Fabrication Techniques for Mems-based Sensors: Clinical Perspective

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Lecture – 52
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Welcome. Today we will see an interesting equipment that can form an integral part of a lab that deals with translational research. So, what do you mean by translational research? A translation research is that research which the outcomes of your research work finally gets converted or translated as the word means into a final product that can go into the market and help people and have a societal impact. So, that is basically translational research. So, when you are doing translation research, you need to look at your research from the point of view of product development.

So, even though you will be looking at fabricating sensors as this course has taught you and characterizing them and testing them with different types of samples, you should have a bigger picture of what you are trying to do. In the sense your sensor cannot work stand alone. It has to go into some kind of packaging and the packaged sensor would finally end up as an individual product or would form a part of a system of products. So, in order for you to realise this end product which you imagine in your mind, you need to be able to do something called prototyping.

So, what is prototyping? You integrate your sensers or your macro level components of your system that you have designed and you integrate that in a packaging that is ergonomically designed for ease of use and for in environmental friendly operations and several other criterion that are set out for products for this an important. So, what we have looked at it? We told that we will have sensors, we will be fabricating sensors, we will be characterizing them, we will be doing lot of experiments to test their response, then we will look at how we can make the sensors as a product that that can have a societal impact in the population and it can enter the market or in the actual field, clinical field because we are looking at clinical applications here.

So, before we make a product, we have to prototype the product. So, prototype is the first working, fully functionally working version of your final product. So, your final product

would be the one that is sold, but your prototype need not be sold, but your prototype would meet the specifications of your final product with almost 100 percent and near to 100 percent faithfulness. So, to prototype such products that integrates your sensors an important equipment that is very versatile and useful to have in a lab environment is something called the 3D printer. So, you know you all know about printing. It has been around since you were born I guess.

Most of you are looking at, watching this lecture would know that it is around since the time you were born. So, printing what does it do? You put a paper and you will have some source file that you want to be seen as a hard copy. So, your source file will be a soft copy and you will print whatever is written on your soft copy, on a sheet of paper of varying sizes like 3A 4A 2A, one different size of papers are there using different technologies like inkjet printing, laser printing, dot matrix printing. So, different technologies are there, but at the end of it what do you get is, whatever you are trying to convert from soft to hard version, you will get it printed on a 2D material that basically your A4 sheet.

The thickness the, A4 sheet also has some thickness, but that thickness is negligible compared to the other dimensions of the sheet in this. So, in effectively rendering your printing as 2D printing, so you print it on an A4 sheet. So, basically what is 2D printing? In the last couple of decades we have seen of new technologies that has been mind blowing to say the least and one of the major technologies that have entered the market is what do you call 3D printing. So, as you have seen you are seen 2D printing.

So, if you can print these 2D layers on top of each other, stack them, you will effectively get, what you will effectively get another dimension which is the height and you can actually make 3ad printed sub 3D printed versions. So, when you print at some something in 3D, you are actually making some material or what do you call a form, you will get a form that you can look and feel and feel the depth, length, breadth everything. So, for you to print such 3D version of your design if you call you need, you cannot do it on ink because ink cannot form layers, multiple layers.

So, for that you use specific other materials which we will be introducing shortly. So, that is the overall essence of 3D printing. So, if this 3D printing we will be able to make quickly, quickly prototype that is the main thing here. Quickly you can whatever you are

thinking in your mind whatever you are conceptualizing in your mind, you can quickly make a design and get it visualised and printed out to see how it can look at, how it will look when it is made us final product.

So, for rapid prototyping it is also called rapid prototyping; for rapid prototyping use 3D printer. So, the 3D printing is part of a class of technology is called additive manufacturing. So, what is additive manufacturing? It is basically you are adding slowly one layer over another to manufacture something that you conventionally manufacture using other methods like conventional moulding, injection moulding and making a mask and then, pouring molten material and making it from those are conventional methods.

Instead of making the conventional, following conventional methods, you use something called additive manufacturing. So, what you do each 2D sheet is stacked on top of each other, multiple designed components in your overall design are added on to each other through this stacking. Finally, you get the 3D printed version of your design. So, that is additive manufacturing. 3D printing is also or some other times called additive manufacturing and these words are used interchangeably. So, there are different versions or technologies in use for 3D printing.

So, today we will be showing one technology where we take the material, we melt the material at the point of injection where it is deposited, we melt it and then, that it will immediately dry solidifies and forms the 2D layer. There is another method where you have your material is in liquid form in a place and then, you develop the material. So, what happens we would by meaning developing you mean when the material develops, it becomes solidified. So, you develop a material by using some photo, illumination by illuminating some specific light of wavelength like UV wavelength or IR wavelength. You illuminate the liquid which is the material and wherever depending on whether it is a bright mask process or a dark mask process, wherever the light falls, the material gets developed and it solidifies and the remaining part remains liquid. So, you can take the 3D printed product out. So, that is another technology. So, there are like this there are many other 3D printing technologies.

Today we will show you the first technology which is you have the material that comes into your 3D printer, it is melted at the point where it is deposited and then, it is deposited as 2D layer it solidifies and then, it is stacked on top of each other to form the

3D printed version of your design. So, without further delay let us look at the actual 3D printed we have in the lab.

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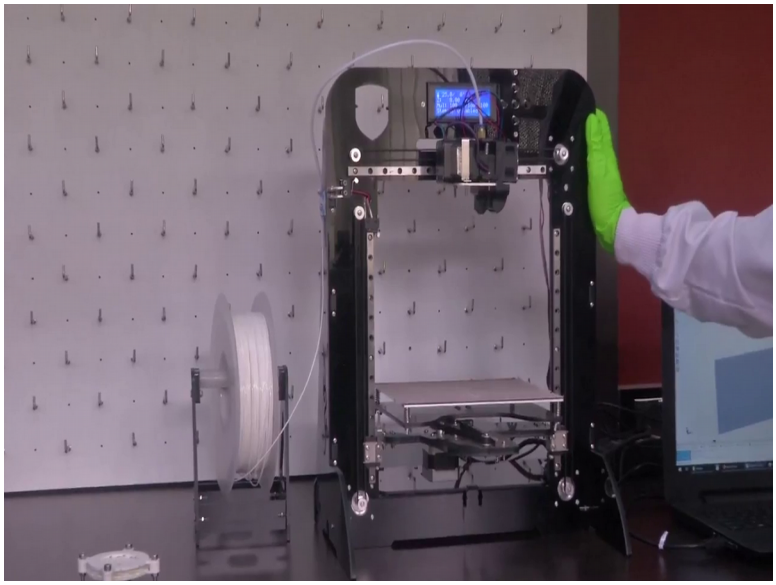

So, this is the 3D printer we have. It is a very simple and cost effective version 3D printer that serves the purpose for us in this laboratory too quickly prototype whatever design we want. If we if you remember correctly in our session on micromanipulators, we had useda 3D printef indenter, a white colour pencil like structure which we have attached to the probes of the micromanipulator and we had screwed it to see how it will intend. So, that intender was printed using this very same 3D printer. So, now let us quickly look at what are the different components of this 3D printer.

So, to start of you have the platform. This red colour surface you see, this is a platform whatever the design you have made will get printed, ok. So, because your design will span the x y x y and z directions, you need motors to control your material deposition. So, your material the material that we have used here is called PLA called poly lactic acid. So, it is a white colour here. You can see the material. The material is rolled up on there. There is what you call liver that can hold a material in place. So, the material is like a wire here. It goes into this extruder. So, this pipe takes it into this extruder here.

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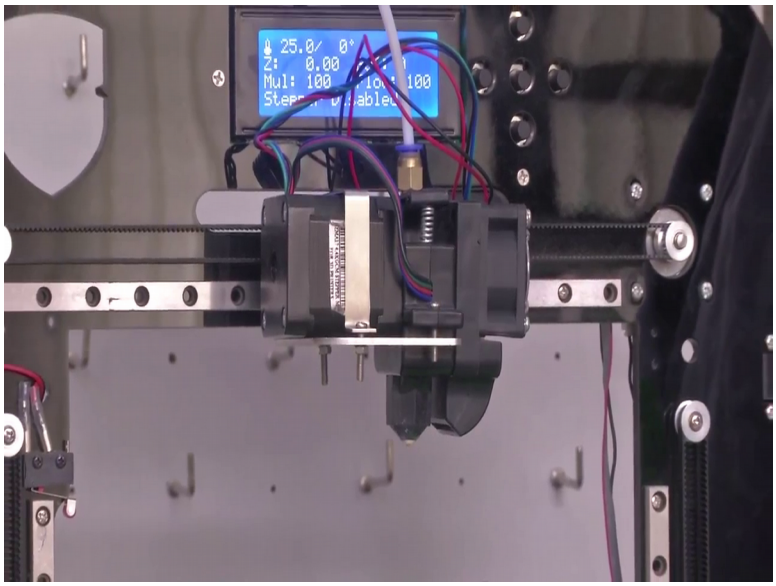

So, it is clear that the material, this polylactic acid will melt and gets deposited. When we will quickly will show you one design, real time printing of one design, then you will understand what is happening. So, the material melts and it gets extruded from this tip and gets deposited here, ok. So, for that for that extrusion process, you need one motor that is here and then, for other x y and z movements, there are individual motors. So, for y movement, there is a motor here below. You might not be able to see. It is there below. There is a motor here, then for x movement there is the motor behind here, and then, for z movement there are two motors behind here.

These are change to do the x y staging x y movements. So, these are basic components of the translation mechanism of the 3D printer. So, you have a small display to show you how much percentage of the printing is remaining. So, if you can see this blue colour display, if you see this blue colour display, this will show once we start printing you can see how much percentage of the design is pending and how much is done.

Now, how do we load the design and how do we make a design? So, usually the designs are made in CAD using CAD softwares like proe, solid works etcetera. So, those CAD files are then converted into another format called STL. STL stands for Stereo Lithography. So, this is a version of stereo lithography. Actually the stereo lithography dot STL file is then converted to something that this machine can understand. So, that is

called G code. That version is called G code. So, that G code file can either be sent through USB cable. So, we have will we have the laptop here, right.

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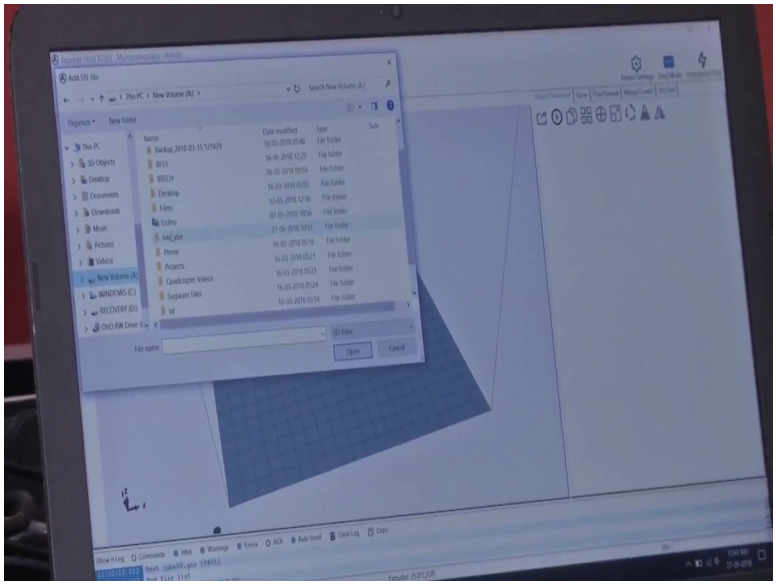

So, we have one software open here that is for controlling the final printing of the 3D printed version. So, the G code file you can send instructions that is that are contained the machine level instructions that are contained in the G code file. You can send it via USB cable here where it is connected to the back side of the 3D printer or you can copy your design in SD card and insert it into the 3D printer and it will start reading from the SD card and it will start printing. Hope till now it is very clear to you.

Now, let us see what are you trying to do. So, let us print something here. So, you have you all remember the intender that we tried to be that we showed you in the session on micro manipulators. You will again print that intender here and show you how quickly it gets printed and see how much time it takes for to get printed. We can see real time when it gets printed. So, let us get started with that we have one more member of our lab here to help us with this. So, we have the software will be in putting the design. So, we will be adding the design. So, you can look at the computer monitor. So, it is called micromanipulator intender. So, this is the design.

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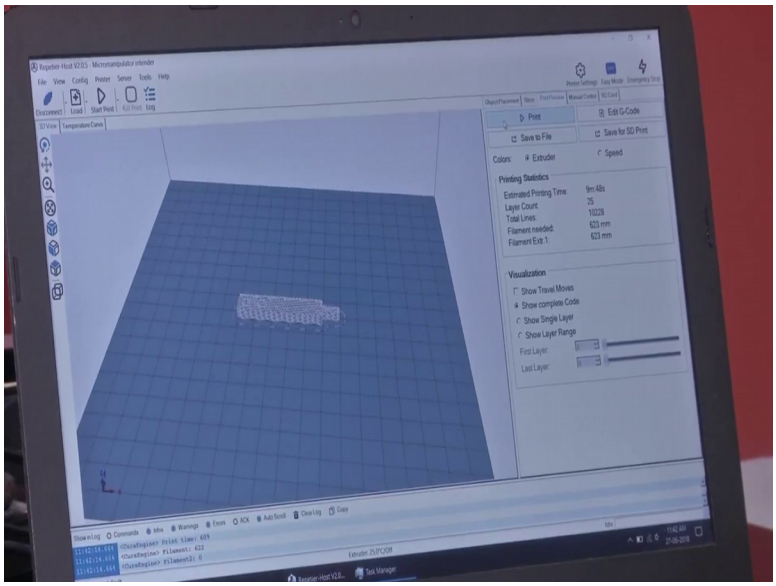

So, that is a design. He can he is rotating in all axis to show you all the design. So, this is the design that will be printed on the platform, the grid like structure that you are seeing is in fact your platforms dimensions. So, your structure will get printed on the platform of the 3D printer now this. So, he can control the printing from the software because it is connected through USB to the 3D printer. So, he will start it now. So, you can see that there is a print option there. He has made layers of the design here. Now, he is going to give print option. So, before he starts printing, he has to just over see the first levels of printing. So, if you see the 3D printer, a stage is moving up.

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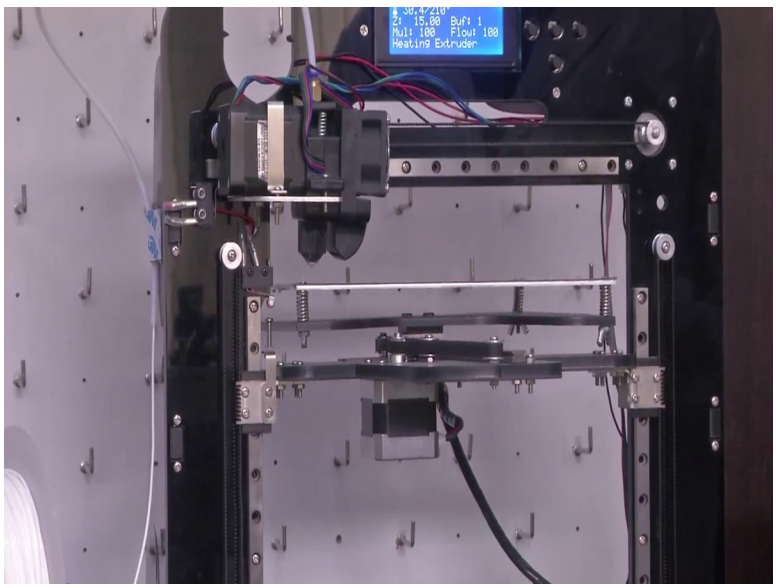

To start off with the printing, so what happens is the printer will go to its home state or zero state where x equal to y equal to z equal to 0. And then, align itself before it starts printing. So, it takes little bit of a time to start. Let us just see it.

So, now what is happening is the software is reading the file, the G code file see it and trying to predict what all it has to print and where all it needs to do the post corrections in the printing process. So, that that process you are seeing here extruder is trying to like the progress is happening. It is heating the material and the temperature progression you can see in the software here.

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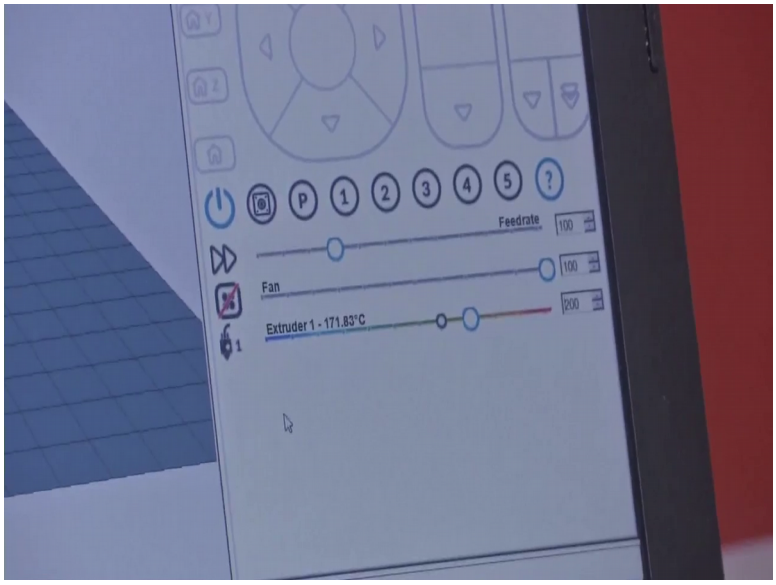

So, once it reaches the target point, it will start. So, now let us look at the 3D printer. So, you can see the material is melting and coming out from the tip if you can see this, so the material is melting.

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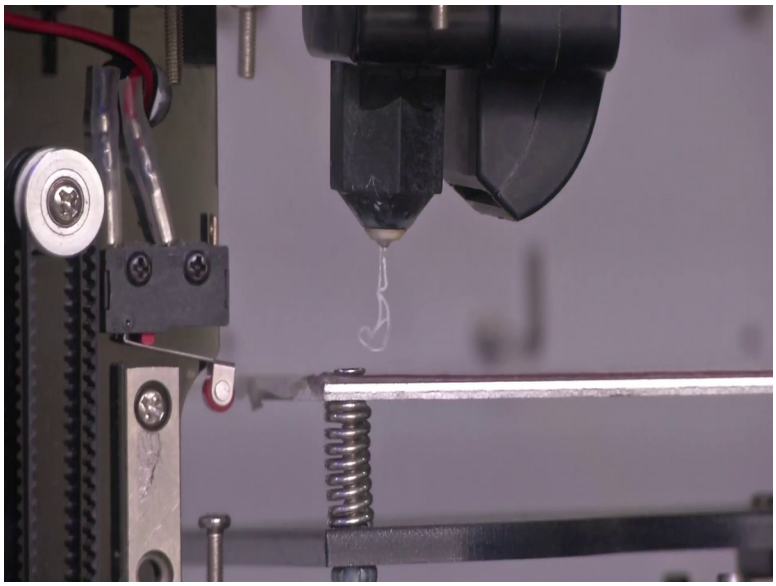

So, it is testing out how if the material is coming out properly. So, once it is melting that it is coming out properly, it is starting the print.

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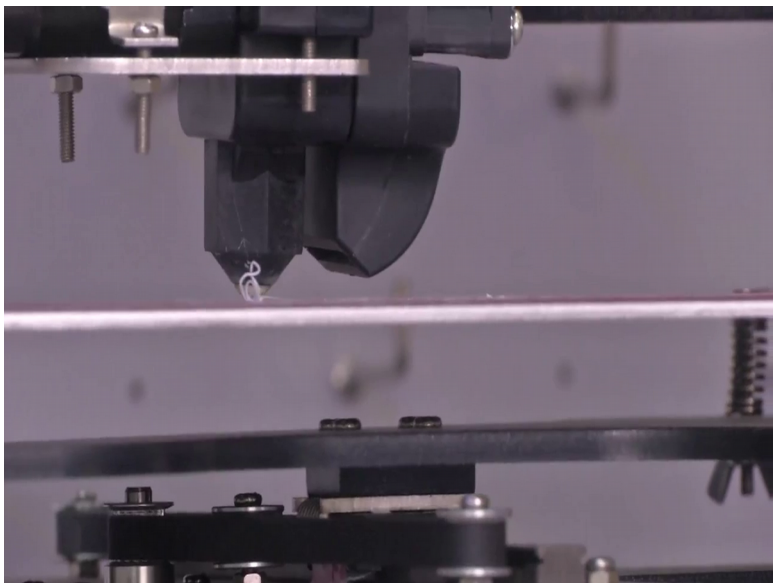

So, he will inspect it whether it is starting out properly and slowly the outside pattern is getting formed. So, he will just check it if everything is fine and then, lock the platform.

So, the extruder is now depositing material slowly. So, it will take some time. As per the predictions, it will take around 10 minutes, 10 to 15 minutes for to get printed. Let us wait and watch. We will also try to have a closer look at this, yes.

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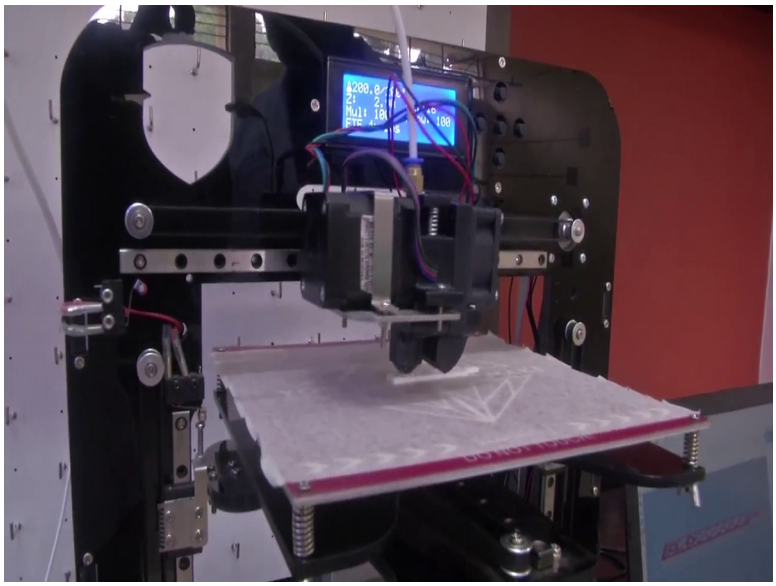

So, the first layer base layer is formed. You can see that pattern getting formed here. So, you can see that it is trying to print it with maximum precision as much as possible. So, it if you see the display, you can see that estimated time remaining is around 7 minutes 39 seconds.

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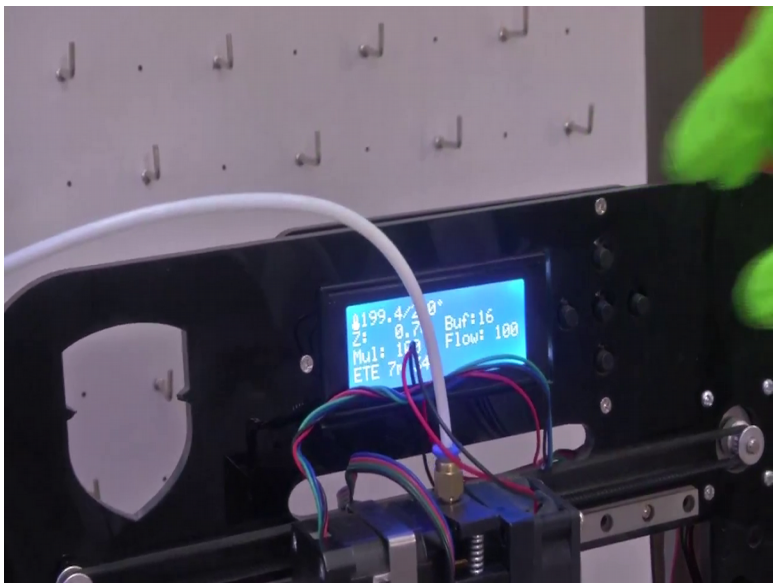

Can see it here, and then, this shows how much percentage is remaining. So, how much percentage is completed? So, we will see. So, there is another display option that shows how much percentage is completed. Either you can see as percentage completion or you

can see as estimated time. So, now we are seeing it in estimated time. So, now we are just focusing on the printing mechanism. So, let us see. Quickly see the computer monitor once before we come back to this process.

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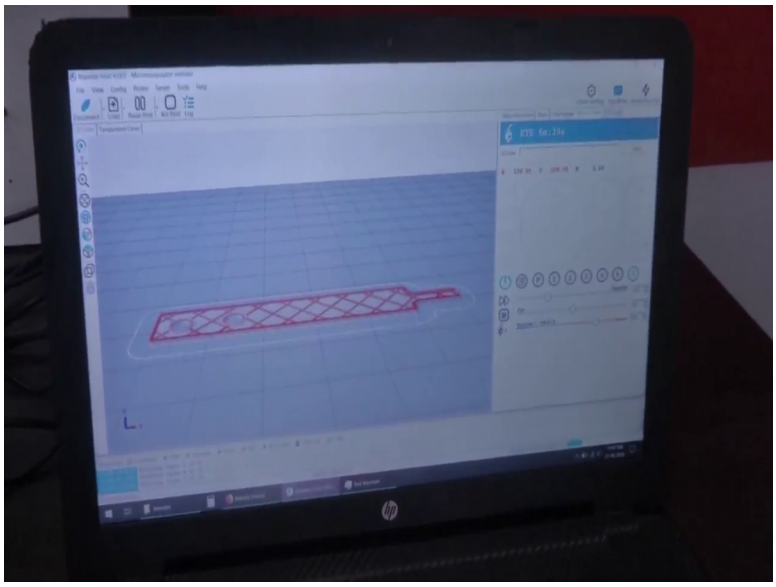

So, if you see the monitor, you can see a real time update of what is getting printed being covered on the software. Also you can see whatever patterns the extruder is making, that is get coming as a red marks on the software. So, this is very interesting. So, you can know real time how your printing is progressing and how each layer is getting formed. So, this is a software with which you have to control the printing. So, this is not the software in which you make the design. You make the design using conventional CAD softwares like solid works, pro etcetera and then, you have to convert it as I have mentioned to STL files. Then, the STL files have to be again converted to something that this machine can understand. This is a machine code. It is same as what you do assembly programming in microprocessors, but here the machine is different.

So, the code will also be different. The code will fundamentally consists of what are the x y coordinates that have to be deposited and then, where all the total has to deposit material, how best it can deposit the inner structure. So, if you see the outer structure is coming properly, but inner one is not actually solid material. It is forming messieurs like this. So, this way it actually save little bit of material. So, long as you do not want that much rigidity, if this is prototyping right, you just want to see how your product will

look like. So, you can have a support structure inside, but need not fill everything with material. So, these well are there, they may not be filled with material, but outer structure will look smooth. This way you can save some material.

So, these material there are 3D printing materials of varying cost. So, this role that we showed you that is around 2000 rupees per role, but there are materials that cost even 2 lakh per role. So, they have their different properties. When they get printed, the smoothness of the surface, the shine, the colour options that are given for a material, everything varies.

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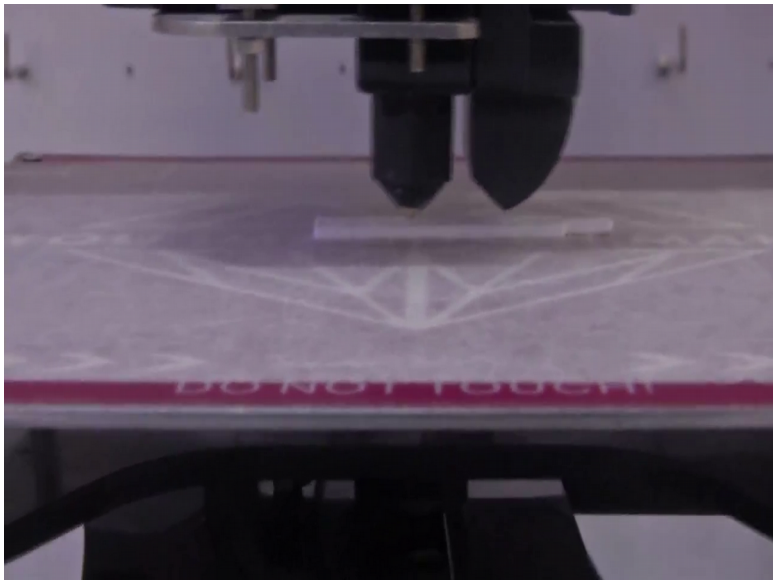

So, now let us look at how the printing is progressing. So, you can see that the intender is slowly getting formed and the estimated time is around 4 minutes, now 5 minutes, 4 minutes 58 seconds. So, in another 5 minutes, this printing will get over.

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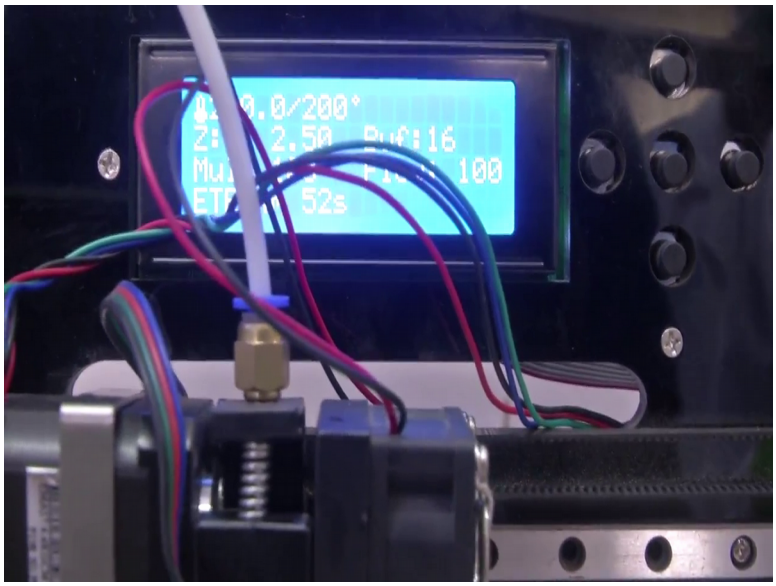

So, you can see it here 4 minutes 47 seconds is remaining. So, the extruder is printing very fast. So, this is this is a 3D printer that we have assembled in the lab. Actually we have procured the individual components of the 3D printer and the enthusiastic members of our lab actually assemble the 3D printer together because of which we were able to make it work in much cheaper cost, even one-tenth or one-fiftieth of the actual cost of 3D printers that are available. So, it is getting printed.

We now in order we came close to the machine now because it has formed enough will be able to see it from far also on the platform. So, we will wait for it to finish. It is looking like white. So, the material, you have seen that the material is getting deposited at white colour. So, you have other colour options also like grey, black, blue and they have different price ranges. So, in case you want to make whatever 3D printed prototype that you make, they may not be of a single part. You might have to fabricate different-different parts and then, assemble them together. Once this is over, we will also show you another pattern that we have made in the lab to make you understand that you can make working prototypes using multiple 3D printed parts.

So, if you are having you are someone who has an aesthetic tendency and you want to have different colours in your product, even actually print get your multiple products printed using material of different colours like you can use black and white, blue and white and all to make your product look much more like a product and much less like a

prototype. So, it is getting printed, but one problem is that preferably you will use the same technology right to print the multiple parts of your design. So, you might have to use the same material for all your individual parts.

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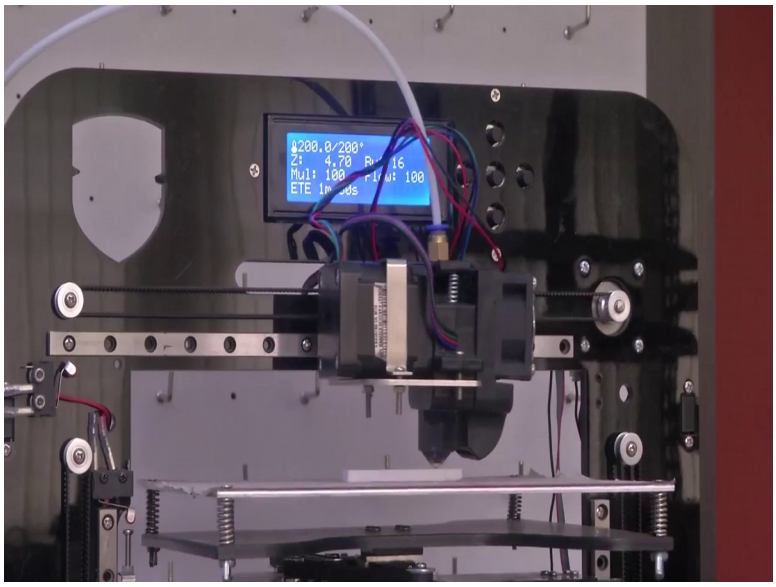

You can also go ahead by printing integrating different materials, but you would need those different types of 3D printers. So, only cost would be a consideration there, but if you want to just get it done and see how it looks like, this is more than enough. So, in another two and a half minutes this printing will get over. So, I have told you that.

So, our sensors are very delicate materials as you would have understood during the course of this course and they are very fragile, brittle and all and they need to be handled very carefully. So, the packaging of sensors that we have seen till now is very important. So, once they are packaged as I have told, they have to be took nicely enclosed and they have to be introduced to any potential customer in the most aesthetic manner.

So, for that 3D printer is very much important in any lab and labs in India are slowly gaining, they are trying to understand the importance of having 3D printers within their lab spheres which is a good thing. So, now we can see that almost the structure is formed nicely, same intender which we show saw micromanipulator is here. So, in another 2 minutes, it will get over. So, once it gets over, you should observe. So, immediately once you gets over the extruder, goes up the platform, not extruder goes up, extruder stays there. A platform immediately drops down like a fall. Then, you will know that your

printing is completed. So, because ours is not a very high end 3D printer, it is very important that we need to have a continuous power supply. In case supply goes while it is getting printed, it does not have memory to restart printing. So, that is one short coming. So, higher grade printers have that option. So, it is better that you have a backup power supply for these printers. So, when it is about to get finished, we will focus back again on the printer and you will see the platform dropping down. So, that is a thing.

So, I hope this video showed you how important the 3D printing is and their versatility and utility of having such an equipment within your lab space. This I think it is going to get over. Let us just see it. The printing is about to get over. Now, it is around forty seconds away. So, you can see that its as nicely form like milky bar [laughter] white colour. So, it is about to end. Just let us just wait and watch now. I will not speak now. So, as soon as it is over, the platform will drop down and the control system in the printer make sure that always the material gets melted at 200 degree Celsius around and gets deposited. So, those are all control system details. So, it is about end in 8 seconds, it will get over. It is doing the finely finishing touches if you see the outer surface. Now, it has made it smooth all out surface inside. When you had seen, it was all messy.

Now, that mess structure is not there on the outer surface. So, it has fallen down. The printing has ended. You can see that the structure is formed nicely on here. Now, it is stuck to the platform. Now, we have to remove it. So, let us see how he removes it.

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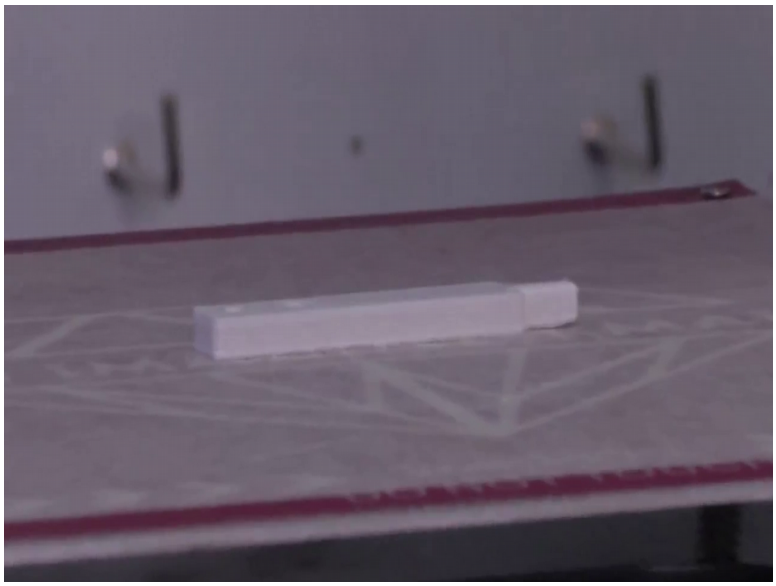

So, it is removed. So, this is how this is our final 3D printer intender. This is the same intender that we saw with our micromanipulator. Clear nice, right? In under 10 minutes, it got printed.

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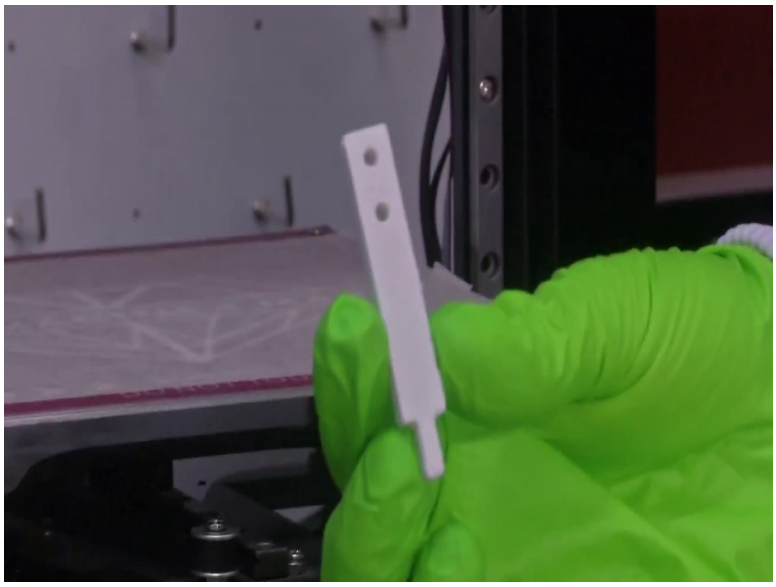

We have something solid in our hands which we can use. It is very solid. Nothing will happen to a reasonable extend. It is very strong. So, you can handle it with good roughness. So, let us see one more thing that we have printed here.

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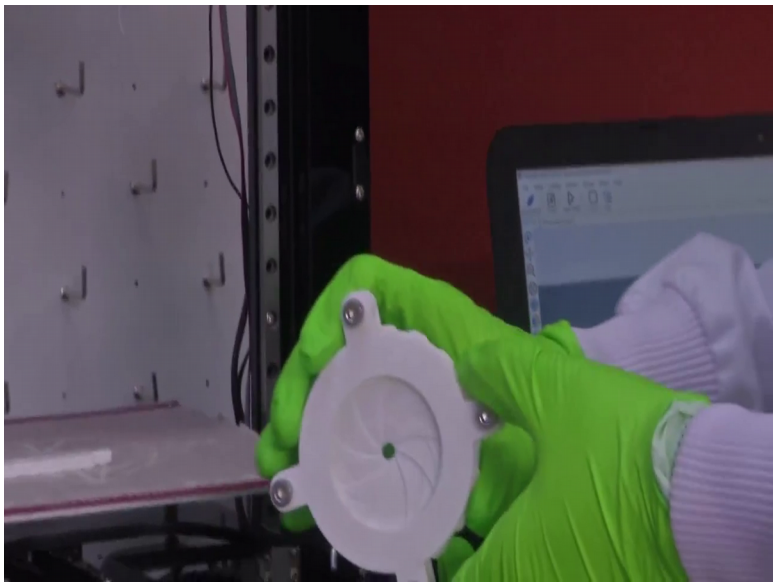

I was telling you that we can use multiple parts, right multiple parts to make a 3D printed system. So, this is like the mixture mechanical aperture. So, you might have seen similar mechanisms in camera lenses. So, if you rotate it, here will open up; if you do this, it will close up, ok. So, this let us see how many parts are there. In this top part, there top circle there is one part. Same way there is a bottom part, 2nd part, then there is this controlling lever mechanism here which I am rotating that is a 3d part and there are leaves here inside. If you see closely, there are leaves there are 9 leaves which have been printed separately.

So, total 9 plus 3, there are 12 separate parts that are printed on 3D printer and the integrated put properly aligned and then, attached with screws to make a final working prototype of a mechanical aperture. See this is what happens. So, we have seen how 3D printing is done basically. So, what I was talking to you was this is a course on fabrication, right.

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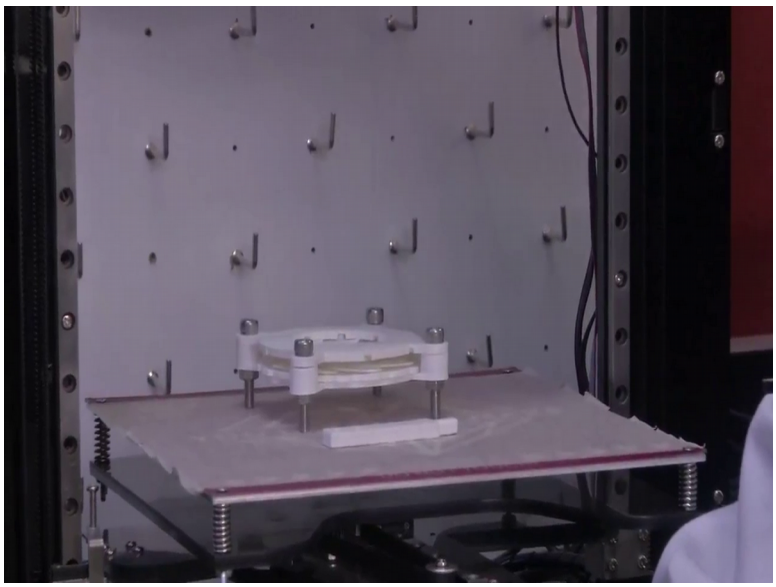

So, in during the course of this during the journey of this course, we have seen the micro fabrication techniques, but if you look at it, this is also fabrication, but this is not micro fabrication. This is you can say this is macro fabrication, where fabricating stuff physically if we you can substance that you can physically feel just like your micro fabricated sensors. So, introducing you to this technology, many of you might be already exposed to this, but we wanted to show you how it is exactly printing it. Introducing you

to this technology will give you a holistic idea of macro fabrication and fabrication need not necessarily be micro fabrication, but that is the focus area of our course, but fabrication is a very general term. You can always have macrofabricated components that will be your microfabricated sensors.

So, we hope that this video will make you think every time you make a system, every time you make a system or if you make a very small sensor also, you should always look at how your sensor can go to your society as final products which way can actually use. So, preferably not always it is not possible all the time that we have to accept, but whenever possible or as much as possible you should make sure that your design is translational. And whatever research you are doing has final end value to the society and you can make the world little bit more a better place to live.

Thank you.