Transcript

It is a simpler process, typical for composition. It means we are using also gas, but no plasma. Gas is heated by heating surface. It is more cheaper. We can also do this process with this machine. But plasma and cancer chemical vapor deposition has more advances on the chemical vapor deposition. We can lower the temperature of the heated surface more wafers. This machine consists of a vacuum chamber, a microwave oscillator, it is beside this part. The microwave ostinator is beside this wall. Wave guide system is this part. Wave guide surrounds the vacuum chamber. Inside of this wave guide are slots and microwaves goes through the parking chain through these slots. Another part is we need the vacuum pump. vacuum pump is there vacuum pump to the pipe you see here is connected to vacuum chamber here there are some valves one valve in this pipe another valve in the chamber to connect the chamber with this area. Now we will produce graphene from the two gases. Hydrogen and hydrocarbonated gas. It is metal. We use two bottles. These are pipes. The pipes go to the machine. Inside the machine there are flow meters. Gas flow meters for each of these pipes. For each of the gas. and after water they are mixer it mixes together and through this And the bigger climate, it goes to the back chamber. Well, I think it's all. And there is the control panel of this old machine. There is touchscreen, some buttons, and the computer is inside of this machine. There is touch screen, some buttons and the computer is inside. I have said it's using gases for the processing of the solid state fluid. But it can also be used as fluids. We have made such a system. There we find that more fluid, it is a evaporator, heater and it is now disconnected but we connect it here to the gas inlet and it is a right see what we find in the ground. To open the chamber, there must be more vacuum. Therefore, we must press the vent button, open the walls to the area, and we have no vacuum more. There is small one chamber. The frequency of the oscillator is 2450 megahertz and maximum power 5 kilowatt. The power we can change, but the wafer over here on it, I will lift this holder and show you what is inside. Here is a heater. It is also a temperature. I'm controlling the temperature of this heater. Now we can start with a silicone made of metal. We use silicon oxide. This machine is only one problem for us. Because this machine is

designed for producing of the diamond. And there is in the chamber very powerful plasma. And if we want to grow the graphene, we get nothing. So it's direct plasma-future? Yeah. Because plasma is too hard for this process. Therefore, we have designed some cups. It is a shielding cage. We have made several constructions, a lot of constructions. There are some examples of it. Okay, we can put one of them on our paper. They are just to protect? Yes, it protects from the direct heating of the ions, very powerful ions ions and lower the electrical field because if you know plasma builds very strong electrical field gears from plasma to the surface The 2nd of the store is a good one How do we set the parameters of our process? First we must press vacuum button to get the vacuum in the chamber. Now this valve close valve to the pump for vacuum pump opens it's connected to the chamber connected to the valve here we can see the pressure in the vacuum it lowers when it gets to zero it links to the Next button means... This button is preparing for the plasma process. Not the plasma process, our process, but preparing. The machine needs it. Before it, we must set our parameters. We set temperature here. Usually we use 700 degrees where I said we can lower because of the temperatures we grow different films now we set it is 700 kg. And pressure in that chamber, usually we use 10 milliwatt. It is the power of the microwave oscillator. It's 1 kilowatt. And as I said, there are flow methods. Here we set the parameters for the flow methods. We set now 200 cubic centimeters per minute for the hydrogen. Our process consists of two parts. First part is used to clean and anneal our wafer. We clean and anneal it with the hydrogen plasma. Because we tried to clean our wafer's chemical cleaning, to use chemical cleaning, but we have get better results only with cleaning with plasma. And now we start with this. You can see the ignition of the plasma now. You must be hit. Now you must want to see. It is full. Look all. Yes. And after that we press process. It takes our parameters and now we switch on the heater in the heating is also two parts. First part is lower heating, low speed heating until it reaches 500 degrees. And after we can press this upper button and then works controller of the temperature. Here I have now mentioned, here is the waveguide. Yes, and this part two of waveguides is for matching general oscillator to the chamber here we measure the return of the microwave oscillator incomes to the vacuum chamber and if it is not matches the resistance some part of the waves go there. It is that for us. We must adjust this to

get no return power. You see, there is zero return power. It is poor. You see, the temperature is rising 250 degrees. We will wait until it reaches 500 degrees. We have another thermometer. See here. It is spirometer. Maybe it is not in English. Why the thermometer? We will check. The thermometer is here. We can measure the temperature at that distance. And through the chamber it reaches our sample. If it is not covered by the car, it reaches it and can measure No, this temperature is temperature of the cup. I can brush this pattern and it is laser to show where is the temperature measured. You can see this red point. Laser helps also because we can adjust this point of measurement and if we have no laser we don't know where is the temperature measurement. As I said, this machine was designed for diamond growth and therefore there are no cup and you can measure this temperature directly on the surface of your wave. But in our case, we can measure it. And yesterday I have made a hole in that car. This matter reaches through this hole. My wave has measured its walls. Thank you. It is slow raising of the temperature because it is 20% where power is switched and 80% is switched off. that reflected power is measured also here See? See? so so If it is 500 we can connect the temperature controller. Now it's 600 and 700 and we wait until it reaches it and stay. What's the material for these protective sheets? It is steel, steel number 321 so Thank you. I made one trick because at the beginning the control overcomes the temperature and you can use any of the hydrocarbons gas. People use different gases. Because of the gas you can get different products. But we have chosen for net and we leave it. Yes, and the first part of the process will take 10 minutes. It is annealing and peeling of the water. I have no mention of all this machine. This machine needs water cooling. But temperature of the water must be higher than the temperature of the environment because of the condensation. And we have here a mixer. And you can see here is the temperature of the incoming water and outcome I'm going to get a little bit of stuff out there. Here is some parameters in my memory. But you can see on the... on the... This is good. so so so Super serious I think it's okay because we cannot wait to the end of the process because it is too long. The same process takes one hour and after this machine must be cooled and it takes about two hours. I think we end the cleaning process and now we start the rolling process okay for rolling where that's the temperature the same 700 the pressure the same 10

millibar we can change it to the 5 millibar or 20 millibar or 30 millibar but we for the planar graphene we use a pitch special but we lower the power of the oscillator we. Maximum can be 5 kilowatt, but minimum is for us will be better to lower power. and hydrogen and how we start the growing. The methane gas shows 25-50 cm. And now that process begins. I can start the time. For one hour, yes? Yes, growing, growing. Yes. First process part was annealing cleaning and second main process is growth of the graphene fuel. In the growing process we use two gases, methane and hydrogen. The graphene grows only from the methane because it needs carbon atoms. Hydrogen is used only for the... in our case is hydrogen atoms edge the film and don't let it fast grow. We need to slow grow. And it adds the perfect points of this film. And we get more uniform graphite by using hydrogen and in this case we use more of hydrogen and in the same metham only one atom of carbon and four atoms also of the hydrogen we have here we have a lot of the hydrogen and the theory theory is the etching of the hydrogen depends on the temperature of the process. Here lower the temperature, therefore, is more etching. Therefore, we must use higher temperature to grow. Means the growing must be system to measure it. And then we come back, I will show you how to end the process. It is not ended, but we can end. Okay. measurement, that's ready Yeah, it is a Raman spectrometer. Do you know something about it? About spectrometer, yes. About this particular one. About Raman? No. No. It has a... You have your film. With laser you excitate, excite these atoms of the film and then you get the... You excite with the laser photons and you get back another photons. And these photons you register with the detector. It is bases. This system has two lasers, red and green. For the graphene we use green one. The procedure is first we must calibrate this device. We take a simple silicon wafer view. This is a microscope and you can select, you can view the optical view or you can connect it to the laser. Because the laser comes with this objective. Anyway I use the laser to focus my... you see this laser point green laser point. I will focus it. Yes, it is in focus. It's connected. By switching this, I can switch to the optical view. It's not clear. It is a stage, it can be moved. I'll switch to the measurement. Now it's calibrating this device. I get this peak, this peak is for the silicon. This 500 inverted centimeters. Here I have some parameters of how it works. It is the center of the 500, the width of the other people, the height. Now I take off the

calibration wafer and I will take the wa laser to focus. I will lower the power of the loser. It is the optical view of graphene. It has no contamination, no defects. Therefore, I will use the parameters for our measurement. Press bottom measurement, Q and set the object position. Here we set the parameters. Scan extended over all of the... It is from 100 to 3000 inverted centimeters. And acquisition, it is time exposure. I leave it 10 seconds. Here is the power of this green laser. I set it to 10% file. I will set it where I will get the results. Manual folder. And I checked these fields, it is auto-implement. It means you can make several measurements. You must press only start and changes the name of the second measurement. I press auto-increment and auto-export to text. It means you can get results in the text file. Because another way you get get in the file who understands only this machine. It's all set. Press the same button. Run. button run Usually we measure in the dark, but I don't switch with light. You see it is from this light.'s all start. You must remove it. The program can remove this, but it works slow. Biggest pick. Okay. Now we can discuss what we have got. We have got... It was one big pick from silicon. This pick is also silicon, for the silicon. It's about 900. For graphene, it's interesting. Three, these three peaks. One, two, and three. About 1,300 inverse centimeters it is its name d peak distortion peak yes this peak's name is g for graphic G for graphite. It is about 1600. And this is very interesting for us because it shows the graphene. It is 2D. It is about 2700. If the graphene is very good, I don't mention it, the graphene is only some atom layers. It means less than 10 layers. It's good, two, three layers. But you can get it only with chemical vapor deposition using copper catalysis. We don't have to get such results. And if the graphene is good, you get only this peak and small this one. You don't get this peak. We have got three peaks and... Combination of these two peaks G and 2D shows how thick is our graphene. It is too thick. It is a lot of layers. It is maybe more than 10. If it is the same height, this becomes this, you can say about 10 layers. And this picture shows the distortion. We have not uniform carbon in our film yes it's all if you need this curve I will give you because I have it at my computer I have measured you can send us yes I have matched it before. If you need it, I don't know. Yeah, we need it for the report. If you give me your address, maybe you later give me. Yeah, we'll later give you. Someone from us will email you today. To me? Yes. Yes. Okay. You can write? Yes. You know my

email? I don't know. You can tell me you'll write it now. Yeah, every month. Point. so Okay, now we can be stuck with the switcher. Thank you. I I will show you how to end the process on this special. You mean it ends the core power? This is the plasma. and now the temperature is over, we wait about 2 hours until the temperature falls down. I open the temperature by one pocket. At the bottom of the observation. No, everything is better. I will give you this measurement file, if you step slowly you can take it back so... I use Excel. But you here. Yes, here.