Sensors and Actuators
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Lecture - 35
Installation of Oxygen Plasma System

Hi, welcome to this particular module. Now we are also in between our theory classes we are using some experimental class right. And today we will show it you how to Install a Oxygen Plasma System. Now this oxygen plasma system is a system which uses as its name says oxygen addresses a vacuum and creates a plasma and this system is used for bonding PDMS with your silicon or PDMS with glass.

Now I have already discussed that there are different kind of bonding methods; one is silicon to silicon bonding, other is silicon to the glass bonding, other one is glass to PDMS bonding. So, when you have PDMS, PDMS is used for creating micro fluidic chips right. So, today we will show from the installation side how to install an oxygen plasma system and when you use oxygen plasma system, you have you can tweak the power, you can tweak the pressure and you can tweak the time.

So, three things you can edit or you can change it and depending on your application this time variation, pressure variation and power variation have to be taken care. We will see by taking an actual example of a micro fluidic chips and that time I will explain you where exactly we are using this particular system. Today you focus on the lab class and a I will see you then in the next lab module which will be on some other experimental class.

Till then you take care, if you have any question you ask through NPTEL forum I will request now my student Anil to take that particular lab class where we will show you the oxygen plasma system. Bye.

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Hi everyone, welcome to this module today. It is a interesting module. We have a plan to show you installation of a very useful equipment that is used in a clean room. we have just opened the curtain for the oxygen plasma system here. So, oxygen plasma is a very multipurpose system that can be used for surface activation, surface cleaning. Let us say you have a substrate or a glass substrate you want to clean it so, oxygen plasma can be used for that. It is also used for surfacing enhancement, surface activation in order if you want to coat antibodies or other materials on top of glass.

Another important use of oxygen plasma system is to bond PDMS membranes to the glass substrate. So, let us say if you are making micro fluidic devices and you have patterned your electrodes or sensing material, sensing layer on a glass substrate and you want to overlay a micro fluidic channel on this glass substrate how do you attach this micro fluidic membranes which is more often use made using PDMS on to this glass substrate?

How do you attach those two or how do you stick those two together? So, that is usually done in the most efficient way using an oxygen plasma system, it is called plasma bonding. So, we keep the layer of PDMS on this glass substrate and then we keep it inside the plasma system and the two layers bond. So, we will be showing you a bonding process eventually, but first step what we are going to do is we will actually open up this curtain and we will set it up here. So, that you know how when you set up a clean room what are the process involved, what are the things that you should take care while we set up a system.

So, this main box here is the chamber of the plasma system. There is the chamber we will be showing it you. This is a cylinder this is the pipe that will be connecting the vacuum system to this chamber. So, vacuum system is also here next to it, we will show it to you it is there inside. Then another important thing that we need is an oxygen cylinder which is also be there, we will be connecting and showing to you. Oxygen cylinder, vacuum chamber vacuum system a chamber for creating the plasma are the main components of an oxygen plasma system.

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Now, let us dive into the installation and then I will run you through it. So, we are setting this thing up so, the chamber is there we are just opened the bag and kept it now. You can see how a little bit sophisticated it is. We will tell you **is** what each port does in due course of time and when we can actually show you the bonding process. So, big now as you observe they are not actually ground or they not varying sugar because right now we have suspended the activity of the clean room, because we are installing an equipment.

So, that is the protocol when you are installing a equipment you actually suspend all functional activities in the clean room, then you install it check everything and restart all the cleaning process and you again follow the protocol of governing it. So, that is the next one there is the vacuum system so, he will connect the vacuum system to the chamber. So, this is an oil-based vacuum system, there are oil less vacuum systems also.

So, as you have seen we are trying to assemble the system. We have now assembled to the plasma bonded system and this is the main unit, this is a vacuum pump and then we have the

oxygen cylinder. **T**he blue tube that you can see here is the oxygen supply that is going connected to the back side of the main unit ok.

Now what is this I told you that plasma cleaner or plasma bonder is used to clean the substrate, activate the substrate, surface modify a substrate before coating and all its a standard material processing technology. It is also conventionally used in biometric devices especially in micro fluidic devices to bond channels micro channels made with PDMS on to glass substrate. This I already told you before.

Before I get into how this system is, how does it operate and showing you all live demo and all, you need to first understand what is plasma ok? This as you know is oxygen plasma so, but what is plasma? Plasma is any gaseous substance ok, it can be that air which has all the constituents of its nitrogen oxygen argon and all or a particular gas, let us say oxygen in this case; oxygen that is in the plasma state. So, what is plasma state? It is rich in a normal gaseous state, the gas has only molecules ok, the oxygen molecules O2 molecules will be there.

Now inside in the plasma state when you apply any electric field or RF energy in this case, we are using RF energy here RF is a radio frequency radio frequency energy, the gaseous mixture gets ionized. When I say ionized what it means is that the potential is so high that the electrons in the molecules the electron electronic cloud in the molecules gets gains enough energy to escape the attraction of the nucleus and enter the common space between the molecules and thus the whole confined volume of the gaseous mixture gets charged with ions, with electrons.

There is a lot of things that happened in a plasma the electrons will be there, charged ions will be there, molecular ions will be there, atomic energy will be there. When I say atomic ions it is the O2 with the energy becomes O-O atoms **o o atoms and the those atoms** also get ionized. So, the atomic ions will be there, molecular ions will be there, moving electrons will be there normal oxygen molecules will be there.

It is a mixture of lot of entities. Such a mixture is called plasma. So, it is actually quite active. Such an plasma system is quite active and if you place some substrate on it this free moving electrons and atoms have the property to what you call modify substance whatever the environment of the plasma.

Let us say I keep the glass substrate, if there are some impurity on top of it this plasma will actually because of so much things that are there in the plasma it will go on to the surface and

clean the slide glass slide. So, that is what happened, that it is a in a very common way that is what a plasma system is does. So, we have oxygen plasma here ok. Another thing is when I tell about plasma, the biggest thing that anybody who are studied science in at least till class tenth or twelfth that comes to their mind is that colour. So, plasma as a unique colour for different properties.

Let us say argon plasma oxygen plasma if whatever if you make plasma out of different entities, they will have specific colour ok. So, oxygen plasma has a kind of pink colour. We will be creating plasma here today will be very interesting for you to watch. We will create plasma today how the process and all we will see. So, the plasma has a unique colour.

Why does different materials have different colour? This is because in a very crude way I will tell there are lot of processes that are happening that emits just colour, but in a very simple way if you break it down, I told you that we are applying high potential or RF energy to supply that energy to transfer that energy on to the oxygen molecules, the electrons in the oxygen molecule right. So, the electrons escape. It is a continuous process of giving energy releasing energy and all these things are happening.

So, the electrons escape the outer nuclei, they go out. So, that they have gained energy, but after sometime they lose energy and they come back to the ground state. In this process they release energy that is h nu you know right from a Planck's theory and all hc/λ. So, when this movement to a higher energy state and coming back to low energy state happens this energy is released usually in the form of visible light. That light is what we see as a plasmas colour.

So, how is plasma coloured different for different materials? There is this is because each molecules has a different radius, Radius in the sense if the atom itself as a different radius the nucleus I mean not atom the nucleus itself has a different radius, because nucleus consists of different number of protons and neutrons per each atom. Oxygen has some defined atom, oxygen atom is a bigger atom then let us a hydrogen atom, but and the oxygen molecule is even bigger and there is a electronic cloud surrounding it.

So, the energy with which the oxygen molecule or the oxygen atom attracts the electron and keeps it within its control is different from how a hydrogen atom keeps its electron within its control. So, that energy is fundamentally released as a light right how I told you before.

So, because of the difference let us say for hydrogen let us say its I am I cannot remember the exact number let us say it is a 10 electron volts in the hydrogen and if its let us say 40 electron volts in oxygen, the electron that is excited and comes back to the ground state will release more energy in the case of oxygen then hydrogen, because of this binding energy.

It is called binding energy because this binding energy is more in oxygen. Because of this as you know that if higher energy is towards the ultraviolet range hc/λ. So, when lambda is less; when lambda is less the energy is more. If you take the visible light, your red is towards the infrared spectrum which is higher wavelength and your ultraviolet spectrum which is to the left of your visible spectrum is the higher energy lower wavelength range. That is why because oxygen plasma its around pinkish in colour, it is more towards the bluish region than the red region because it is of little bit higher energy.

So, if we take another material, you make a plasma out of it, it will have its own characteristic colour. So, you might be thinking why we are going before you understand any system especially systems that deal with vacuum, you should understand out and out the basics of whatever is whatever the components are there in system, even if it may not be required for your day today operation with the system.

This is because you should be able to troubleshoot if some issue comes up that this is the reason behind is happening and you can you should be able to fix it. And these are all very safety regulated systems you have to be very careful in handling them and we are handling oxygen also. It is a explosive gas.

So, we have to be extremely careful while handling and with a great responsibility this is also a power you would like you tell its spider man with great power comes with great responsibility. This has also very very powerful system we can lot of uses, but you should handle it with care. One part of handling it with care is understanding what is going on you are not let us say if you are handling an equipment, there is two ways in handling; one a somebody can be trained to handling an equipment there will be a technician, they might not know exactly what is happening.

Or you can be a scientist who is handling the equipment and you know exactly what is happening and you will be able to even suggest improvements in how the equipment is designed. That is how fundamentally throughout history new system have been developed ok.

This oxygen plasma has come through it has become a system like this after the pain and brainstorming of lot of scientists and technicians. Everyone has contributed.

So, technicians would contributes to how easily they are able to use an equipment, how intuitive the controls are, those things they give feedback. A scientists would give feedback in how you can improve the system, how you can improve its range of operation, how you can improve its versatility of operation in what are all fields you can apply. So, this how systems get s developed. So, that is the overall idea about the plasma system correct.

Now coming to workflow of how we test the system. I told you that this is an oxygen plasma system and we have a chamber; I will show you all these things later. Plasma will be created in a chamber, if (Refer Time: 14:42) has a definite body. Now when you open a chamber it will be filled with normal air our normal air which has all nitrogen oxides argon everything.

Now it is very difficult to control a plasma and what we call control the extent of etching or cleaning that it does if you try to create plasma from normal air and more importantly the problem is that you apply a particular RF energy, if its ones species of gas that is there you will know what is the RF energy that you have to apply for it to become plasma.

When I show you will see that exactly at after a particular RF energy RF power it becomes a plasma. Now you should try to do the same in air normal air you do not know there are lot of constituents there is oxygen, there is nitrogen, you cannot fix a particular RF energy level to for the plasma to form. So, it is very random. That is why we need a vacuum system ok. We have a vacuum system first we take out all the air that is there in the chamber. So, that is the base line we create vacuum. Once we create the vacuum what we do is we let in our air or our gas species for which we are going to create plasma. In this case it is oxygen.

So, what we do? We create vacuum sufficiently large vacuum using the vacuum pump here. Once the vacuum is of satisfactory level, you let in oxygen into chamber. At that point you can see the pressure increasing initially when you are create vacuum pressure will drop then you see the pressure increasing, because of oxygen molecules are coming in. So, the oxygen molecules are come in. So, they fill the air, now it is a more definite chamber. You know that this chamber is now constitute a most 99 percentage of oxygen. So, it is controllable.

Especially is such systems the amounts of robustness is measured by how well you can control the system ok, how much of the control of the system is in your hands. So, such that is why the

system has designed in such a way that you can exactly tune your system to perform in the way you want it to perform ok. So, we have a chamber, we create vacuum inside it, then we let in oxygen air into it. After this what we have to do is we have to apply RF power.

So, RF power is just basically applying up electrical potential in the gaseous mixture through radio frequency coil. So, inside the chamber there is a coil that is around the chamber, the chamber itself is made of quartz glass and there is a coil outside the quartz glass, that supplies voltage in to the gaseous mixture ok. And this is RF energy transmission. So, it is like a wireless energy transmission to the oxygen species and its starts become plasma.

Then what we do is we will slowly increase the RF power and at one point of RF power it becomes plasma and you will start seeing a glow. After that when you increase the power, the glows becomes brighter and brighter ok. That shows the energy of the plasma that is getting stored energy that is getting is stored in plasma and the etching power or the cleaning power of the plasma.

Here one thing to note is you cannot indefinitely increase your RF power because there is always a tripping point on any device it will get just get trip. Another thing that you notice this is radio frequency plasma generation so, it is about a transmission lines ok. So, in transmission lines there is there is idea called forward power and reverse power. So, you it is called impedance matching you deliver some power at a frequency RF frequency, here it is 13.56 mega Hertz. At a particular RF frequency you are delivering power to a loader.

Now, because it is a energy that is transmitted over a frequency, there is always a reflection of energy that happens. That is measured using this reflection parametric gamma. You might have studied a earlier in your engineering time. So, there is a reflection that happens. Now this reflected power goes back to the system that is supplying the power.

Now if that refracted power is more it creates currents within the system that is supplying the power and can cause burning of the wires and all that is connected. So, our design objective is to always reduce the reflected power and make sure that the forward power other delivered power only is maximum. So, when we show you we will show you how we have tooled the system to deliver maximum forward power and minimum reverse power. These are the fine things that you need to take care while you operate the system.

So, we saw that we have a chamber, we vacuum it we fill oxygen inside it, then we when we apply RF power inside it and plasma gets created. Before all this you have to load a substrate inside it, because after before you close your chamber we have to load your substrate inside. Then you all these things, then you keep it for a defined time and substrate gets cleaned and then you take it out this is the overall operation of the plasma chamber. Now we will get into individual blocks of the actual system and see let us see whether we can create plasma.

So, now we are going to the final part let us try to operate the system and create plasma in the oxygen plasma system. So, as I am just repeating, we have the main system here, I will getting to details of each of these interfaces soon. So, we have the main system here, I will go into details about each of the system each of the supports to the system later.

So, to this system is connected to the vacuum pump. This is an oil based vacuum pump, it is a rotary pump and the pump tube or from this the air stuck down is this, it is connected to the main system ok. And then the power of the pump it comes from a supply main supply unit on this board. So, we just need to connect the power supply cord of this vacuum pump to this main unit and power will come to that from the main unit ok. And then we have the oxygen cylinder here so, from where the oxygen supply goes to the main unit.

So, for demonstrating you we have kept the oxygen cylinder here, but as per safety regulations oxygen cylinder should be kept outside the lab in a utility room properly chained, but because we have to show you that cylinder connection goes like this we have kept it here. This is now how should be operated. so, oxygen tube is connected there, and supply will go ok. So, these are the three main things that are required for the system to operate.

So, now let us get into understanding the main chamber and oxygen plasma main system ok. I have not powered it on. Before I power on, let me show you what are the individual components of this. So, main the heart of it is where we actually use it is the chamber. This is the chamber ok. It is a magnetically sealed chamber. So, I am pulling it so, there is a magnet here and here magnetic attraction is there, because of the because of which it gets sealed properly.

This is a chamber let us zoom into the chamber now. So, now, we have zoomed in to the chamber you can see a if it is a 2 litre volume chamber the dia of this is around 3 inches 4 inches actually almost 3.8 inches and then the volume is around 2 litre inside. Now if you see look closely you can see a coil that is running around it there is a coil that is a RF coil. We supply RF energy, we transfer RF energy to the oxygen through this coil ok.

That is the RF coil which creates the plasma and if you look at the end of it you can see some holes. So, that is the those are the holes through air is sucked out. There is a big hole that is from where air is sucked out by the vacuum pump. There are two small holes right, those are gas inlet us for giving two different gases. This system allows for giving two different gas inlets. So, you can have a mixture of two gases to create plasma. This is sometimes useful. So, two gas inputs are there then find it there is a vent port through which you can vent. So, those are the inside you can see the ports.

Now let us zoom out. Now, this one is the interface panel which is the touch display where we switch on and we can see how to control the things. Now this one bottom is the RF control, RF control port. These two what we call indicators are the flow indicators for the gases. This is gas in a gas in b. I told you that there are two gas two gas inlet us for each of the gas inlets there is the flow indicators flow meter here we can see what is the flow rate at which the gas is coming in and we can fix it by controlling the knob here ok.

Now this is the RF control I told you right separately, if you want to switch on the RF you have to power on it here and you can set the RF power what is the megawatt power that you want to give what is the RF power that you want to give that you can fix through this knob and I told you that the return power has to be minimised. Only the forward power has to be maximized should be maximum.

So, that return power minimization is done through this tune and load. I told you also that reflection is depended on the load, depending on the load value the refraction parameter changes. So, your load has to be adjusted so, that it is equivalent to what our typical load that you will place inside your chamber and depending of adjusting the load and tune values you can have minimize the reflected power and maximize your deliver power or forward power ok. This is the RF power.

After all this any such equipment will have a safety button safety stop or emergency stop button. So, that is the emergency stop button here. This if you pull the system will shut down immediately ok. Let us turn on the system now, you can see the system booting once it powers on yes we are power it on. So, it is booting system is booting starting and you will get the interface ok.

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Now, the interface is on. Now we need to switch on the plasma control also. So, I am switching it on. You can see here the plasma control coming up that sound you can see and you can see a display on the plasma control that is 150 watt forward power and the RF is off. That is the overall status. 150 forward power and off that is maximum RF power you can deliver and off state right, now we are not touching this.

Now let us look at the interface. So, if you look at the interface there are lot of things that are there and I will tell you how to operate that. Now the first thing that I told you is to create the vacuum inside the chamber correct. Now if you see under the vacuum tab you can see that the pressure is 189180 Pascal ok. So, that is like it is at a normal atmospheric pressure and vacuum is not created.

Now left of it you can see the options turn on pump turn off pump, that this pump is vacuum. When I click turn on pump this pump will turn on and start sucking air out or creating vacuum inside the chamber. That time you will see this pressure dropping. It will drop to tens of Pascal's ok. First step for us when we are trying to make the plasma is that. We will create we will switch on the pump and we will see the pressure dropping to tens of Pascal's from 188928 Pascal ok.

Once that is done, next part for us will be to the gas the gas inlet we have already connected gas, we have to switch on the open the gas cylinder oxygen cylinder, but we are not open the valve for the inlet us of the gas cylinder inside. So, we have to open the valve for the gas

cylinder that will be our next step that is here. So, there is separate controls for gas 1 and gas 2. We are connected our oxygen to gas 1.

So, once we have created the vacuum, next step for us is to in let the oxygen come in ok. So, once the oxygen starts the coming in, you will see the pressure going up again. That is because the oxygen that we are pushing in is reducing the vacuum that its being created. That is in indication that oxygen as actually going in I am just telling you. So, we create vacuum by turning on the pump, then we will see that the vacuum will go down. Then we will open the inlet for the oxygen, the gas will come in. As a second last step is we switch on the RF power.

When you switch on the RF power, we can see the volt other RF power that is delivered. Here it is showing as 150 watt, that we will control from the knob below which I showed you earlier we will see it again. Now I will turn on RF power you can see the RF power that will be delivered, we will keep it at around 50 watt ok. Then as we adjust the RF power we start from very low RF power and we will see at some RF power the plasma getting created ok.

Once the plasma is created, we can leave the plasma for some time to act on the substrate. First of we will not put a substrate we will just create plasma and see then we will put a substrate also and see. Once your cleaning action or bonding action is done, cleaning is done, then the next step is already oxygen is inside right you have to vent out the oxygen and remove the vacuum that is created. So, that last valve is to open air.

Here open-air option is there that will open the air in outlet 1 and allow the air to come in basically, because it is vacuum inside so, air will come expel the oxygen out. So, that is the these are the main controls for the plasma to form. On the right side are some programming options where you can time your clean. Like you can say that a I want to clean for 5 minutes. So, you can time your clean and the plasma will be on for 5 minutes and then it will shut off ok. And there are some other options also which are not really important. So, this area is a major part for us to create the plasma ok.

As you can see this is small sound that is coming. The RF is system is on, but we are not actually delivery any power. So, let us do the first step, we have to switch on the pump. It will take out the air from inside the chamber ok. So, let us do it I am going to turn on the pump, I am going to click turn on. So, you can hear the sound of the pump operating ok. Now you can see the pressure dropping here. See it is rapidly dropping 19000, 18000, 1000, 600, 400, 300,

200, 100, under 100 now. The pressure is dropping continuously. Let it get down to 10 under 10 Pascal, then we will switch on the oxygen supply.

So, from 1881400 Pascal immediately within like 2-3 seconds it has come down to 24 Pascal's ok. Let us wait till it comes below 10 or at least in the range of 10 Pascal's. So, as you see when this happens, I will explain something else to you. So, while this comes down, I will explain some small interesting thing to you as you see as you show that the pressure Pascal value drop very rapidly from that very high value to a reasonable low value of 100 Pascal's, but after that it takes lot of time to reduce 1 by 1 Pascal.

Why is this so? This is because when you start of what is vacuum creation, it is basically you are removing atoms molecules of different gases from the milieu and taking out taking out and creating a empty chamber ideally ok. So, as initially when there are lot of molecules it is very easy to take them out, because there are enough number of molecules to take out. Imagine that you are swimming for fish in the ocean and the fish are the molecules if there are lot of fish in the ocean you just throw your net lot of fish will come when you start of ok.

So, next time in the same ocean if you try to catch fish the number of fish has reduced. So, your and if your goal is to make the number of fish in the ocean 0, it becomes more and more difficult for you to remove that remaining fish because they are very difficult to come by. Because they are its a large space and the fish are very less in number.

So, if the vacuum pump has to exert more energy to extract that last remaining molecules that are creating that defined pressure. That is why the pressure drops from very high value to a reasonable low value quite fast. Then after that going below each Pascal is difficult because it becomes increasingly difficult to extract molecules from that milieu because they are very less in number. We have to put work on the system to take out that molecule. They have to search for that molecule and take it out. That is why its takes time.

So, now let us see what is the pressure it has gone to? So, the pressure has drop to 10 Pascal's ok. Now it is time for us to let in oxygen. So, when I switch on the oxygen open gas 1, you can see you can you observe the pressure there and the pressure will increase, because of the oxygen that has been pushed inside. So, I am going to press open gas 1. So, we have pushed in oxygen inside.

You can see the pressure slightly increasing ok. So, you can see that it is increasing it is become 22-23 Pascal's ok. So, I will not keep it that much I will reduce it little bit. We will keep it to 15 Pascal's ok. That control I am doing using the flow meter below which I had shown you before. So, I have kept it 20 Pascal's this is when the with the oxygen in ok. To confirm that this is what is happening let me just close the gas valve now ok; that means, we are not supplying gas.

So, it should again go back to the low pressure. So, I am closing the gas valve. I have close the gas valve. You can see the pressure will drop from 22 Pascal, slowly it will drop, 21 has become 20. Slowly it will become 19 Pascal. It takes some time as I explained before to reduce that molecules. See it has becomes 19 Pascal. So, like this it will reduce, let us not we do not have time to show you that much. So, I will open the gas valve again ok.

So, I open the gas valve again so, we have set the flow. So, it will go back to again that value of 22 or 24 Pascal's of oxygen ok. So, we have kept oxygen there ok, some defined amount of oxygen is there at some pressure it is difficult to control it. So, now, this is shows that there is oxygen ok.

Now we have created vacuum we have allowed oxygen to come inside. So, next step is to switch on the RF power ok. So, let switch it on, I am going to press turn on RF power. So, I have turned on the RF power so, we have turned on the RF power ok. Now you can see the chamber and you can see the control ok. Now in the control you can see that forward power is 0 and the return power is also 0 ok. Let us now focus on the RF control ok.

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Now, we are looking at the RF control, now it is 0 forward watt and 0 return watt. Now this is the knob to adjust the RF power. So, let me increase the RF power, 1 watt forward 2, 3, 4, 5 so, return power is not just so, this is good condition so, it is tuned properly ok. Now, let us. So, I like this will keep increasing the RF power ok. Now we will not see here now let us look at the chamber where the fun happens ok, let us zoom in on the chamber. So, now, we are looking at the chamber ok, now RF power is 5 watt. You do not see anything special happening inside the chamber right correct.

Now, let me increase the RF power. Now it is 6 watt, 7 watt, 8, 9, I am slowly increasing it. It is 15 watt now forward power, but the return power as become 12 so, I need to adjust it ok. Now you can see slight pink colour coming in the chamber. So, you can see a light pink colour coming in the chamber now that is at 15 watt RF power. Let me increase the power 16, 18 you can see that intensity of the plasma is increasing.

So, I will increase and keep it 50 watt RF power. We can clearly see the plasma inside now, it is pink in colour this is the oxygen plasma that has been created. So, now, you can see properly pink colour plasma inside at 36 watt RF power. I will make it I am tuning it whenever return power comes I will tune the RF control. So, this is at 50 mega 50-watt RF power and plasma is ready for you to work on the substrate ok.

You can go up to 150 watt power, but that it is not really necessary for our operation create this plasma is enough to etch the surface or clean the surface. So, I think you can clearly see the

plasma inside pink colour. Now let us see if the plasma goes away when I reduce the RF power. So, I am just going back I am reducing the RF power, just look at the chamber, keep looking at the chamber ok. I am reducing the RF power now you can see the intensity going down and when I go to 0 power it will become that plasma will get extinguished.

Now, the plasma is gone; plasma is gone and we are come back to a no plasma state ok. Now that we know so, we have seen the plasma now how do you we switch off the system? Now first thing so, what did we follow what is the sequence, we followed we created vacuum, we let oxygen inside. Then we switched on the RF power. Then we saw the plasma getting formed. Now we will switch off the RF power first ok. So, I am turning off the RF power.

Student: (Refer Time: 40:14).

Now we turning off the RF power, that is a first we are switching switch down procedure. Turn off RF power is turned off. Next what we have to do? We have to close your gas supply. So, I am closing the gas supply, gas supply is closed. Now we have to switch off your pump because you do not want to pump it. Pump is switched off. You can hear the silence the pump is not working now. Now, but we have to created vacuum inside right the vacuum level is still quite low, but we want to use it immediately.

So, we can vent air into the chamber. So, for that we have to go here air valve closed is there now here in that you have to put open air. Now you can hear the air coming into the chamber. So, parallelly you can see that the pressure here has become back to the high value. Now you are ready to open the chamber.

Student: Now we are ready to.

Now, we are ready to open the chamber and we are opening it, we are able to open it we can go inside and see it. It will be not be hot because this is RF energy. Next step we will try to clean a glass substrate and the PDMS membrane and see if we can bond the two. That is also another application of oxygen plasma ok. So, that we will do now in another minute we will do that.

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As a next step we will be bonding this glass slide with this PDMS membrane. You can see the membrane PDMS flexible material. So, what we will do is we will place both of them inside the oxygen plasma, both the surfaces will get activated and then we will take it out from the plasma treatment and see if they will bond ok. It is going to be really interesting let us do this let us me keep these two inside the chamber ok.

So, we are going to place the glass slide inside the chamber. So, the slide is placed, now we will flip and place the surface which we want to bond nicely cleaned inside. It is better that you keep it sufficiently inside and the PDMS and the glass should not be one above the other it should be separated so, that both get straightened by the plasma properly ok. Now I have kept both of them inside I am closing the chamber.

Now we will do the same thing that I did before, we will create plasma again. So, what I will do? I will switch on the system first I will turn on the pump. So, the pump will create the vacuum first. Now we will wait for it to go below 20 at least. So, I am waiting for the vacuum to be sufficiently large. So, in vacuum if you try to open the chamber you will not able to open it. It is tight air sealed oh, but you can actually correct here only ok. So, we have created the pressure I mean vacuum it is 9 Pascal, now we can open the oxygen supply.

So, oxygen is coming in, I will let it in. So, you can see the pressure as increased, because of the oxygen inlet input. Now we will switch on the RF power. Now we have switched on the oxygen supply, now we will turn on the RF power and keep it around 50 watt. So, we have

kept it around 65-watt. So, the plasma has been found. Let us look at the chamber. So, now, we are looking at the plasma, it is at 65-watt power. You can see the glass slide and the PDMS membrane inside (Refer Time: 44:58) the plasma. We need to do this plasma treatment for like 5 to 10 minutes, after that we will take it out and see how they are bonding ok.

You can nicely see the pink colour plasma bathing the slide and the PDMS membrane inside in the plasma ok. So, we will after 5 minutes we will take out these two and try to bond it. So, now, we have done around 10 minutes of plasma treatment on the glass substrate and the PDMS membrane. Now we will follow the taking out process or the bonding process which we will try after we evacuate the chamber. So, let us first switch off the plasma, then I will close the gas vent. I will make the plasma voltage to 0, then I will turn off the pump ok.

I have turned off the pump; turn off the pump now, I will vent it. So, I have vented it everything done I can switch even switch off the system now, I have switched of the system. Now we will open the chamber take out the samples carefully, I have taken it out and I will try to keep the surfaces that have been plasma treated on top of each other ok.

So, I have kept the PDMS membrane and the glass substrate on top of each other. Thus, surface that was expose to the plasma is touching the glass slide of the PDMS membrane slides surface that as treated as a touching the PDMS membrane basically. So, I have kept both of them together and they have bonded.

So, I kept I have kept both of them together, and they have bonded. You can shake it and see they are not coming out they are nicely bonded ok. So, this is what so, this way we can make micro fluidic channels on this PDMS membrane and bond it with the glass substrate that has sensors and without using any glue. This is the advantage of using plasma bond ok. So, we have bonded nicely ok. I hope you understood the resource fullness of this tool and we found this module useful. Thank you.

I hope you found this tool to be quite resourceful and you understood the various uses of this tool and how its forms an integral part of the micro fabrication sensors in the actuators course and how it is important for making developing systems that sense physical changes in phenomena. You can go over the video again, understand the concepts that we have discussed, while trying to understand how a real world system works where even looked it how we were installing it how what are the individual components of the system, how each components is important.

So, this is one example of how a system is tested from box to working condition. And through that journey you also understood the concepts that are involved in it and how its fix well with the idea of sensors and actuators. We will be happy to see you in the next module till then thank you.