издается, она у нас в распоряжении уже была тогда, а кроме того, мы получили возможность личных контактов, на конференции.

INTERPRETER: Now we are talking about early 1980s, and the situation had changed dramatically at that time, because at that moment we already had a possibility to lay hands on almost any scientific magazines what were printed in the world and had a chance to meet with foreign scientists and had personal contacts with them as well.

Grekhov: И вот… Для интереса, уже в 1975 году я получил возможность поехать на International Electron Device Meeting в Вашингтон и доклад там делал.

INTERPRETER: In 1975 I already had a chance to visit this conference in Washington..

Grekhov: С докладом

Remacle: Electronic Devices Society

INTERPRETER: Electron Devices Meeting and had

Grekhov: a very good one…

Remacle: Yes, they were very well known…

INTERPRETER: He had made a speech there

Grekhov: We have normal contact with

Remacle: When did IEEE start having meetings in Russia or having members in Russia?

INTERPRETER: IEEE?

Remacle: *IEEE*—International Electronic… I don't even know… What it stands for… you know, Alex? [Institute of Electrical and Electronics Engineers]

INTERPRETER: Когда международный институт инженеров-электронщиков—когда вообще мировые инженеры, исследователи и ученые смогли приезжать в Россию на конференции и делится информацией.

Grekhov: Так вот уже в те годы, о которых мы говорим, это вполне…

INTERPRETER: IRE?

Remacle: IRE was at the beginning of IEEE… It was the first IRE which was International radio… electronics I think…

INTERPRETER: Международное радио и электронная ассоциация, видимо, они начали…

Remacle: We can change the subject, it's ok.

INTERPRETER: Они первые, видимо, имели возможность начать… наладить контакты с советскими учеными, и вот она просто спрашивала, если вы знаете об этих визитах, этих контактах, когда они начались.

Grekhov: Знаете, я наверное, вряд ли вспомню.. Вся эта жизнь, она, наверное, больше была в электронике. И, может быть, Жорес Алферов эту вещь расскажет лучше, чем я.

INTERPRETER: I cannot say a lot about this, because mainly it was in the field of electronics, rather in what I did at the moment. Maybe Zhores Alferov will be able to tell more about this.

Grekhov: Что касается меня, я имел возможность ездить на эти конференции. Но очень редко— раз в год примерно. А так, чтобы к нам на конференции, внутрироссийские, приезжали кто-нибудь из Америки, я не помню в те времена.

INTERPRETER: Concerning myself, I was able already at that time, in the 70s, able to go to the International Conferences, and participate there, but rarely, only about once a year. And actually I don't remember of anyone from international society of scientists to come and visit our local conferences in Russia.

Grekhov: И вот Жорес, наверное, расскажет лучше, у него больше информации

INTERPRETER: And I think that Dr. Alferov will be able to tell more about this.

Remacle: Then you continue to talk about what you were doing… I took you away from that subject… Let's go back to your subject.

Grekhov: Next idea was about opening switch. First switch were closing switch and used with capacitor bank and opening switch used with inductor.

Remacle: Can I explain to Dasha what you are talking about… so… on the semiconductors there is switch for little signals go on. We talk about switchers and gates… that are the things we are talking about, ok?

Grekhov: Generally speaking, power opening switch is more complicated device than closing switch, and there are no opening semiconductor switch, which is capable to switch off… very high electric power for units of nanosecond. Our idea was very simple. Any semiconductor diode is opening switch. You pass the pulse in forward direction pumping electron-hole plasma in the device… then you apply the reverse voltage and pull out plasma from the diode, and when the plasma is exhausted, the voltage on the device arises. It is typical opening switch. But the time for this process in usual device is equal to several microseconds. We have found the situation, when this process can be three orders faster… three orders.

Remacle: It's a big jump.

Grekhov: Yes… yes. It's very simple idea. We should organize the pulling of plasma process in such a way that the plasma fronts moving from the external contacts to p-n-junction, reach the p-n-junction boundary simultaneously. After this collision there are no plasma in the device and the space-charge region of pn-junction expends with velocity equal to electron and hole saturated velocity in silicon. It means that the time of switching process can be equal to electron time of flight through the base region which is units of nanoseconds.

Remacle: It's a very fundamental part of manufacturing a chip

Grekhov: Yes

Remacle: … of functionally GEP, I mean, very important part of that.

INTERPRETER: Это очень важная часть—ваше открытие, то что вы сделали это было очень важно в формировании самого полупроводника и его использования.

Remacle: It's very fast, but very important.

INTERPRETER: Очень быстрый процесс, но необыкновенно важный.

Grekhov: Ну, это да.

INTERPRETER: Основной такой…

Grekhov: Ну да, да… И вот после того, когда… прибор-то ведь очень простой—это диод.

INTERPRETER: And that's very simple device, it's a diode.

Remacle: Yes.

Grekhov: Мы ведь только так подобрали форму диффузионных слоев и режим работы прибора—накачка и выкачка, чтобы обеспечить столкновение плазменных фронтов точно на p-n-junction.

INTERPRETER: We just had adapted diode structure and forward and reverse current pulses parameters in such a way that plasma fronts collision takes place during recovery process directly at pn-junction plane.

Grekhov: И тогда оказалось, что один простой диод, специальным образом сделанный, с площадью примерно 2 кв. сантиметра, может переключать мощность порядка мегаватта.

INTERPRETER: So, it turned out, that a very simple device, a diode with the surface of two square centimeters, can switch off the power of one megawatt.

Grekhov: Yes. So, we connect many such devices in series and make the very large power opening switch, hundreds of megawatts. So after this invention it becomes a usual technique, and used in many areas of application. It was in the middle of 80s, approximately.

Remacle: And this is still in Saransk? You were still in Saransk?

INTERPRETER: Вы в этот момент все еще были в Саранске?

Grekhov: No! Here, of course, in Ioffe Inst..

Remacle: So, when did you move from Saransk?

Grekhov: From 62.

Remacle: 62… ok. I missed that, sorry.

Grekhov: That time I was the head of lab in Ioffe. And this is third idea concerning very high power microsecond switch. Generally speaking, the most powerful semiconductor closing switch is thyristor. Normal thyristor is very good switch for a long pulse, several hundreds microseconds and more. For more short pulse, several microseconds, switching area is very narrow, just near the gate. So big device operates only in the very small area which limited the switching power. We have designed the new device structure which can be switched simultaneously over total device area.

Remacle: How did you discover, this inventions in your lab? How did you get it transferred into production facilities that bring it into products?

Grekhov: Two way. First we have some type of production lines here. We can make simple device in the lab. And then we have a good contact with power semiconductor industry, formal and non-formal. And we can transfer this technology to the factory without problem if the device can be used in the industry.

Remacle: So… Are there formal processes for transfer into industry or is there an informal process?

Grekhov: I prefer informal. Formal is very complicated and very… very long. You see, we organize the mass production for two-three years, and normal way is as long as ten, may be.

Remacle: Oh!

Grekhov: Maybe more. I don't know.

Remacle: I know, for example that Stanford University and University at California, Berkley - both have semiconductor manufacturing lines for research in the University.

Grekhov: This is the best way.

Remacle: Pardon?

Grekhov: This is the best way.

Remacle: Yes. Do you have comparable situation here? Do you have comparable situation?

Grekhov: More or less. I have some technology line in my lab, but it is not good one.

Remacle: It would not be comparable or similar to what Stanford or Berkeley have? It would be different, your situation would be different from what Stanford or Berkeley has?

INTERPRETER: У вас похожая …Ну вот, ситуация в Стэнфорде, и в Беркли, в Калифорнии, у них есть своя технологическая линия, производство небольшое,

Grekhov: но хуже чем…

INTERPRETER: у вас же то же самое, но просто вы говорите, что, может быть, не такого качества. Yes. It's similar situation, but may be the lower quality technological line, than in Stanford or Berkeley.

Grekhov: Ну и вот для примера, когда нужно что-то более сложное, то нам все равно приходится на самых первых шагах уже кооперироваться с заводом.

INTERPRETER: And if it is a little bit more complicated device, we still need to try to produce it at the factory already, even at the first steps.

Remacle: So you will send a team from here to the factory to work with the factory…

Grekhov: Yes, you are correct.

Remacle: There is the connection between the ideas and finish device—you have to bring it together.

Grekhov: Yes, of course, but is is not so simple.

Remacle: Anything with semiconductors is not easy. So, go ahead, go again, I've interrupted you.

Grekhov: About microsecond switch, yes?

Remacle: Yes.

Grekhov: We elaborate the structure of thyristor-like device… It's look like integrated socket, but with typical dimension of element of 2 hundred micrometers. It's combination thyristor and transistor sections. In this device switching processes absolutely different from the normal thyristors, we change the polarity of applied voltage, for short time, and during this short time interval electron-hole plasma injected into thyristor sections from transistor section forming the quasi-uniform plasma layer на всей площади прибора—over the all device surface. Then the polarity returns to the initial state, and this plasma layer, initiates switching of thyristor, simultaneously over the all device area independent of the device size.

Remacle: In general, what is size of devices we talking?

INTERPRETER: В общем, о какой площади прибора вы говорите?

Remacle: I'm a shill…

Grekhov: It is not microelectronics. This one with 3-inch silicon wafer can switch 2 hundred thousand ampere per several microsecond, and pulse duration about 3 hundred microseconds, two and a half thousand voltage. These devices can be connected in series and we can make very high power switch. This work was finished at the end of 80s. We had good contact with American people that time, and device was tested at U.S. Army Research lab, Air-Force lab, and Livermore lab.

Remacle: Livermore is very close to… where I live

Grekhov: Yes. We discus with the Livermore people the possibility to produce such a device at Livermore…

Remacle: So, now during this time frame, in the 80s… Things were better between the U.S. and Russia. We were not so…

INTERPRETER: в конце 80-х годов уже наладились отношения между Америкой и Советским Союзом, Россией…

Grekhov: Да, это все было нормально, и особенно уже это вот началось в 90-х годах

INTERPRETER: And especially in the 90s

Grekhov: Когда мы…

Remacle: So, progress from the late 70s to the 80s and of course first - there were Perestroika and Glasnost…

INTERPRETER: То есть, с конца 80-х, ну 70-х годов уже началась такая оттепель в отношениях между Америкой и Советским Союзом.

Grekhov: Да-да-да. Я просто это чувствовал на себе.

INTERPRETER: I felt it my own experience.

Remacle: That was my only question. How did that impact your work? The fact what there was better communication between the two governments.

INTERPRETER: Оказало ли это какое-то влияние на вашу работу, помогло ли как-то налаживанию отношений с Америкой доступность информации в вашей работе?

Grekhov: Ну конечно.

INTERPRETER: it had an impact.

Grekhov: а если уж говорить честно, в 90-е годы, когда мы здесь были не очень нужны, мы просто делали очень много работ для Америки.

INTERPRETER: and to say honestly, in 90s when there was no money in the country to pay us, and our work was not interesting to the State, and we did a lot of commissions for the States.

Grekhov: Я просто был даже вынужден расширять все эти контакты, не только с Америкой—я смеялся даже, от Сан-Франциско до Сингапура. И просто продавали результаты нашей продукции, генераторы там, все такое…

INTERPRETER: And in the 90s I had to raise all my contacts abroad. I was even joking to the selection from San Francisco to Singapore, to sell some of my works and some of productions we made, in order to raise money.

Grekhov: Но сейчас ситуация несколько изменилась, потому что мы сейчас снова стали нужны здесь, внутри страны, потому контакты стали меньше.

INTERPRETER: The situation had slightly changed now, and now the Government is again interested in our research work.

Remacle: Today?

INTERPRETER: Today, yes, in current Russia, in modern Russia and say they lost contacts abroad, but still have them.

Grekhov: Отношения по-прежнему хорошие, но продавать свою работу за рубежом, ну, можно, но особой необходимости нет, поскольку это можно сделать и здесь.

INTERPRETER: And I still have very friendly relationships with abroad, but there is no need to sell my work abroad anymore, it is needed here, in Russia.

Remacle: I want to take a step back. You were awarded with Lenin Prize in 1966, is that correct?

Grekhov: 1966…

INTERPRETER: В 1966 году вас наградили Ленинской премией, это так, да?

Grekhov: Да…

Remacle: Can you describe the process? How does the Lenin Prize get awarded?

INTERPRETER: Вы не могли бы рассказать? Просто для нас, Американцев, это очень необычный процесс… Как подавались документы, как выбирали, кого наградить?

Remacle: I understand it is very great honor.

INTERPRETER: Потому что это настолько высокая честь, быть награжденным..

Grekhov: Да, в то время это была высокая честь… Вообще это была самая высокая награда в области науки—в то время.

INTERPRETER: At that time it was the highest level of awards in the science

Grekhov: И мы ее получили за создание вот этой индустрии кремниевых приборов, о которой я рассказывал с самого начала.

INTERPRETER: And we received it for the creating industry of silicon power devices that I've started with earlier today.

Grekhov: Техника какая… в правительстве был специальный комитет по присуждению этих премий, и туда входили и чиновники, и ученые из Академии наук и из промышленности. Их много там—ну человек, наверное, 30 в этом комитете.

INTERPRETER: At that time with the Government there was a special Committee, that was in charge of the selecting the scientist who would be nominated for the Lenin Prize. This committee consisted of about thirty people, scientists and the bureaucrats, high officials, but some were scientists from the Academy of Science and some scientist from industry as well.

Grekhov: И существует специально разработанная форма документов, которые должны быть составлены, чтобы подать в этот комитет.

INTERPRETER: so, there is a certain application you can fill in and send your request to be nominated for this prize.

Grekhov: И если скажем, в физико-техническом институте считают, что эту вещь можно подать туда, эти документы нужно подготовить и подать туда на рассмотрение. Есть несколько ступеней рассмотрения, включая, ну… доклад в каком-либо известном учреждении, в другом институте, или на другом производстве. И все эти результаты сходятся туда, и этот комитет рассматривает, кому дать, кому нет.

INTERPRETER: Well, and… if for example, physical-technical Institute where I worked will consider something of my work worthy of such prize, or even the application for the such prize, I would fill in the papers and send them to Committee, but there would be several steps of all the nominees should go through, and one of them, for example would include presentation in another research institution or another conference of some level or meeting, and after all the stages go through, they will choose who is the best this year.

Grekhov: И эта премия может один раз в жизни присуждаться.

INTERPRETER: And this prize can be given only once in your lifetime.

Remacle: So, you, personally can only get one.

Grekhov: Эта премия… Там может один человек быть, а может быть и коллектив. В нашем случае там было человек 9.

INTERPRETER: Но вот все из них только один раз могут в жизни ее получить?

Grekhov: да.

INTERPRETER: So, it can be awarded to one person, or to several, to group of people, and now a case to six people, but all six people can receive it only once in a lifetime.

Remacle: Is there certificate, is there the ribbon around your neck, is there the pin, where is it?

INTERPRETER: Вы ее не носите?

Grekhov: Нет, конечно.

INTERPRETER: Дома она у вас хранится? It is at home.

Remacle: I would like to see it.

INTERPRETER: Очень бы хотелось увидеть.

Grekhov: Это, по-моему, можно организовать.

Remacle: You are the first Lenin prize winner?

Grekhov: Oh, no. Вот, пожалуйста: Жорес Алферов тоже лауреат Ленинской премии, и если ему позвонить сейчас, чтобы он захватил завтра на интервью, он может принести.

INTERPRETER: Dr. Alferov is also one of the winners of the Lenin prize, and if you would call him today, then tomorrow at your interview he can come bring to show it to you.

Remacle: Ok, it would be wonderful, but you… You have the distinction of being the first Lenin prize winner I have ever met.

INTERPRETER: Но вы—первый лауреат ленинской премии, которого встречает Розмари в своей жизни.

<laughs>

Remacle: Ok. What was the other of your accomplishments, your discoveries, that would you like to talk about?

INTERPRETER: И есть ли еще какие-то ваши изобретения, о которых вы хотели бы рассказать?

Grekhov: Нет, дело в том, что поскольку мы говорим об истории, то вот это все кончается в 80-е.

INTERPRETER: Because now we discuss the history, it finishes with the end of 80s.

Grekhov:Но потом.. вы же понимаете, потом был провал больше чем в 10 лет, когда мы вынуждены были думать о выживании.

INTERPRETER: and then, unfortunately, the Russian science and economy of the country was in deep fall for ten years when all we could think of was to survive

Grekhov: И за эти десять лет мы, конечно, отстали от мира довольно сильно. И вот сейчас мы, я лично занимаюсь тем, что пытаюсь это отставание ликвидировать.

INTERPRETER: And, unfortunately, for these years, we fell much behind, and all we think of is to catch up.

Grekhov: Это касается двух позиция для меня: это силовая микроэлектроника и электроника на основе карбидо-кремния.

INTERPRETER: for me it concerns two fields—one is the power microelectronics, and the second one is power electronics based on the silicon carbide.

Remacle: Can you talk about power microelectronics and silicon-carbide a little bit?

INTERPRETER: можно немножко обсудить вот эти две темы?

Grekhov: Пожалуйста.

INTERPRETER: What kind of… What would you like?

Remacle: I would like to find your areas of interest and exploration in both, start with microelectronics and…

Grekhov:Японский прибор силовой микроэлектроники

INTERPRETER: This is a Japanese device of power microelectronics

Grekhov: It's IGBT-module. It consists of IGBT-device and superfast diode… This one approximately one hundred and two thousand amperes… and, may be, two thousand volts.

Remacle: Can you show the camera?

INTERPRETER: А можно показать пере камерой, чтобы мы видели?

Grekhov: Ну, вы понимаете, он вскрыт для исследования

INTERPRETER: And, of course, it's open for the research work

Grekhov: Там основа—IGBT—это силовая интегральная схема, где несколько сот тысяч приборов с характерным размером такой ячейки порядка 5 микрон.

INTERPRETER: Может, вы попробуете сами сказать по-английски—у вас так хорошо получается…

Grekhov: Yes, why not? IGBT—chip consist of several maybe several hundred thousand elementary cells, and each cell consist of bipolar and field-effect transistor in one cell… all cells connected in parallel and this is IGBT-chip. And it's very good device that can be switched on and switched off by very small energy very fast. It's a very good device for converters; maybe for drive… many areas of applications. It's many device in power electronic now. And this device can be produced only using sub-micrometer technology.

Remacle: Submicron capabilities…

Grekhov: Да-да-да, less than one micron resolution. And because of the situation in our microelectronics during this time interval I told you about we have no possibility to produce such a device. Only import. But we… our country… is a country with a lot of energy, and we need some device for transfer this energy very effective, and we import a lot of this device from Japan and other countries.

Remacle: Let me ask you a question, it's a little controversial and you do not have to answer we understand. I was told by Russian in the Silicon Valley—he was born and raised here , but now works in the Silicon valley—he said— *I don't think Russian bureaucrats, Russian government people early, like in the 50s and 60s even, but particularly in the 90s… they didn't appreciate semiconductors because they were so small. They liked big things like rockets, like tanks, like submarines, and they didn't appreciate semiconductors enough… soon enough*… oh, you don't agree…

Grekhov: No. Our bureaucrats understand everything

Remacle: He was wrong.

Grekhov: They have no money…

Remacle: It's a money problem, not understanding problem… <laughs>

Grekhov: Because this is modern semiconductor factory, microelectronics is very expensive… two billion dollars per one fab, approx.

Remacle: Intel announced that they are building new fab, that is going to be between 5 and 7 billion dollars…

Grekhov: Yes… That's the reason we cannot produce such a device because we have no instrument and we have no money to buy the fab. So we should find the different way to produce such a device.

Remacle: What consideration that has been given between the Russian semiconductor world and I'm sure you aware of the fact that in the U.S. we have now only IBM, INTEL, MICRON—which makes memories TI… those are the only four companies which still have fabs, wafer fabs… everybody else is a fabless semiconductors company… They do the designs in the United States, and then they send them to Taiwan, to USMC and TMC where they met… where they have very sophisticated in some cases probably not better than Intel… but some cases better than perhaps what IBM and Micron have… Because that's all they do… just make chips… Do you have a parallel idea? … is there parallel thinking,

here, in Russia about doing designs here and then sending them to Taiwan to be manufactured or to China?

Grekhov: Нет… I think it's impossible now, because to design the modern device in sub-microelectronics we should have an instrument, and unfortunately we have only two or three submicron lines in Russia now—in Zelenograd two of them and maybe… I don't know maybe with resolution 0.18 micrometer and 90 nanometer too. And… but…

Remacle: I think Intel has moved all of their lines, I think everywhere now 0.05 or less and this new fabs that can be 0.03, 0.02. And I'm sure Samsung… the Korean memory folks are way low because the U.S. has given up on memory. So, can we go back a little bit and talk about the formation of Zelenograd … and how it impacted what you were doing, if it all. Did having the center of Russian semiconductor or Soviet semiconductor production move?

INTERPRETER: Розмари спрашивает, формирование Зеленограда, вот немножко если вернуться во времени, и его вообще влияние, формирования Зеленограда, на вашу работу оказало какое-то влияние на вашу работу?

Grekhov: Нет.

INTERPRETER: No. <laughs>

Grekhov: Исчерпывающий ответ.

INTERPRETER: It had no influence on what he was doing, and say Dr. Grekhov, I guess he was not involved much in this.

Grekhov: Вы помните, я говорил, разделение электроники и электротехники—ну вот, типично…

INTERPRETER: Remember there was division between electronics and electro-techniques, so that's the reason.

Grekhov: and the result.

Remacle: What about the change—you mention that after the 90s, it was very difficult time frame for all science in Russia… for development of new projects.

INTERPRETER: What's the question?

Remacle: The question is can you talk about more about what this period was like on day-to-day basis, week-to-week basis.

INTERPRETER: Вы не могли бы немножко рассказать о 90-х, когда был такой провал в науке, чем вы занимались, каждый день, как проходили ваши рабочие дни.

Grekhov: Да, очень даже происходили. Дело в том, что знаете, было совершенно четкое понимание того, что если мы хотим выжить, мы должны думать об этом сами.

INTERPRETER: So, it was a clear understanding that in order to survive we need to think about it ourselves.

Grekhov: И когда вот я, например, это понял, то совершенно четко решил для себя и для своих сотрудников, что пока мы не нужны в государстве, мы должны работать на мировой рынок.

INTERPRETER: and when I got to realize that… I understood for that for me and my colleagues, you know, whole institute, we take care about ourselves to work for the world market.

Grekhov: И мои друзья в Америке устроили мне поездку в Америку, и я делал доклады о наших импульсных делах, один на Восточном, другой на Западном побережье Америки.

INTERPRETER: and my friends in the United States had arranged a trip for me, with presentations on the East and West Coasts about the pulse-power devices that we created.

Grekhov: И вот интересно, на Восточном побережье я делал доклад в лаборатории армии—сухопутных сил США, ну я наверное, никогда больше не увижу такого количества американских генералов, собранных в одном месте.

INTERPRETER: And on the east coast - it was interesting thing - I was making the presentation on the army base, and I think I would never see again at the same place the same number of generals, gathered together.

<laughs>

Remacle: We have too many generals. This is my personnel opinion.

Grekhov: Очень интересно, значит, после доклада ко мне подошел генерал, у него внешность была не американская, он немножко похож на… монгольские такие черты…

INTERPRETER: Азиатская…

Grekhov: И на хорошем таком русском языке 19 века рассказал мне, что ему было интересно в этом. Я был ужасно удивлен—его коллеги не меньше—что он так хорошо говорит по-русски.

INTERPRETER: And after this presentation one of the generals approached me, and he didn't have a typical American appearance, he has the features of mongoloid in a type of slightly Asian, and he started to talk to me on a pure Russian, but a little bit old-fashion of the type of the 19th century language, and both me and his colleagues, other generals, were greatly surprised of his knowledge of Russian.

Grekhov: Оказалось, что это потомок донских казаков, которые бежали в Америку от Троцкого, когда он там расказачивал… И у них недалеко от Вашингтона такое хорошее поселение, где они, в общем-то, говорят на русском.

INTERPRETER: And it turned out to be that he was one of the descendants of those Cossacks from the Don area, he had emigrated from Soviet Russia in the early 20th century running away from Trotsky. They settled down near Washington and he was coming from that area.

Remacle: Another question that you just reminded me of—to what degree again… to what degree did the fact that the communist philosophy was the basis for the government of the country, of the Soviet Union… What effect did that have on your work and the development of semiconductor devices… semiconductor device physics in Russia, in the Soviet Union? What was the impact of communism, can you talk about that?

INTERPRETER: Коммунистическая идеология и коммунистическая философия, насколько она повлияла на становление науки и на вашу конкретную работу в Советском Союзе? Было ли ее влияние?

Grekhov: Вы знаете, да конечно было. Дело в том, что вот… ну… у нас как-то совершенно не было меркантильности… мы делали интересные вещи, но даже в голову не приходило, что за интересные вещи надо получать интересные деньги. Такого не было понимания, а было интересно

работать, и думать, что для страны работаешь. А то, что сам с этого немного имеешь… так все так кругом.

INTERPRETER: Of course, the communist philosophy had an effect on the work… There was no idea of earning money from what you invent. It was natural to think this way, and you would have work for people, for your country… and the fact that you don't earn much wasn't even a thought, because everyone lived the same way, and only later we learned that you can get good money for a good invention.

Remacle: How would you describe the impact of the work that you and your colleagues have been doing at Ioffe and also had been done in other research institutes, academies, organizations, and companies in now Russia and the rest of the world, semiconductor and computing?

INTERPRETER: Как бы вы описали вклад института имени Иоффе и других ваших коллег в России на мировую науку. Какой вклад оказала российская наука в сфере полупроводников?

Grekhov: Так, если говорить о физтехе, то две вещи вы уже знаете—то, что я говорил о pulse-power…

INTERPRETER: There are two things that I have already mentioned among great inventions—about pulse-power…

Grekhov: Второе—Жорес Алферов, heterojuncs…

INTERPRETER: ...and the second was heterojunctions by Zhores Alferov.

Grekhov: И… я думаю, были еще какие-то такие вещи в физтехе, просто я бы не стал о них говорить…. Вот Алферов—у него лучше память и больше сведений о физтехе, он на этот вопрос больше бы ответил.

INTERPRETER: there were other things that were made here, in physical-technical institute, but it would be Dr. Alferov, who has better memory, and he would tell you more about it. And it's concerning our Institute.

Grekhov: Насчет остальных…

INTERPRETER: Ну, может быть, как-то в общем… Было и влияние на мировое…

Grekhov:Ну было, конечно, были такие, точечные. Понимаете, тут ситуация такая… можно иметь несколько ярких пятен, но когда нет фронта, который вот так идет, то это плохо. Вот… наше влияние на мир в этой области—оно скорее точечное, чем фронтальное.

INTERPRETER: I just asked Dr. Grekhov to give a general idea, and he said concerning the whole Russian scientists of in a sphere semiconductors they were just circling spots in the whole front of the research work in the field of semiconductors that were invented by Russian scientists, and they had some impact in the development of the industry, but unfortunately there was no whole front that would go forward in the industry, you cannot break through, so Russian scientists were just some parts of this front.

Remacle: I think that's consistent that you and Dr. Popov said yesterday… very consistent point of view. Now you had two state prizes—I'm jumping around about with—you have two state prizes?

INTERPRETER: У вас две государственные награды есть? Просто Розмари опять перескочила немножко… <laughs> Она хотела бы о них поговорить.

Grekhov: Пожалуйста.

Remacle: For what?

INTERPRETER: Расскажите, за что вас наградили, как это происходило?

Grekhov: Часть я вам уже рассказал. Ну, первая, которая Ленинская—это за индустрию, вторая, которая СССР—за импульсную технику, pulse-power, и вторая, уже государственная премия России была тоже за pulse-power—мы сделали некоторые новые вещи, о которых я не рассказывал, потому что это уже не история, а сегодняшний день. Вот это значит, 2 вот этих, а премия правительства—это то, что я получил вместе с Саранским заводом «Электровыпрямитель», по сути, техническая, которую я получил за то, что мы сделали серию приборов, известных, в общем-то, но с хорошими характеристиками на мировом уровне. За то, что сохранили на мировом уровне ту часть производства силовых полупроводниковых приборов, которая была раньше.

INTERPRETER: А в каких годах вас награждали?

Grekhov: Сейчас, хорошо… да там написано…

INTERPRETER: Some of it you are already familiar with the Lenin Prize given for the industrial, part of my work, and the first governmental prize …

Remacle: The state prize…

INTERPRETER: Yes, the state prize… I think… в 87 году, да? In nineteen-eighty seven, it was given for inventions in the pulse power, and the second state prize in 2002 concerns more modern research work in pulse-power field, that we didn't have time to talk about, because it's more modern days. And another one is a governmental prize 2006… Это вот та правительственная награда в 2006 году, которую в упомянули последней?

Grekhov: Да, это просто техническая… за техническое…

INTERPRETER: Not mentions on the electronic fields, but technical details for this. He was awarded together with the Saransk—да?—plant for creating equipment and technology for semiconductor devices.

Grekhov: Diode and thyristors… new generation diode and thyristors according to world level. It's a technical prize.

Remacle: It's still is an important one… It's one you are proud of?

Grekhov: Yes.

Remacle: And before I move right to last couple of questions I have this general question. Is there anything else about your career and development of Russian semiconductors—anything I haven't asked you or we haven't talked about… that you would like to mention…

INTERPRETER: Есть ли что-нибудь в области ваших разработок или какая-то часть истории исследования полупроводников в России, о которых вы хотели рассказать, но еще не было возможности затронуть?

Grekhov: Да нет, пожалуй… Я думаю, что я должен оставить большой кусок для ваших разговоров с Жоресом Ивановичем Алферовым.

INTERPRETER: Oh, I think I should finish with this. I think I should leave some space to fill in by Dr. Alferov for your next interview.

Grekhov: This is the first work of Alferov… yes, this one… in semiconductors, and that time of we work together.

Remacle: that must have been a very exciting time—you each went separate ways… So, couple of more just general questions—how, what was the most exciting and rewarding part of your career?

INTERPRETER: Какая часть вашей карьеры была, может быть, самой радостной, вот для вас, самой важной?

Grekhov: Pulse-power.

Remacle: That was the most interesting?

Grekhov: Yes.

Remacle: And you looking back on the all the things you have done… Is there anything you would done differently in your career, that you would change?

INTERPRETER: Вот, оглядываясь назад, есть ли какие-то вещи, которые вы хотели бы переделать? Которые, может быть, получились не совсем так, как вы хотели?

Grekhov: Ну конечно, я хотел бы другой институт кончить и получить полупроводниковое образование, а не механика.

INTERPRETER: Of course, first of all I would like to finish a different university and have degree in semiconductors field.

Grekhov: Потому что это было очень тяжело

INTERPRETER: Because it was very difficult to start…

Grekhov: с нуля, за один год осваивать совсем новые области…

INTERPRETER: From the beginning to embrace the whole new field of science for one year.

Remacle: If you could give any advice to a young engineer, male or female, who is starting today, what that advice would be?

INTERPRETER: Если бы.. давая совет молодому инженеру сейчас, начинающему работу в области проводников, какой бы вы дали совет? Если бы вы встретили…

Grekhov: О. Так это, наверное, не зависит от того, где ему начинать работать, в полупроводниках или где—просто нужно, чтобы эта работа увлекала и она интересной для него была, и в конечном счете, становилась целью жизни.

Remacle: it wouldn't depend on the field of science where the engineer would working, it would be the semiconductors or any other sphere, but the most important that the student engineer would be interested for what he or she was doing… and this work eventually should become essential part of his life.

[Missing audio]

Grekhov: Не только этот музей, а музеи вообще, потому что у меня жена долгие-долгие годы работала в Русском музее, и я эту музейную жизнь представляю себе и понимаю, насколько это важно—иметь реальную информацию о сегодняшнем дне, сохраненную для поколений на многие года впереди… потому что нам, где мы крутимся, все кажется обыденным—что тут интересного, а лет, например, через 50 это будет вещь необычная, и очень интересная для всех.

INTERPRETER: I understand what the museum is and what important work it is doing, because my wife has worked for many years in the Russian Museum in St. Petersburg and…

Remacle: That is one of my favorite Russian museums…

INTERPRETER: and I've been part of her work, and I know what the museum life is about, and that's why I understand that it's very important to collect something that we do now to keep it for years later because when 50 years would past it would look quite unique and different, even if now it seems to us routine and not interesting in everyday life.

Remacle: I think it was a wonderful answer and I think it would be seen in the Exit Theatre in some place [in the Computer History Museum]

INTERPRETER: Я думаю, что ваш ответ… он настолько объемный и настолько вмещает в себя суть нашей работы, что мы, может быть, даже поместим его на заголовок всей нашей темы.

Remacle: One of the reasons why the museum does this oral history is for the people like yourself, Dr. Popov, and Dr. Alferov, is because we feel like now we have the technology that is economical enough and high enough quality to do these interviews and capture the stories of people like yourself in your own… personal… You can see the smile… you can see the passion in your eyes, you can hear your way of explaining it, instead some historian saying: In 1894 George Smith said… It's totally different presentation of history… that's one of the reasons we have to do this now... So we can have these kinds of stories.

INTERPRETER: Да… очень важно… вот эта работа, мы решили ее проделать, потому что появились технологии, которые позволяют записать вживую, и видеть выражение глаз, настроение, а не то, что слушать других историков, которые просто сухо читают из учебников.

Grekhov: понимаю, сейчас бы послушать Джорджа Вашингтона…

INTERPRETER: It would be interesting to listen to George Washington these days…

Remacle: Or Michelangelo… or Lenin!

INTERPRETER: и даже Ленина, да?

Remacle: Some of Lenin, because there is a little more recent… But not an oral history in the same ways… Be very interesting.

INTERPRETER: Это гораздо ближе.

Remacle: So, thank you for your time.

Grekhov: Thank you very much for your visit.

END OF INTERVIEW

