Biomedical Ultrasound: Fundamentals of Imaging and Micromachined Transducers

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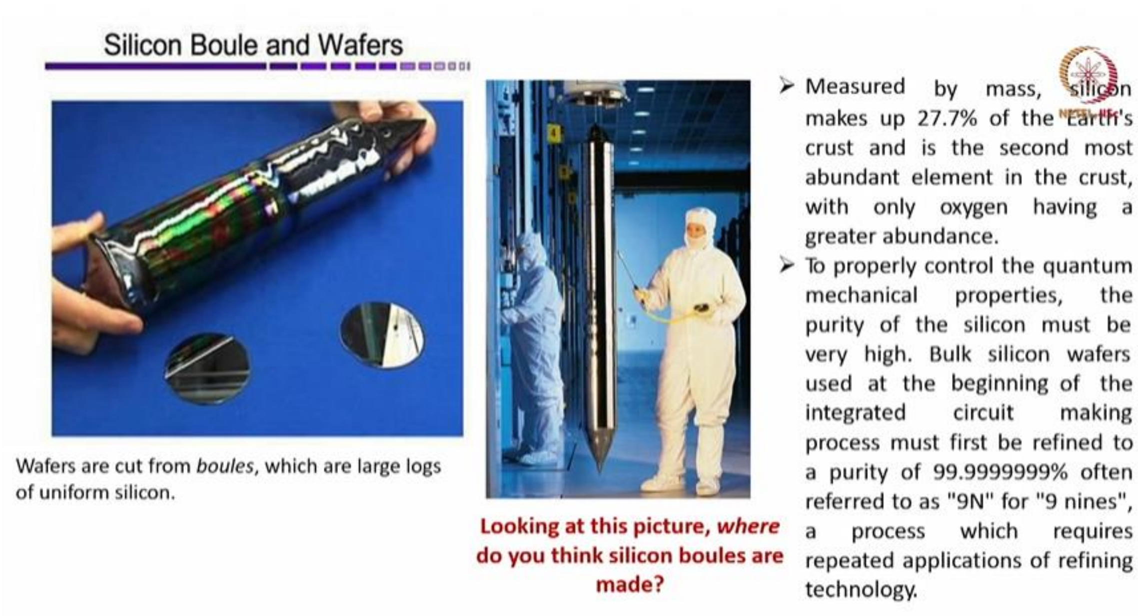
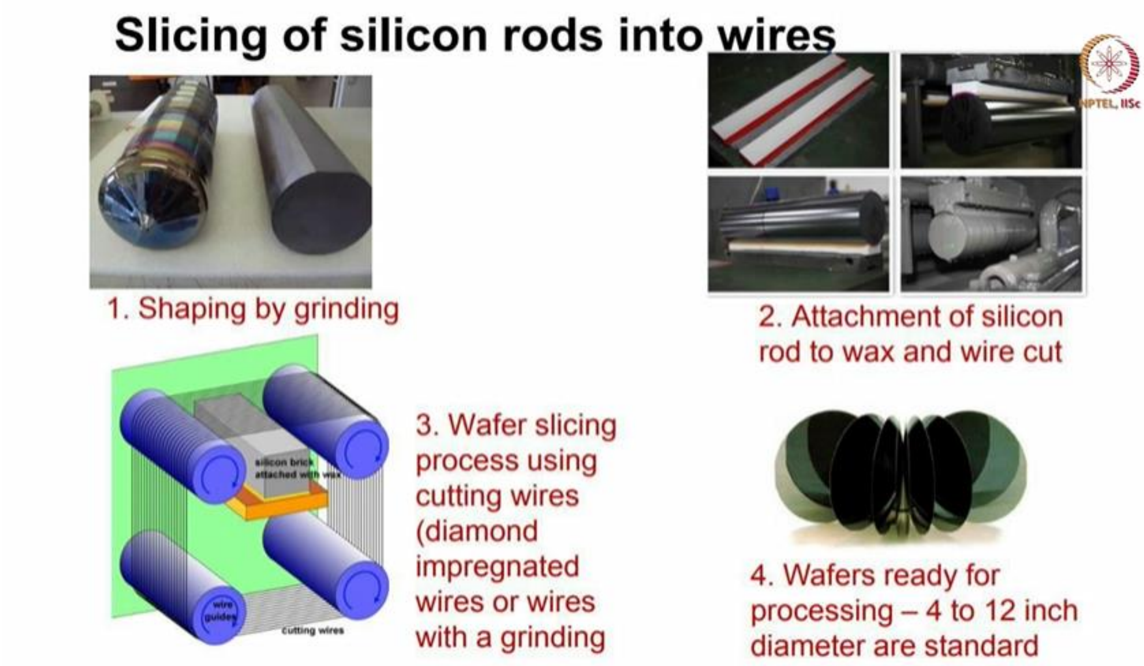
Lecture: 58

Wire bonding lab demo

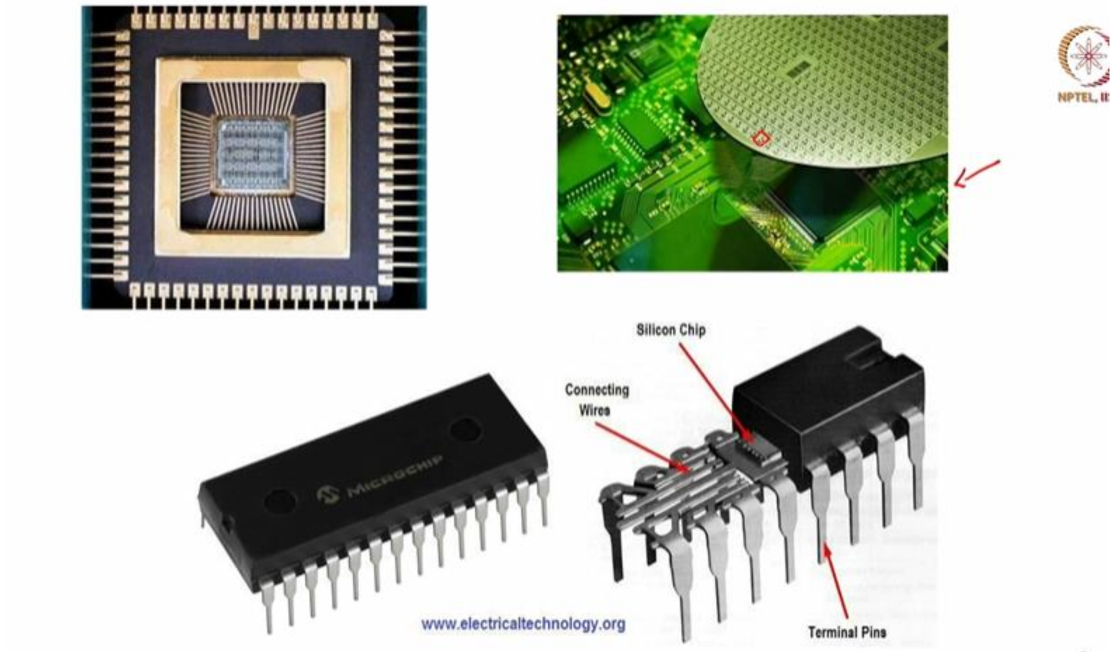
Hi, welcome to this lab class. Today, we are looking at wire bonding. Now, before we go to wire bonding, let us understand and recall why we need to learn this particular process, and what exactly wire bonding is. So, if you see the screen, what we have been looking at is the silicon boule.



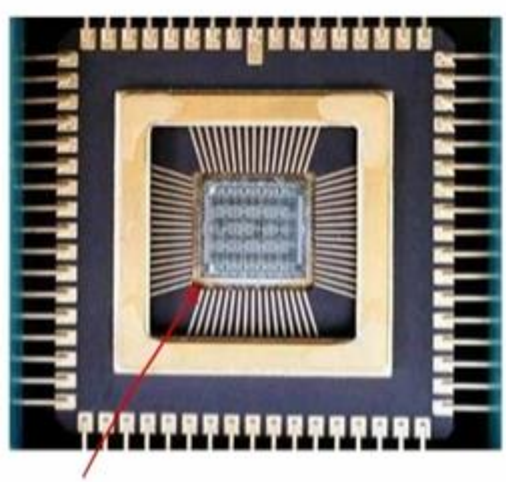
You remember, we have seen Czochralski technique, which is CZ technique, we have seen float zone technique. And then we also know that 95 percent of the silicon or the semiconductor devices still today are made up of silicon which is a substrate. Now, once you have a boule, the purity of silicon needs to be 99.9999999%. And we also know that this kind of boule can be fabricated in a fab lab or we can say foundry.



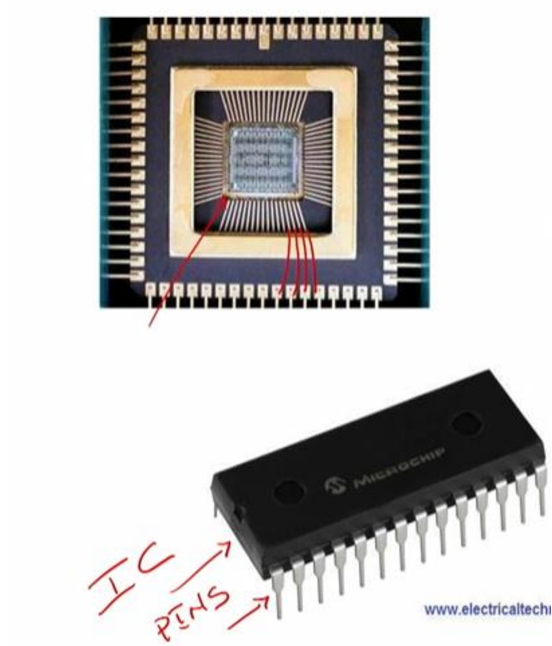
From silicon boule we can get the silicon wafers, which can be single side polished wafer, or double side polished wafer. Also we have seen and then once we perform this slicing of this particular boule and then polishing CMPVs, chemical mechanical polishing, grinding, and then we can get the silicon wafer of different size that means a 4 inch diameter to 12 inch diameter and even bigger diameter as well. What we do? We do the entire process flow to fabricate our devices. Now once you have the devices, this entire silicon wafer have many devices. So, once you have many devices, you slice this device or you dice this device. So, dicing is a process by which you can have individual die. You can see in this particular image where you have silicon wafer and each of this particular rectangle in red, that I am drawing here is a die.



So, you need to dice each of this, and then you can place it in a packaging system where you can do the wire bonding. So, with you see a silicon die with lot of circuits integrated onto it.



Now, it is it may be ASIC or it may be something else. When you say ASIC, it is Application Specific Integrated Circuit. Now once we need to take the contact from this particular die to the external pins, which we generally call as a integrated circuit or IC and these are our pins of the IC. Internally when you open this casing what you will find is a silicon chip and this silicon chip is wire bonded. From the chip, there is a wire that comes to the bond like this. 1, 2, 3, 4 and so on.



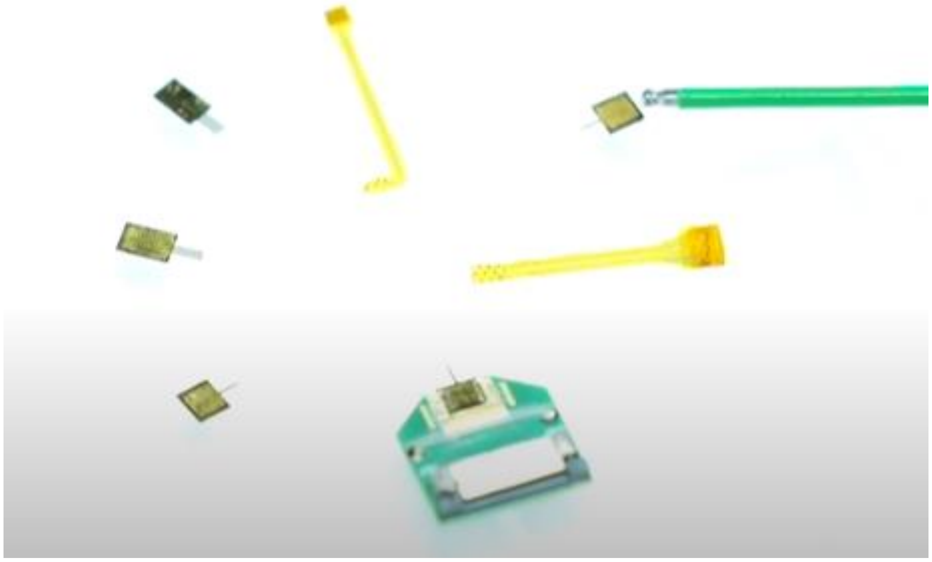
So this process of how the wire bonding works, have been recorded in the lab class. So you will see how to utilize this very important tool. Now we have taken example of a chip but in this course what we are looking at a device. It can be either a PMUTS or piezoelectric micromachine ultrasound transducer arrays or it can be any sensor. It can be gas sensor, it can be pressure sensor, it can be temperature sensor, it can be accelerometer, it can be any sensor. So, if you want to take the contacts from the sensor all the way to external electronic module, and that particular sensor is made up of silicon and the pads are made up of gold or platinum, then you can use wire bonding. There are different kind of wire bonding, but we will not go into detail of those particular aspects. But I hope that you like this lab class and you learn something out of this lab. Till then have a nice time with the lab class.

Hello everyone, in this lecture we will have a demo on wire bonding machine. My name is Srinivas Bhaskara, one of the TAs of this course. So, what exactly a wire bonding machine does? You might have seen a soldering process, in which people take lead, and they melt it and put it at the contact where they want to connect it. That's how the soldering will takes place. So there the method is a little bit different compared to this wire bonding, but more or less the concept is the same. Here we are again doing the same kind of process, the difference being the contact pads are at a micron level. The pad sizes are very small here. It can be 300 micron by 500 micron pad, where the traditional soldering may not work. Now I will also show you lot of micro fabricated devices, to show you how difficult it is to try it using a soldering gun.

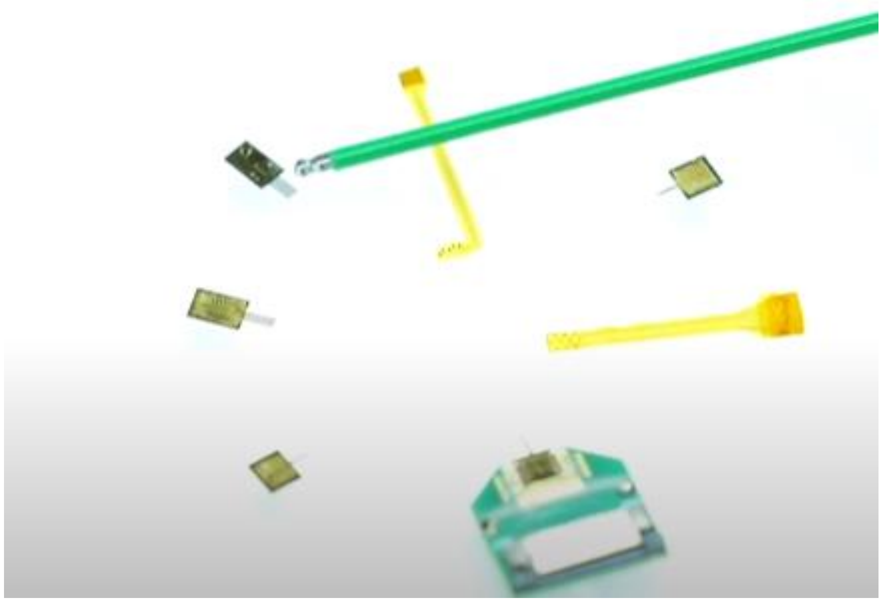
If we consider the alternatives to soldering, at micron level, One of the alternatives is the wire bonding machine and it is the kind of the technology that uses is different methods. One way of doing is using ultrasonic power. Like you use the vibration as a energy to melt the material and apply some force and then make sure that the metal and the wire are in contact. And take that wire on somewhere else and then again do the same procedure. This way you can create a wire bonding.

Or, you use thermal energy by heating it up. You make sure that metal gets melted and then try to apply that. I mean, it's not like just a thermal energy. You also use ultrasonic power and pressure also at the same time. So here what we use, we have ultrasonic power. You use a force with a particular contact time. Based on these three parameters the machine will work.

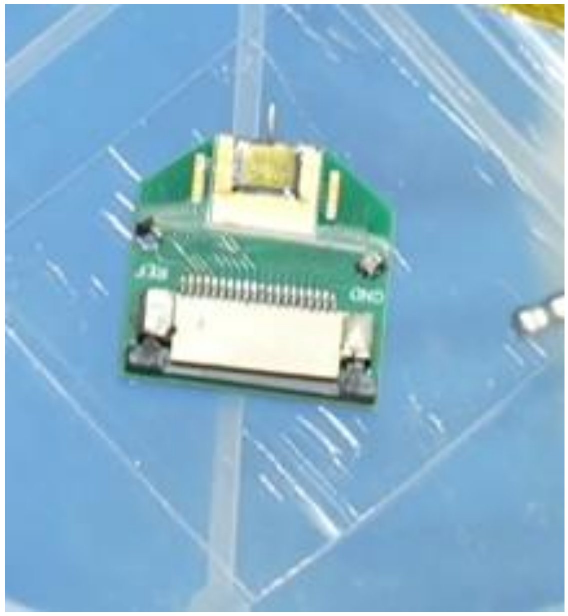
So if it is aluminum, you can use ultrasonic power, If it is gold then you have to use thermosonic along with vibration you also has to supply some heat so that the gold will bond to that particular contact pad . So, in the next few seconds I will show you some of the devices where you can feel what is the importance of wire bonder . So, let us have a close look at those devices now. Now these are all the neural implants that we use for rodent models. Forgetting about those application point of view, if you look at this this implant, it has around 11 to 12 electrodes within the device along the shank and there are the contact pads here for individual electrodes.



So you look at this one. This has four shanks



From this device, if you come anticlockwise, you can see the devices with three shanks, one shank and finally on the bottom, you can see a neural implant with an electrode interface, which is the green color board that you can see. This is called as electrode interface board. Now in the fabrication, we will fabricate this neural implant separately. Finally it has to be interfaced with electronic systems, and how do you do that? You put it on the electrode interface board that is that green color and you attach it using some epoxy and then fix it. Now how to get the electrical contacts?

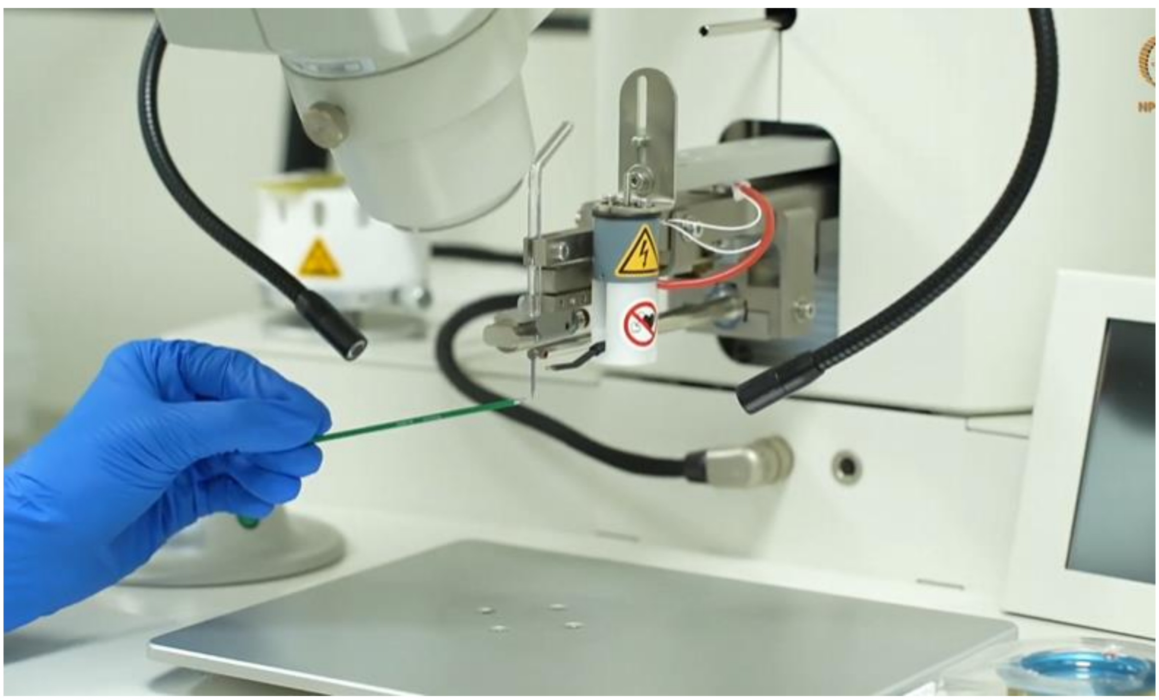


Changing the view for better visualization, now the green part is electrode interface board, the white connector is an FPC connector the other end will be connected to the electronic systems. On the device, there are so many electrodes. Viewing through a microscope is needed for seeing it properly. Now you can see the thin wires that are coming from the implant to the electronic interface board. The dimensions is around 30 micron thin wire and you look at the contact pads, which are very very small, and hence soldering is not feasible. So how to get the electrical contact from the neural implant to the electrical interface board? Now that is where we give much credit to the wirebonder. So when the contact pads are very, very small, that's where the wirebonder will help you.

And this is what precisely IC industry also looks at it. Because as the dimensions of the transistors are reducing, the contact pad size is also reducing. So, the way you get the electrical connections between the pads also need to be in the same order . So, that is the significance of a wirebonder. Now, we will look into the system peripherals and then see what are the different things present in the wirebonder.

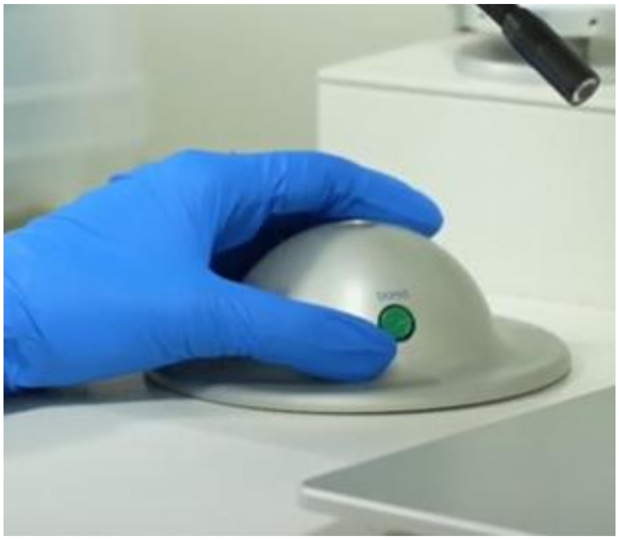
Now, let us look at different peripherals of wirebonder ok. So this is tool.

If you look here, wire comes up from this part of the tool.



The diameter of the wire that comes out is around 30 micron and the end dimension of the tool opening is around 80 micron. So it's very precise and it is made of tungsten so that it can withstand very high temperatures. Because tungsten we all know that it has very high melting point.

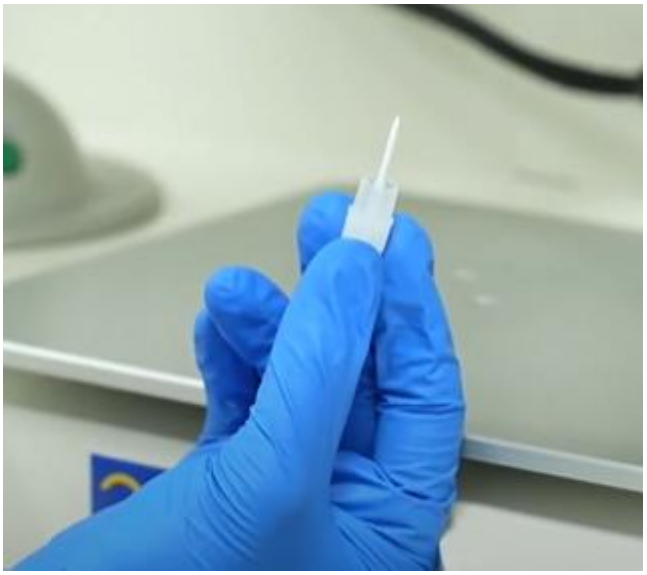
Now I have a zig here, it's like a gearbox.



I can move the stage linearly with this. This is very very important because when you are doing a bond, you may need to move from one place to another place. so this will help you to move the stitch.

Now this is the holder substrate holder. You can also see the symbol indicating that this stage you can heat it up whenever you are doing gold bonding.

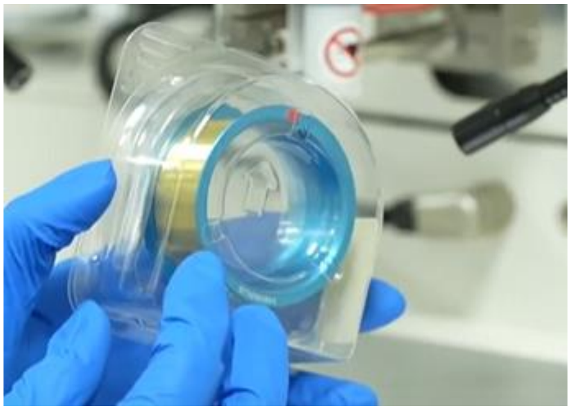
Now I am showing one more tool. These tools are very very costly Can you see this tool? You see how thin it is.

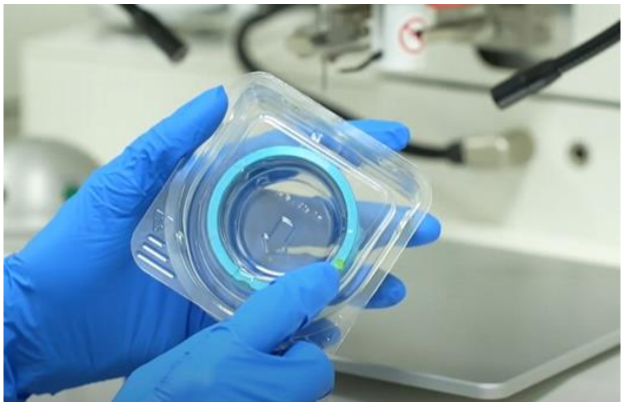


So depending on the material that you are using, we have to change the tool and also depending on the type of bonding that we use.

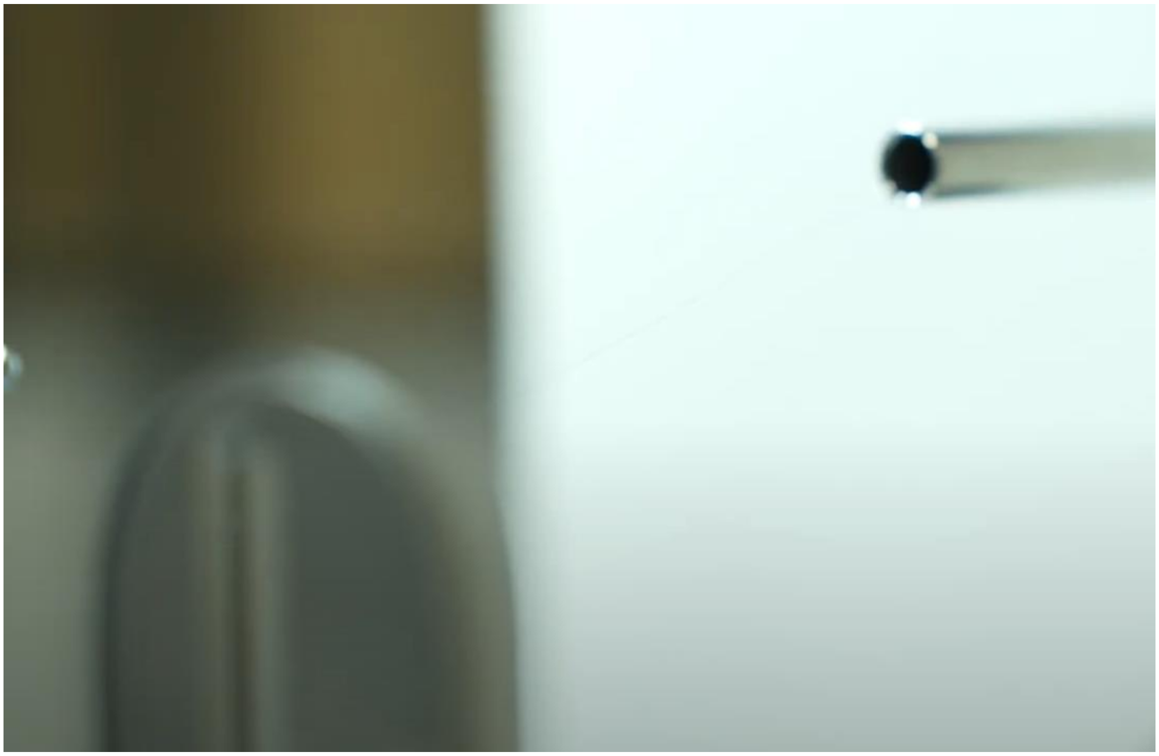
We have ball bonding, wedge bonding and ball bump. I can briefly explain about thesde, once I show you the GUI and other parts.

I want to show you the spool also. This is the spool of gold wire, of 30 micron thickness and around 25 meter long. There is an indication for the end and where you have to start is indicated by the green color spot. This is from where you take out the wire and then start fixing it.





And you can also see a closer look of that. There is a very very thin wire, which is very difficult to identify because it's 30 micron, which is less than the diameter of a human hair.

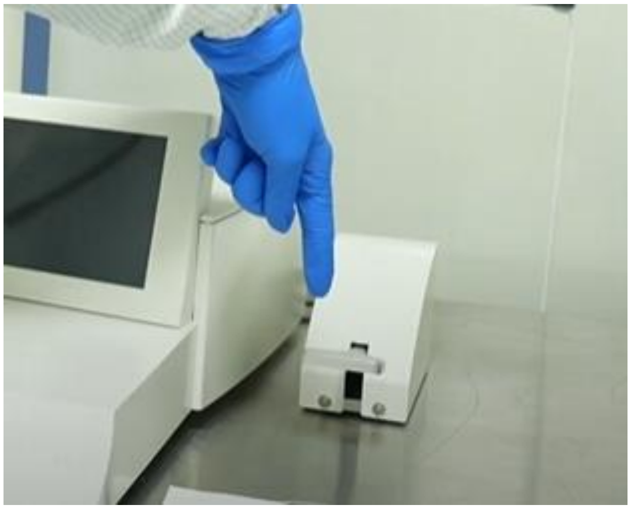


It is coming out from this port and that port is connected to the spool and that wire will directly ends up going to the capillary that I have shown you. And that's where the mechanism takes place.

So the entire setup looks like:

The zig controller and PCB holder with the PCB is in place. If I move the zig, the entire setup will move and it is also connected to the heater. I can set the temperature so that the PCB gets heated up during the gold bonding.

One can manually do the bonding as well. Now it's automatic bonding now , but one can manually as well. We can say that we don't use it or we rarely use it. Manual movement of the wire bonder tip is through this part:



I a turning on the tool now, This is from a company called TPT. So whenever the thing turns on, the height of this tool has been changed and the capillary has moved down. So make sure that there are no nothing nearby that. Otherwise you end up breaking the capillary and it is very costly, and we have to import it.

Now what are the different options available for us in the in this machine? Particularly I will explain you by exploring the GUI.

If you look at it, there is an option for height setup. What does it mean? So if I take the same example of the neural implant, you have to put one bond at the implant and the other one at the interface board. And you see there is a clear cut difference in the heights. So those two bonds are at different height levels. So the machine will calibrate what is the height bond one will takes place and what is the height bond two will takes place. So that is the reason why we need a height setup.

These are different options available. This is test USG.

So when there is a dust or something like that blocking the end of the tool, if I click on the test USG, it will give some kind of ultrasonication such that the particles will be out. Now there is some option called loop height. Now, if I can program this, then I can make it whatever I want. So this loop height is the difference in heights between bond 1 and bond 2.

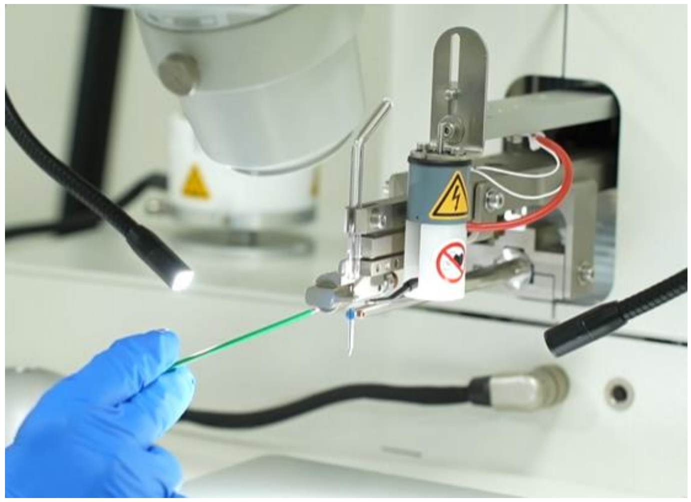
Now lets see what is the Y way option? It is the horizontal distance between the bond 1 and bond 2. After some experience with this tool, you will know what value to enter for this, based on whether the two points to be bonded are very close or very far or somewhere in the middle.

Now bond 1, you can see the US.

It's the ultrasonic power that we have to give. Here, we are giving 220 mW. The time to contact is also a parameter. It dictates the time, the tool will stay at a point, before moving out. It is set to 200 ms, and pressure is the force that you are applying. It is set to 250 mN.

Once I do the bonding, you will understand clearly from the tool that the wire will come out from the end and because of the ultrasonic power, this gets melted and now you go to the contact area and touch it and apply some force and then leave it. That's where the bonding happens. Again similar concept you can use for bond 2 settings on the right side of the screen.

Now there is an option that is, clamp close and clamp open. Now this is very important because now again if you focus on the tool you can see the clamp.

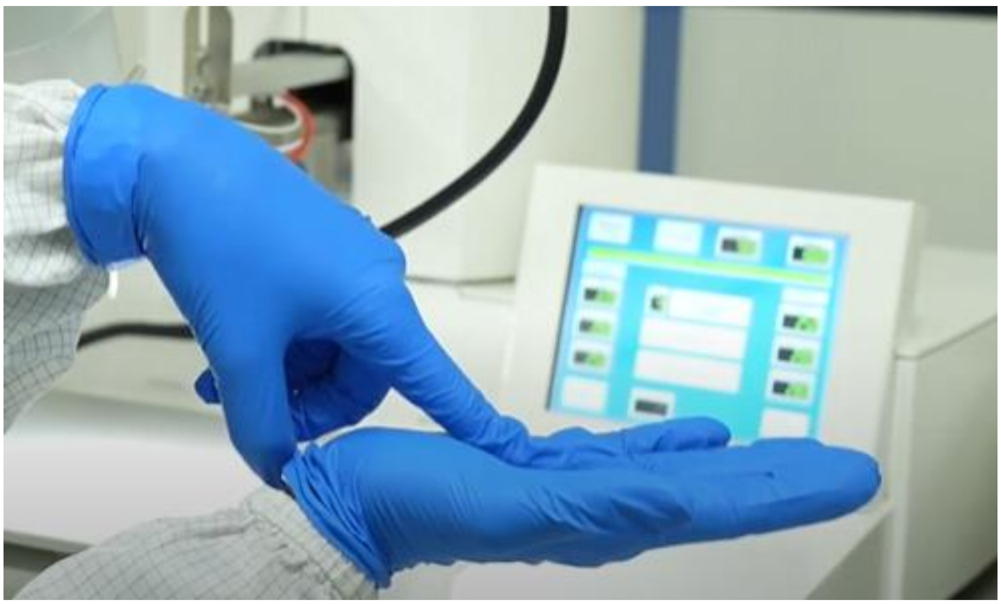


This will hold the wire so that it can move the wire up and down. So there is a time that you have to move the wire up, if there is an extra wire coming in out and there is a time that you have to move the wire down. Through this everything will happen.

Let's focus on the GUI again And there is a something called program number or program wedge, and you can see something called as wedge bonding.

Whenever you bond a surface, if you leave a ball kind of mechanism at the surface, that is called ball bonding.

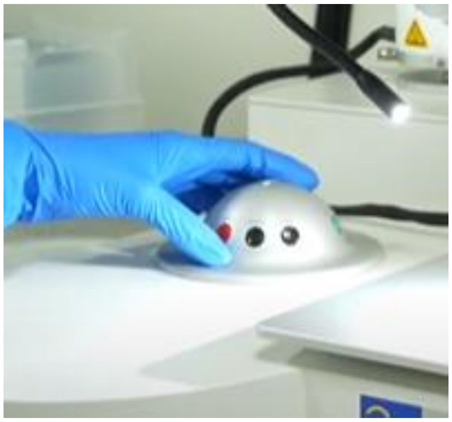
Otherwise it is called wedge bonding, which looks like:



On the GUI, we have an option for ball bonding, wedge bonding and there is something called ball bump. So, these are the three different options that we have . So, generally if you want to maintain lot of strength with the surface, then it is better to have a ball. The strength of this bond is very high compared to the normal wedge bonding.

Now, let us look at another option where you can select between semi-automatic and manual. So if you are in manual mode, you have to go with the tool towards that contact pad area step by step using this lever I showed you earlier. We don't use that anymore at all but for some applications we may use them. Then there's something called fully automatic. So once you give the location, the bond 1 bond 2 will take place on its own. So here you have to mention just the loop height and y way, In the semi-automatic mode, what happens is, it will go to the bond 1 location and stop near the bond 1. It will not bond it. It will just stop. In fully automatic bond 1 bond 2 both will happen. In semi-automatic bond, we have to literally take it to the location then you have to click for the bond 1 to take place. Then it will go to the bond 2 and then stop again. You have to click on the bond button for the bond 2 to happen.

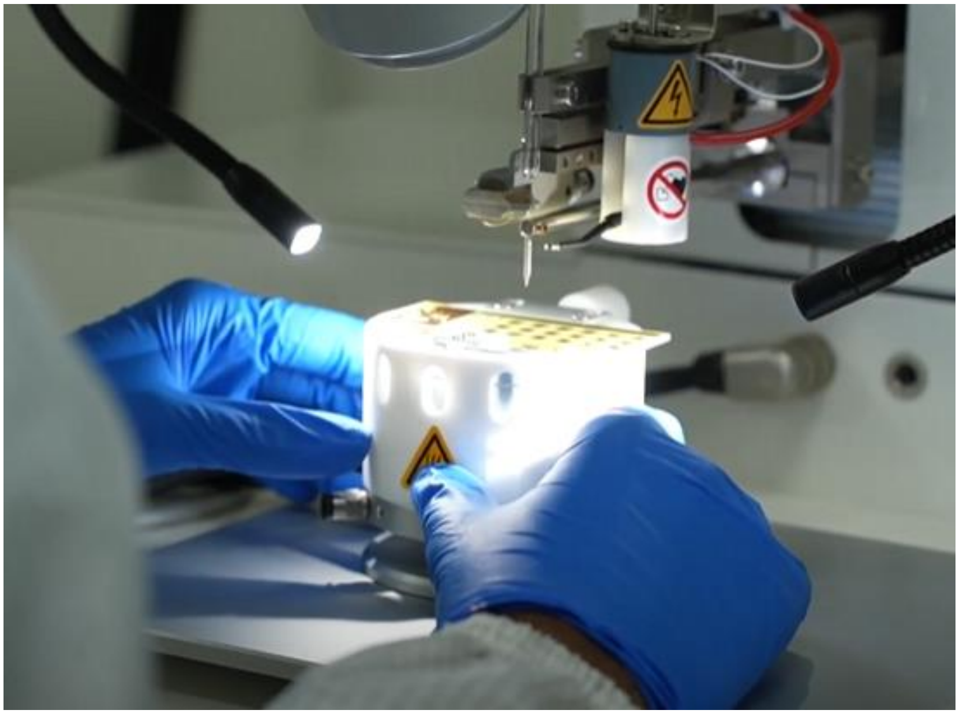
Now if I click on the height setup, it will say: “move to first bond and press bond button”. In the controller that I have shown you, there is a bond button. There are also the up button, down button, and the reset button.



Now if you want to do any bonding, you have to click on the bond. What happens is the tool will go there and stay very close to the contact pad. It will not bond. It will just stay very close. Once you release the bond button, then it will bond and then come out and then go to the next place.

If you want more wire to come down you can click on the down button, and if there is a lot of wire hanging, so you want to move it up, then you can click on the up button. Now let's say you want to reset it. Let's say the first point has not bonded properly and you have to reset the entire thing, then just click on the reset, and the tool will come back to the home positions.

Now let me take this substrate or PCB holder and fix it in place. Now what I will do according to the GUI is to move the tool to the location of the first bond and press the bond button.



what is the instruction move to first bond and press bond button. Once I do this, the tool will come down and touch the PCB surface. This is to measure the vertical distance. After this, the machine will ask to move to the second bond button, and press the bond button. This will measure the vertical height of the second bond location. Finally a “Setup Ok ”message will come on the GUI.

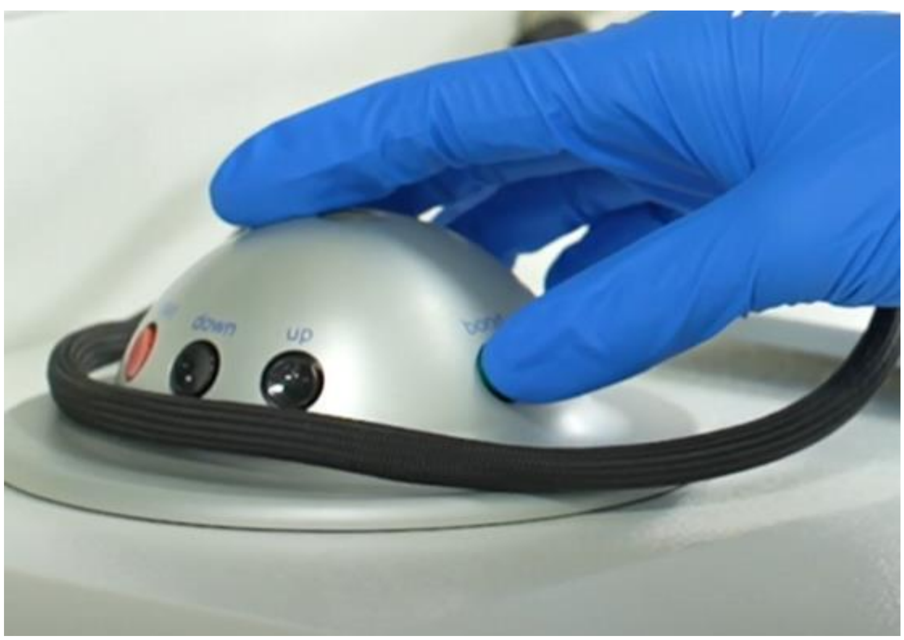
If you go to advanced settings, you can see the SH Bond1 and SH Bond 2, which are the measured vertical distances. Its 3485 and 3486, respectively here.

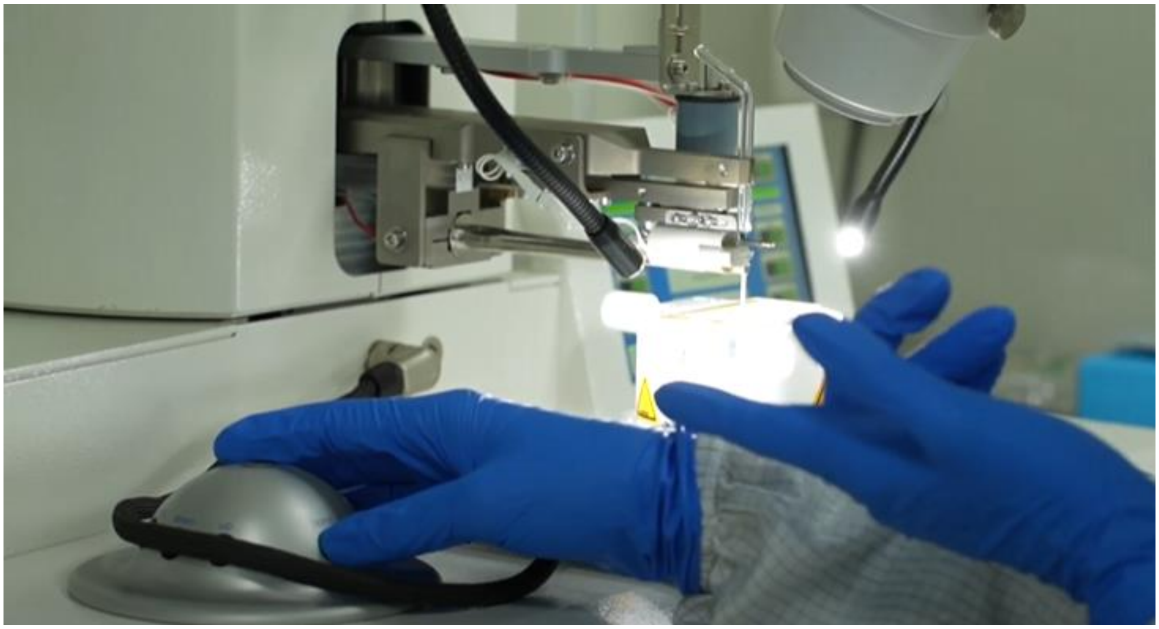
The values are very close, means that the PCB is planar. But for some other PCBs it might be at different heights. You can also see the tail step, which decides, how much the wire should come down when I press the bond button. According to this, 80 microns should come down. The tail feed dictates how much wire has to be released once bond 1 is completed, and the tool is moving to bond 2. Its set to 200 microns now. Now, once you are ok with all these parameters, you can go to the bond and start bonding.

I will first show it from the outside, and then we can focus on the eyepiece of the microscope to see how bonding is done. The PCB is fixed on to the sample holder using clamps.

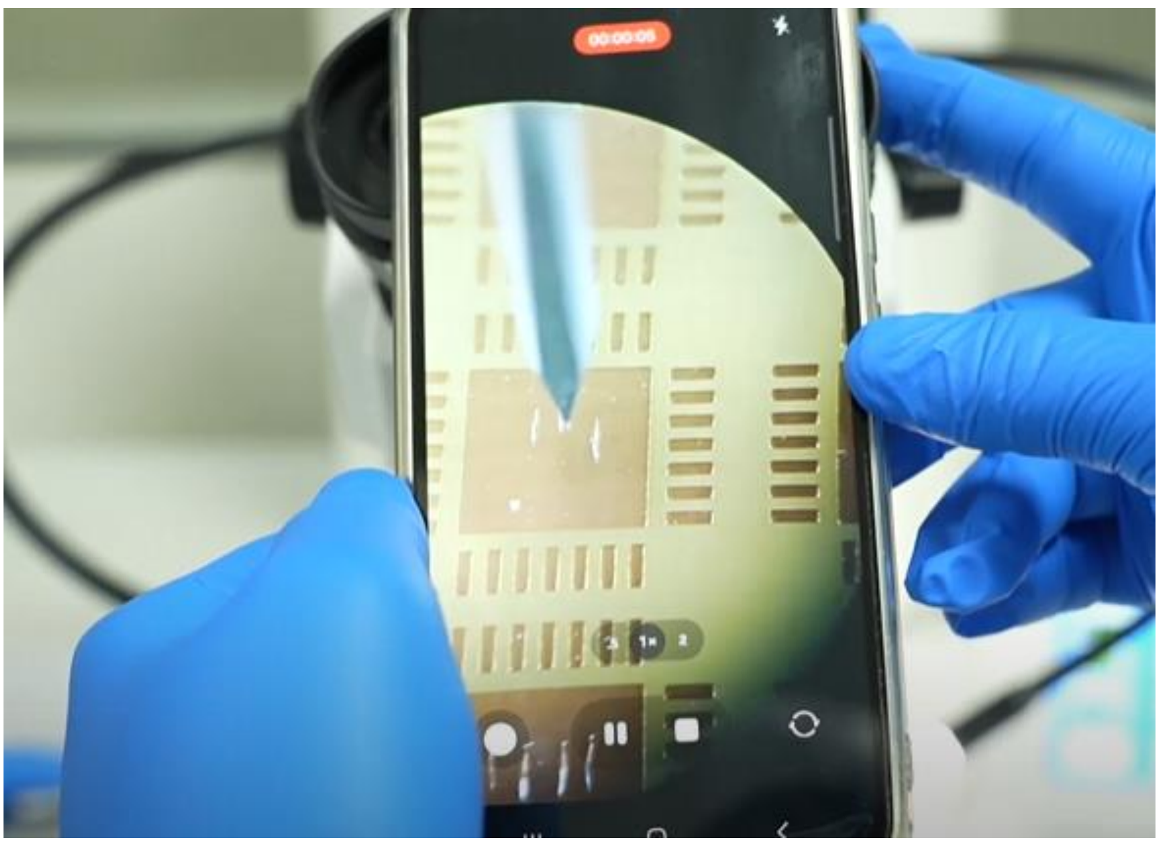
Now, I will place the sample holder in the location, I am intending for, and we have a lens to view the process and move the parts accordingly.

Now I carefully look through the eyepiece, place the tool at the appropriate location. Now I am pressing the bond button. Once I release the press, the first bond will be done.

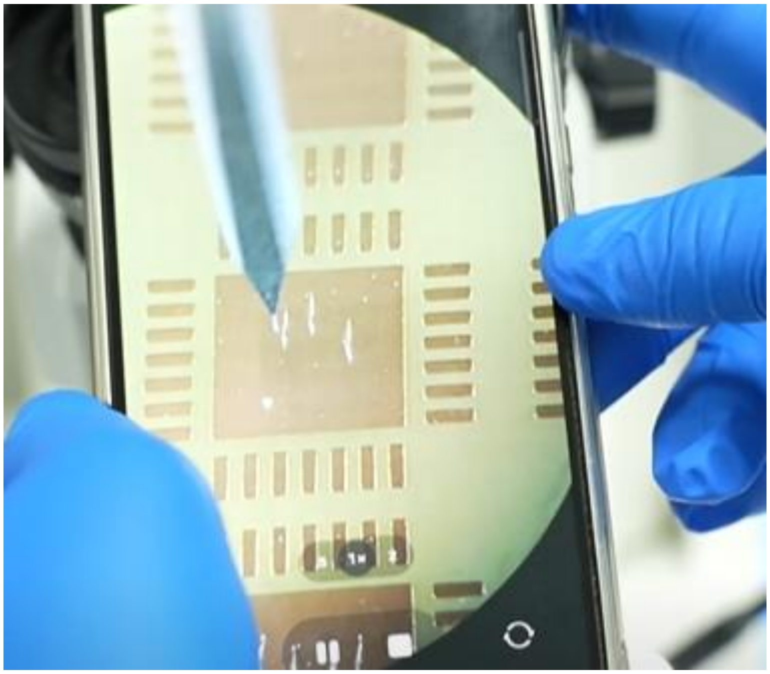




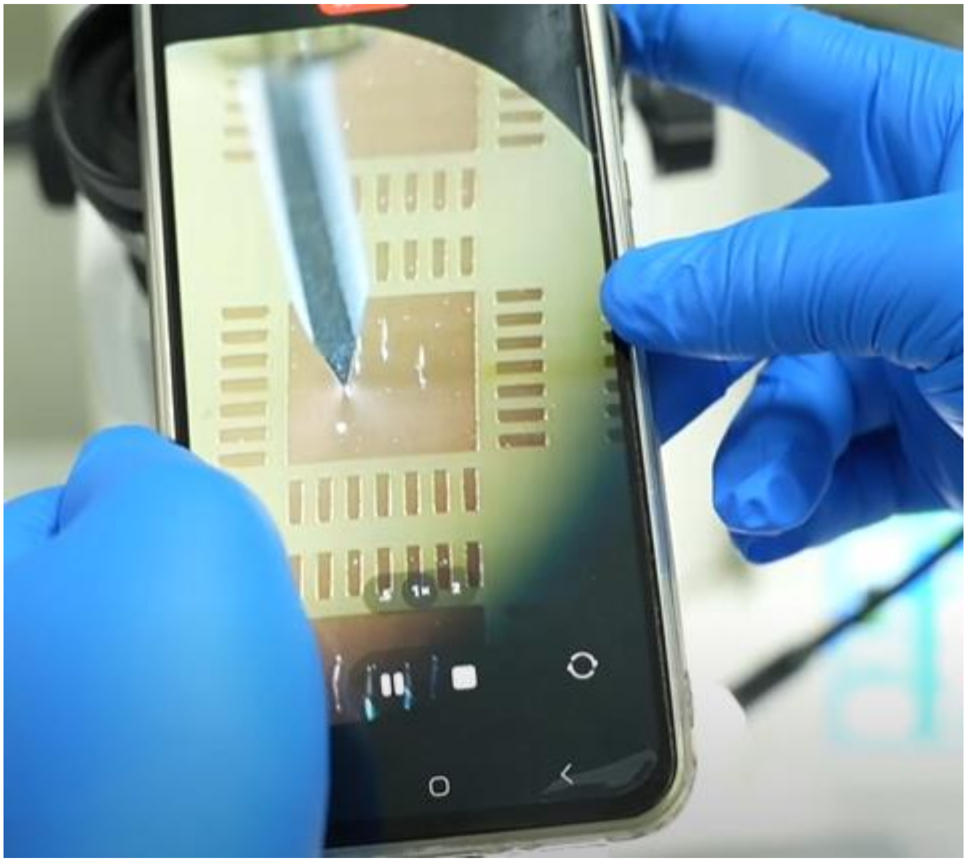
Now, let me show it through the lens.



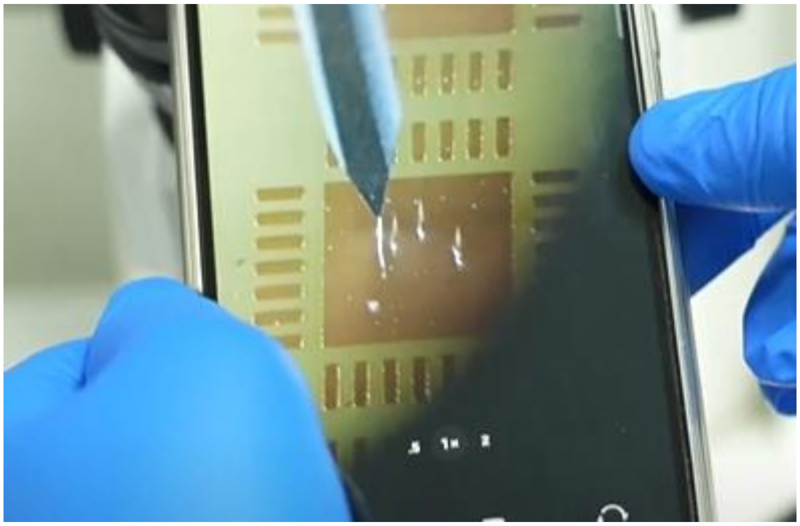
You can see that we have already formed three bonds, which is visible through the eyepiece. I am moving the tool to the desired area



Now, I am pressing on the bond, and the tool touches the surface, but bonding has not taken place.



Once, I release, the bond has taken place



Again I can press bond and release it to do the second bond.

If I now change, Y way to 500 from 1000, I can create smaller bond lengths.

So let's conclude this now. So we have seen how a wire bonding machine looks like from outside and from inside views, GUIs and different parameters like ultrasonic power, time, force, these different things. And we have also seen multiple demos on how a wire bonding looks like. But what exactly would be the application from industrial point of view? Let's say for example you have a chip that has some 10,000 contacts that has to be brought to the interface board. Like you might have seen a lot of chips in your mobile phones and all. Every chip might have some 5,000 contacts, 1,000 contacts, 500 contacts. And that has to be precisely connected to the electrode interface board or a PCB for the application. So one can use automatic wirebonder where you have to just take the image, mark where is bond 1 and bond 2, and then through algorithms, it will understand what should be the height of the bond 1, what is the height of the bond 2, what should be the height, loop height, what should be the y-way etc. It will only analyze the optimum parameters and it will start bonding. So the machine can do almost 60 to 120 bonds per minute. That's what is required in industry, less interference from the workforce. In semi-automatic wire bonder, we have seen already that it will go there stand there and the bond will take place once you release the bond button. In manual mode, everything has to be done manually, which can be used for some very specific applications. But it may not be effective. You can think about how many bonds it can do in a minute.

So that's all about the wire bonder. I hope you enjoyed this session. See you soon with other content. Thank you.