Introductory Neuroscience & Neuro-Instrumentation
Indian Institute of Sciences, Bangalore
Lecture: 21
3D Printing Applications and Demonstrations

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What are the advantages of 3D printing or additive manufacturing over traditional techniques? The first advantage would be speed because it is fast production. That means from prototype to final products the design can be developed quickly. The second, the other point in the speed enables prototype making in few hours compared to large time, few days to few months. It is easily accessible and easy to learn.

I, we will show you the videos, video that we have made of how you can use 3D printing. So you will understand it is extremely easy to operate. A complex design can be uploaded from a CAD model and printed in a few hours. It is a single-step process. Once you print it, you have to just, you do not have to do multiple processes, you just wait till printing is complete, it is a single-step process.

It is cost-effective, really low cost compared to the existing traditional techniques. We can, we can create several designs, we can test it quickly and is a less waste production. There are several advantages. Now let us see how 3D printing we can use in the laboratory, I will play the video and we will end the module at that particular point. Let me play the video.

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Narrator: Today, we will see interesting equipment that can form an integral part of a lab that deals with translational research. So what do you mean by translational research? Translational research is that research in which, the outcomes of your research work finely 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 translational research. So when you are doing translational 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 standalone, it has to go into some kind of packaging and that package sensor would finally end up as an individual product or would form a part of a system of products.

So for you to realize this end product that you imagine in your mind, you need to be able to do something called prototyping. So what is prototyping? You integrate your sensors 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, and then friendly operations and several other criteria that are set out for products.

For this, an important, so what, what we have looked at? We told that we will have sensors, we will be fabricating sensors, we will be characterizing them. We will be doing a lot of

experiments to test their response. Then we will look at how we can make these sensors as a product that can have a societal impact on 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, near to 100 percent faithfulness.

So to prototype such products that integrate your sensors 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 are born. So printing, what does it do?

You put the 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 A3, A4, A2, A1, different sizes 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? Whatever you are trying to convert from soft to hard version, you will get it printed on a 2D material.

That 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, ineffectively rendering your printing as a 2D printing. So you print it on an A4 sheet. So basically, that is 2D printing. In the last couple of decades, we have seen a surge of mind-blowing new technologies, to say the least. And one of the major technologies that have entered the market is what you call 3D printing.

So as you have seen, you have 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 make 3D printed (sub), 3D printed versions. So when you print something in 3D, you are making some material or what 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 a 3D version of your design if you call, you need it, you cannot do it on ink because the 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 with 3D printing, we will be able to make a quick 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 visualized and printed out to see how it can look, how it will look when it is made as a final product.

So for rapid prototyping, it is also called rapid prototyping, for rapid prototyping you use a 3D printer. So the 3D printing is part of a class of technologies called additive manufacturing. So what is additive manufacturing? It is you are adding (slowly) 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 form, those are conventional methods.

Instead of making that 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 design components in your overall design are added 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 called 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 liquid immediately solidifies and forms a 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 happened? By meaning developing you mean when the material develops it becomes solidified. So, you develop the material by using some photo illumination, by illuminating some specific light of wavelengths like UV wavelength or IR wavelength. You illuminate the liquid which is the material and wherever the, depending on whether it is a bright (mask), bright mask process or a dark mask process wherever the light falls the material gets developed and it solidifies and the remaining part remains the 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 once it is deposited as a 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 audio let us look at the actual 3D printer we have in the lab.

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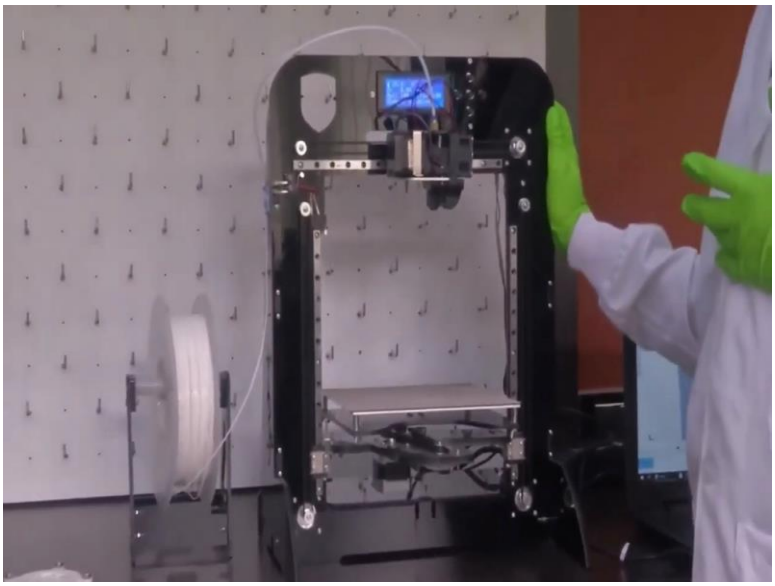

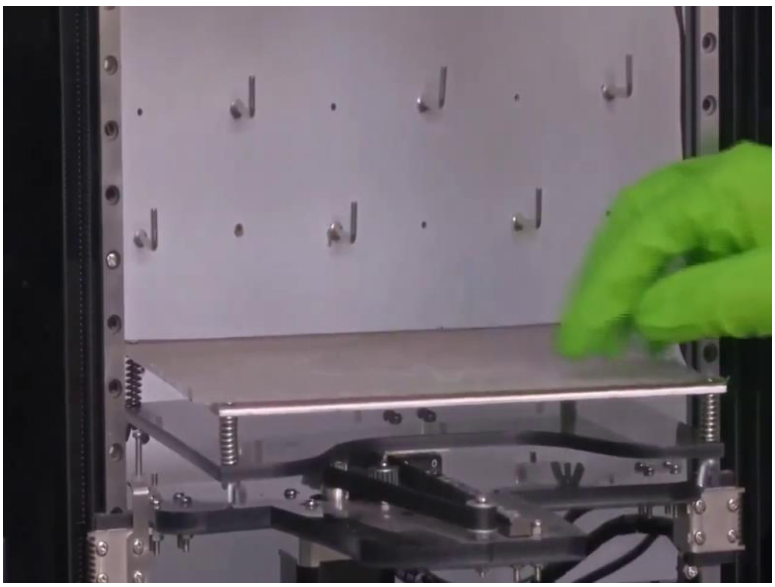

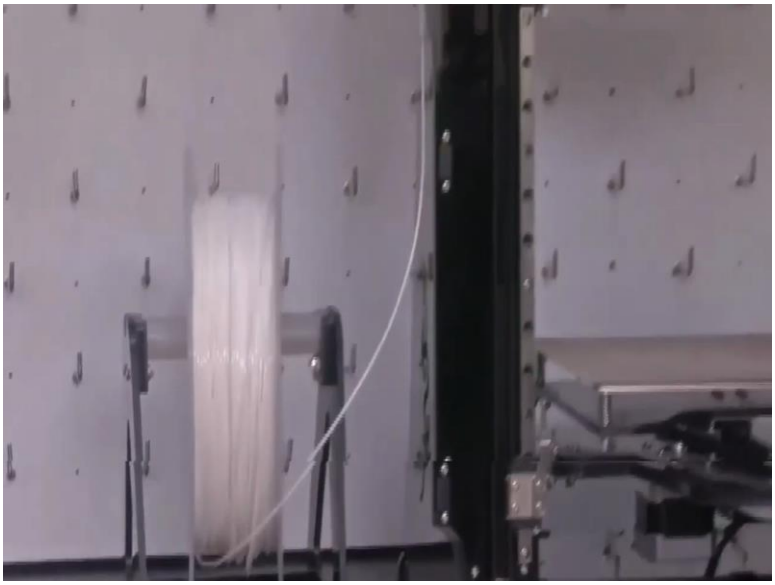

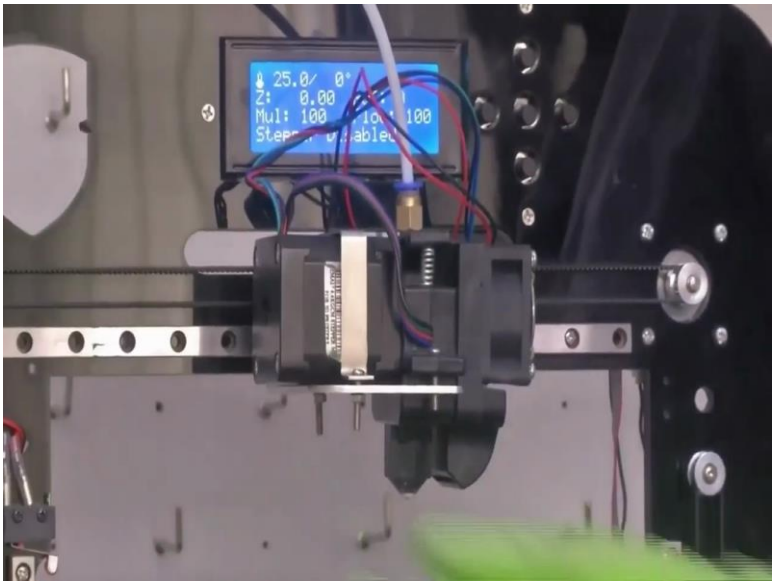
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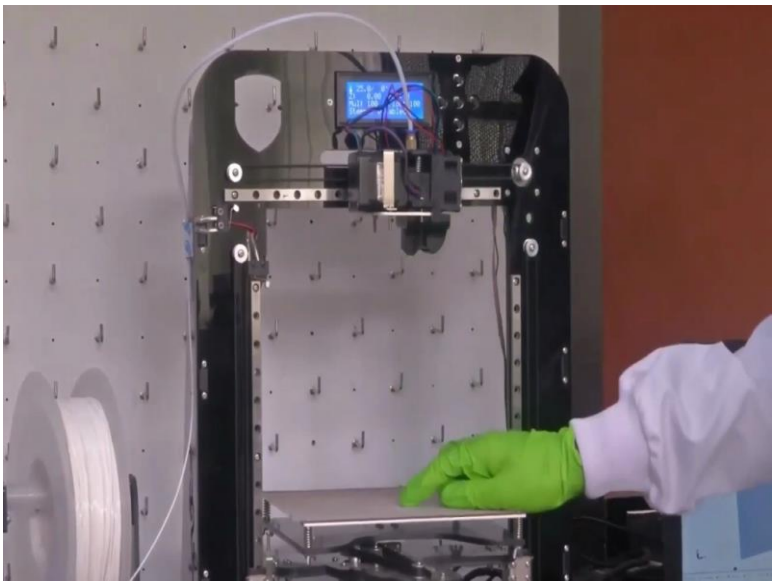

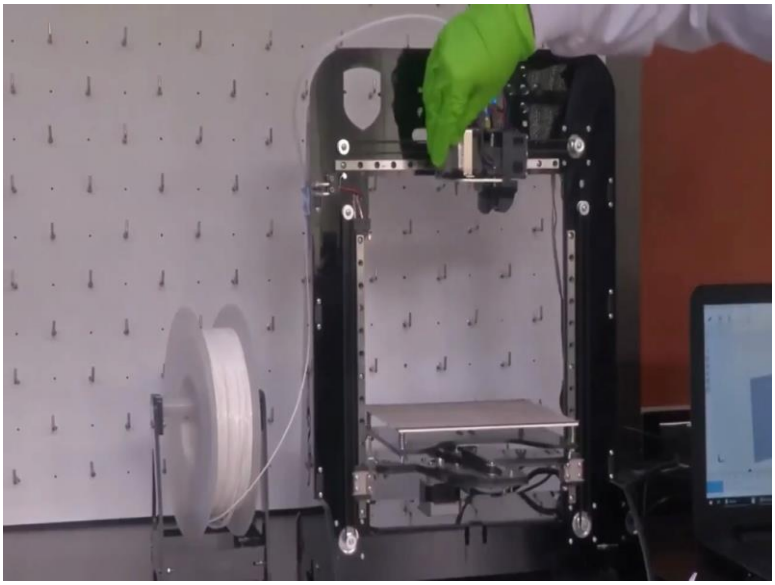

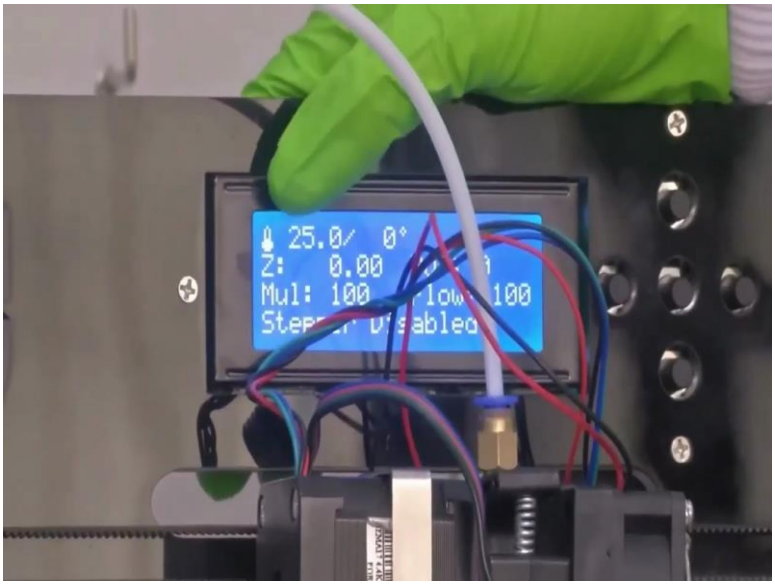

So this is the 3D printer we have. So it is a very simple and cost-effective version of 3D printer that serves the purpose for us in this laboratory to quickly prototype whatever design we want. So now let us quickly look at what are the different components of this 3D printer. So to start, you have the platform. This red coloured surface you see, this is the platform where, whatever design you have made will get printed.

So because your design will span the x, y, the 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 polylactic acid, so it is a white colour here. You can see the material, the material is rolled up on there is a, there is a, what you call lever that can hold the 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.

So it is here that the material, this polylactic acid will melt and gets deposited. When we, we will quickly, we 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. 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.

For y movement there is a motor here below, you might not be able to see it, it is there below. There is a motor here. Then for x movement, there is a motor behind here. And then for z movement, there are two motors behind here. These are chains to do the x, y staging, x, y movements. So these are the basic components of the translational mechanism of the 3D printer. So you have a small display to show you how much percentage of the printing is remaining.

So if we can see this blue coloured display, if you see this blue coloured 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 Pro E, SolidWorks Etcetera.

So the CAD files are then converted into another format called STL. STL stands for stereolithography. So this is a version of stereolithography. So stereolithography 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 a USB cable.

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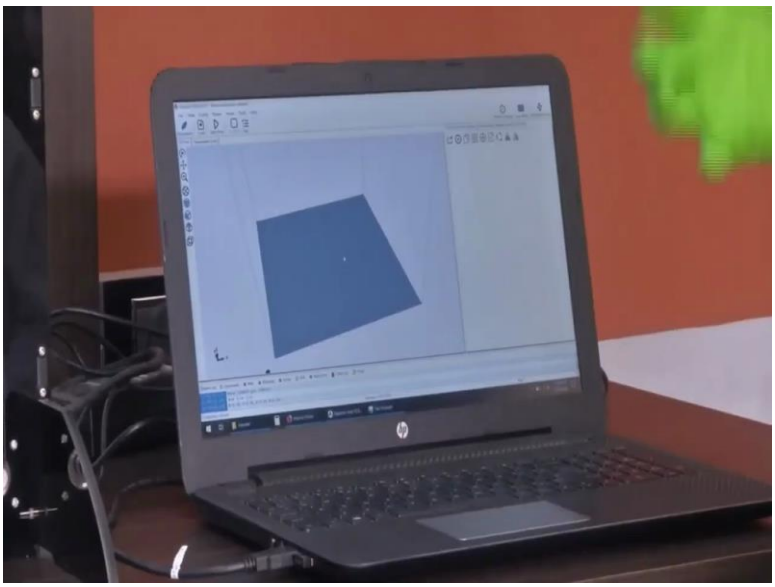

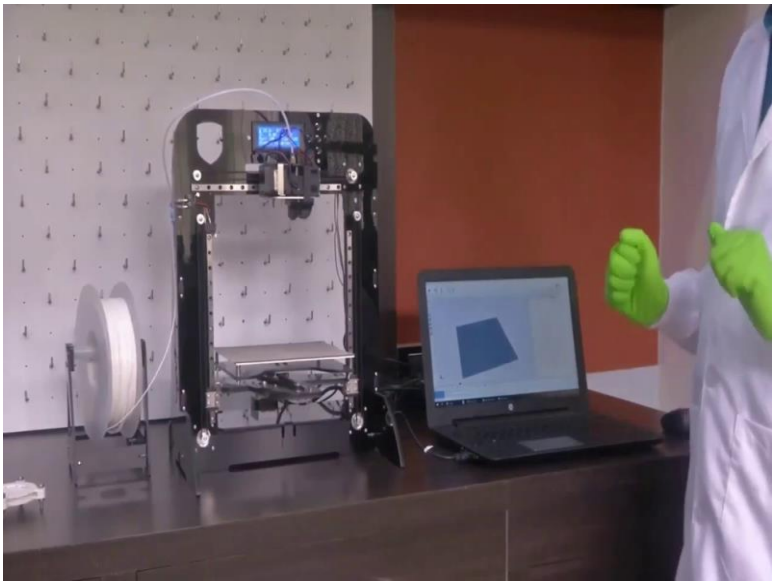

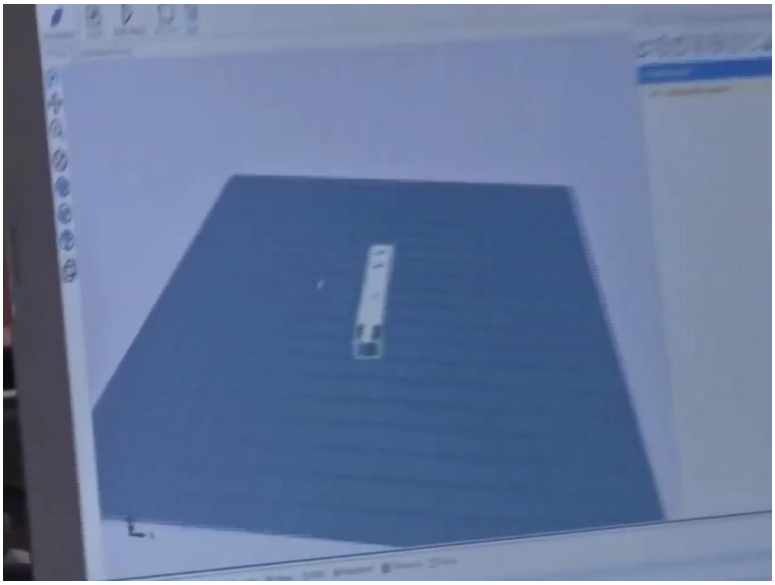

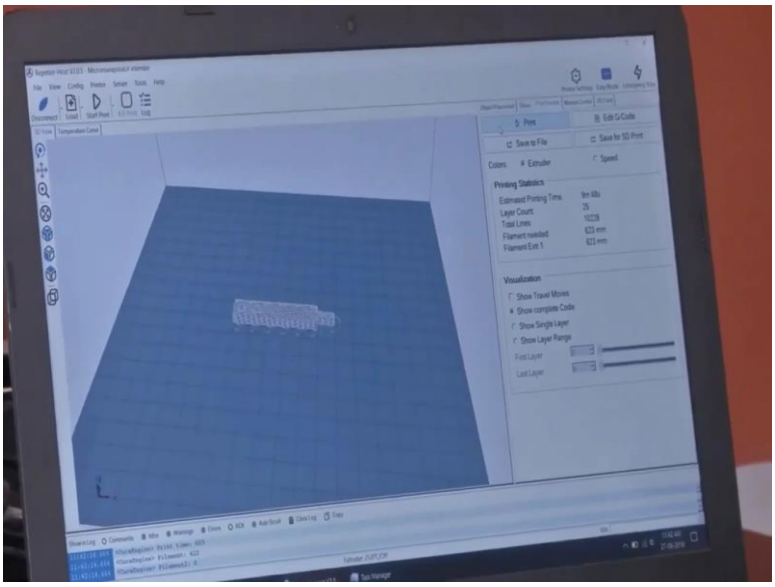
Print
Edit G-Code
Save to File
Save for SD Print
Extruder
Speed
Printing Statistics
Visualization
Show Travel Moves
Show complete Code
Show Single Layer
Show Layer Range

So we have a, we have the laptop here. So we have one software open here that is for controlling the final printing of the 3D, 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 backside of the 3D printer. Or you can copy your design in an 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 we trying to, so let us print something here. So you have, you all remember the intender that we tried to, that we showed you in the session on micromanipulators. We will again print that intender here and show you how quickly it gets printed and sees how much time it takes for it to get printed. We can see it 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, we will be inputting the design. So he is adding the design, so you can look at the computer monitor. So it is called micromanipulator indenter. So this is the design. So that is the 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 inside your platform's dimensions.

So your structure will get printed on the platform of the 3D printer. Now this, so he can control the printing from this 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 the print option. So before he starts printing he has to just oversee the first levels of printing.

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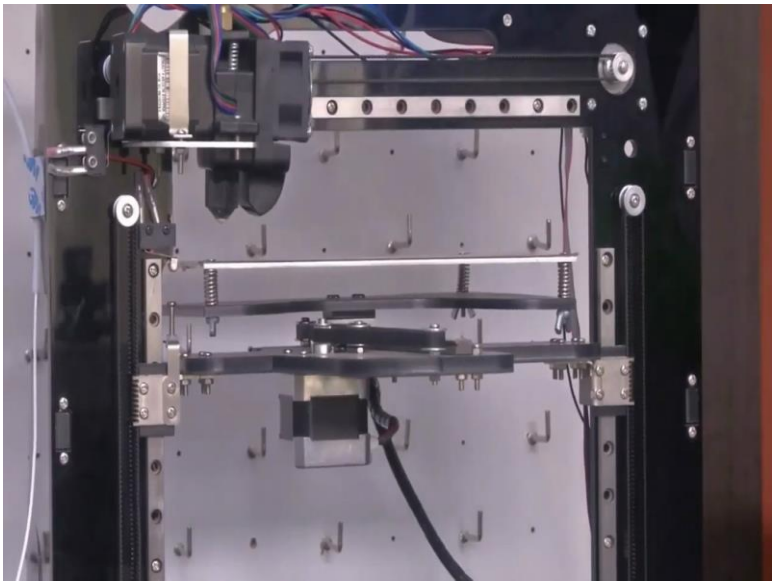

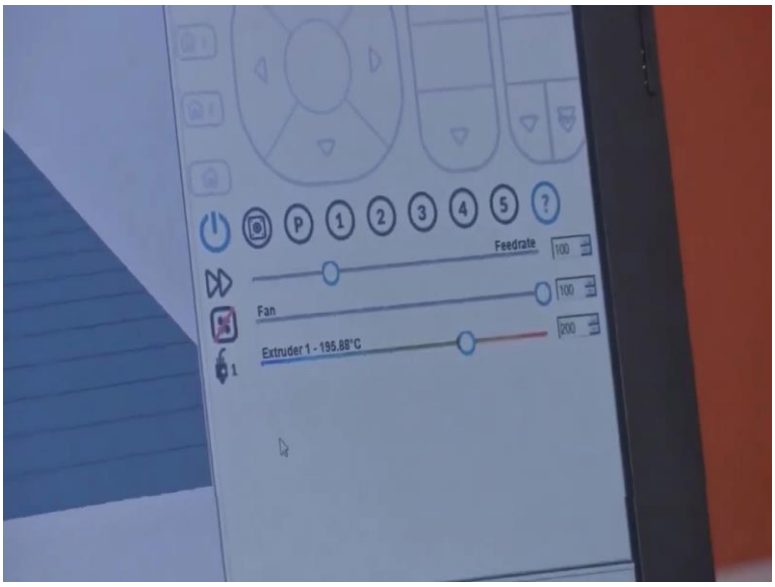

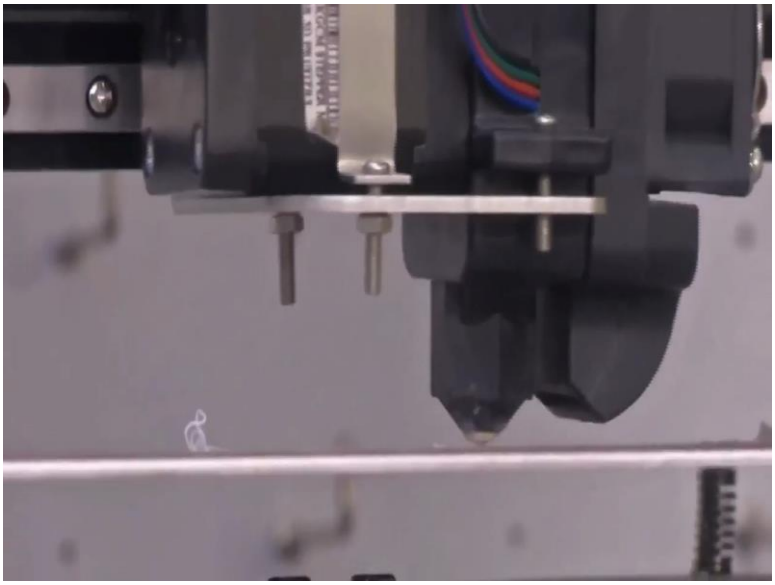

So if you see the 3D printer, the stage is moving up to start with the printing. So what happens is the printer will go to its home state or zero states where x equal to y equal to z equal to 0 and then align itself, before it starts printing. So it takes a little bit of a time to start printing. Let us just see it. So now what is happening is, the software is reading the file, the G-code file, see it is trying to predict what all it has to print and where all it needs to do the coarse corrections in the printing process.

So that (process), that process you are seeing here, extruder, the extruder is trying to, like that progress is happening, it is heating the material and the temperature progression you can see in the software here. 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, so it is testing out how if the material is coming out properly.

So once it is clear that it is coming out properly, it is starting the print. So he will just inspect it whether it is starting properly, and slowly the outside pattern is getting formed. So he will just check if everything is fine and then lock the platform. So the extruder is now depositing material slowly. So it will take some, as per the predictions it will take around 10 minutes, 10 to 15 minutes for it to get printed. Let us wait and watch. We will also try to have a closer look at this.

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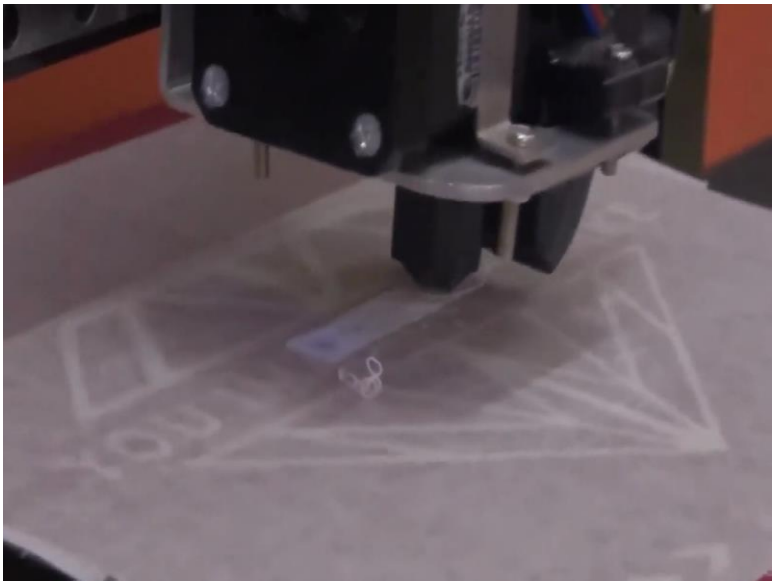

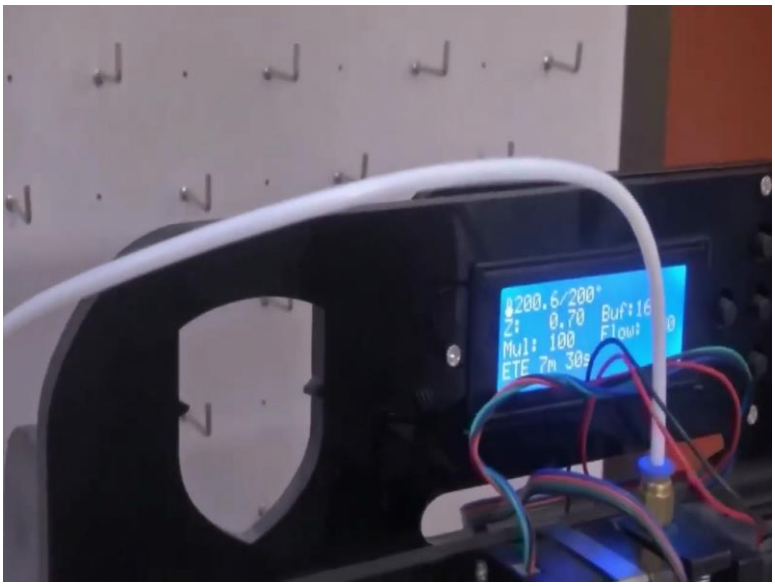

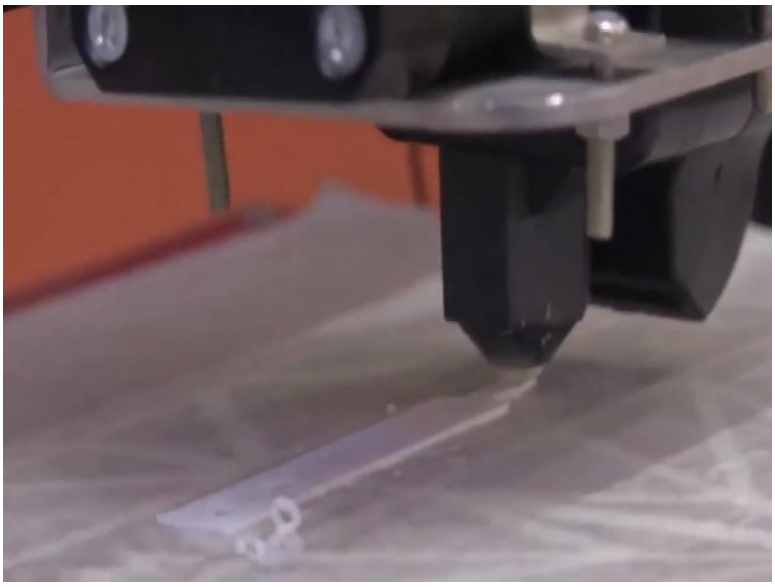

Yes, so the first layer, the base layer is formed. You can see the pattern getting formed here. So you can see that it is trying to print it with maximum precision as much as possible. So if you see the display, you can see that the estimated time remaining is around 7 minutes 39 seconds, you can see it here. Yeah, and then this buff 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 it as percentage completion or you can see as estimated time. So now we are seeing it in the estimated time. So now we are just focusing on the printing mechanism. So let us just quickly see the computer monitor once before we come back to this process.

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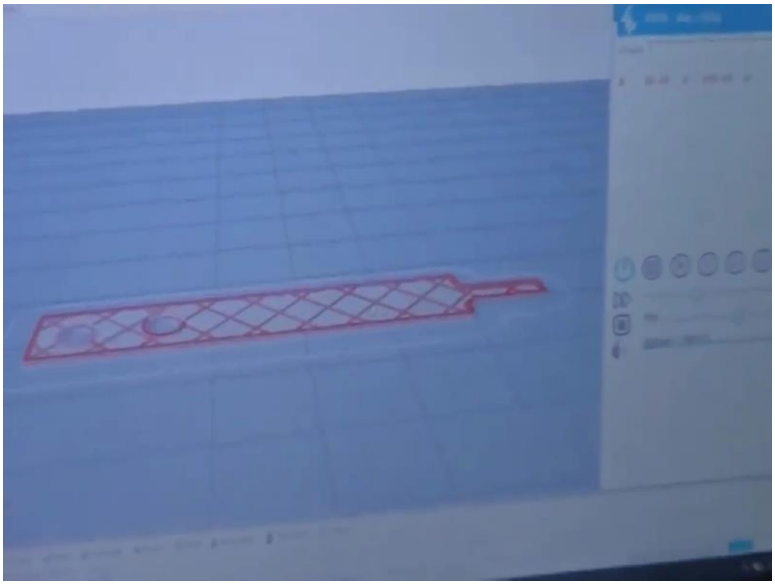

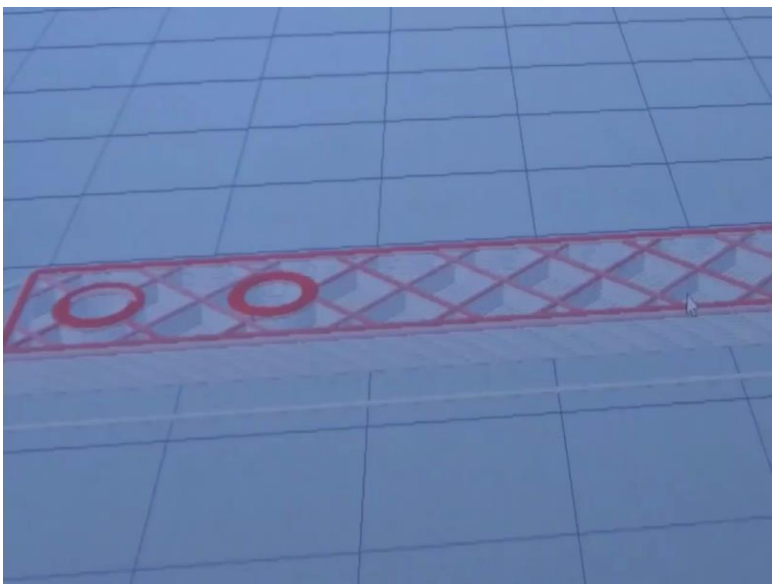

If you see the monitor, you can see a real-time update of what is getting printed being covered on the software also. So you can see whatever patterns the extruder is making, that is it coming as red marks on the software. So this is very interesting. So you can know real-time how your printing is progressing and how each layer is getting formed. So this is the 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 SolidWorks, Pro E 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 which is a machine code. It is the 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 consist of what are the x, y coordinates that have to deposited and then where all the extruder has to deposit material and how best it can deposit the inner structure.

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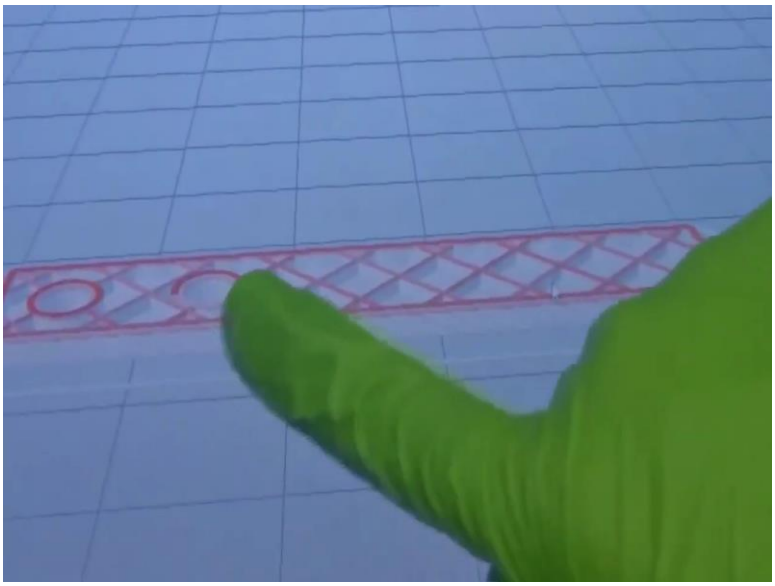

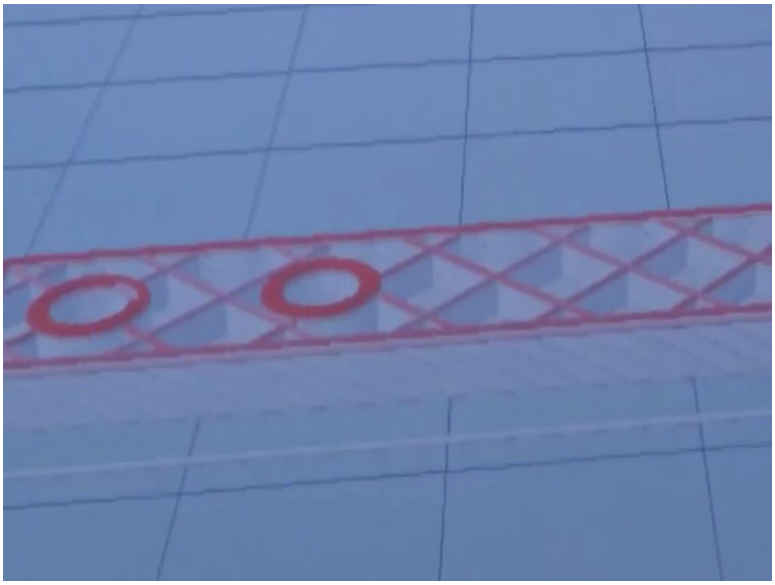

So if you see the outer structure is coming properly but the inner one is not solid material. It is forming meshes like this. So this way it will save a little bit of material so long as you do not want that much rigidity. This is just prototyping. You just want to see how your product will look like. So you can have a support structure inside but need not fill everything with the material.

So these wells are there, they may not be filled with the material but the outer structure will look smooth. This way you can save some material. So this material, there are 3D printing materials of varying cost. So this roll that we showed you that is around 2,000 rupees per roll. But some materials cost even 2 lakh per roll. So they have their different properties. When they get printed, the smoothness of the surface, the shine, the colour options that are given for the material everything varies.

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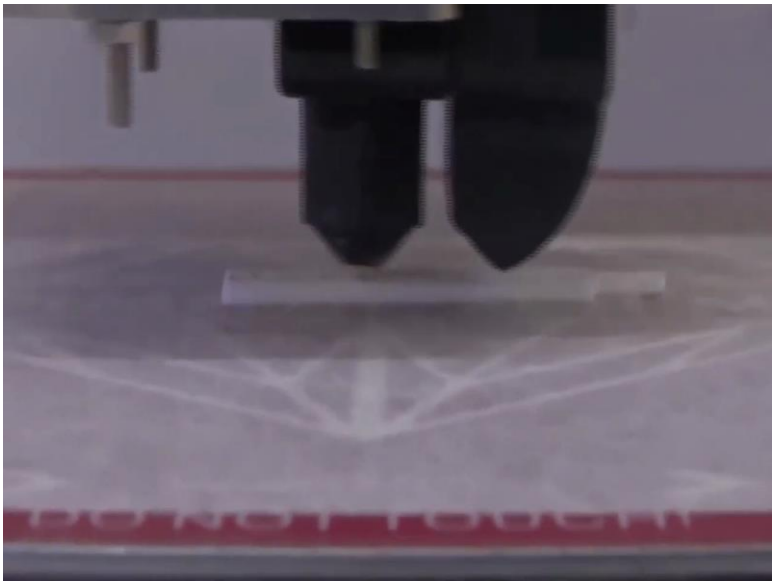

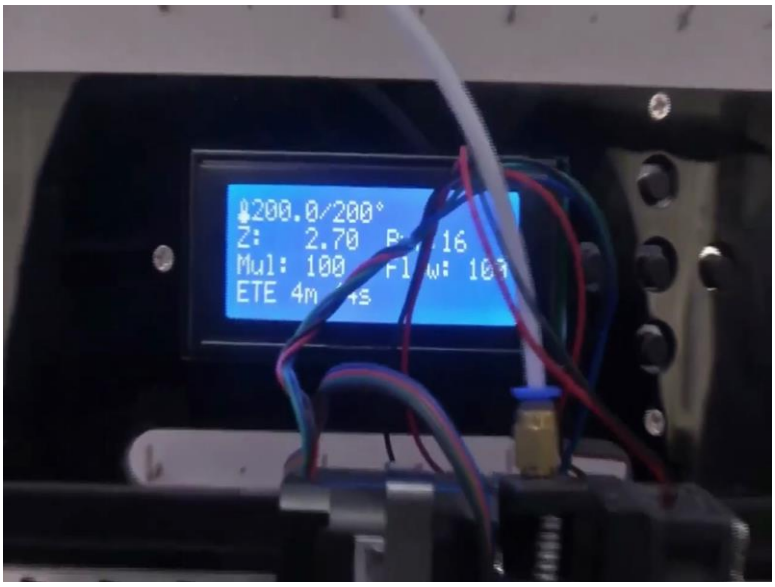

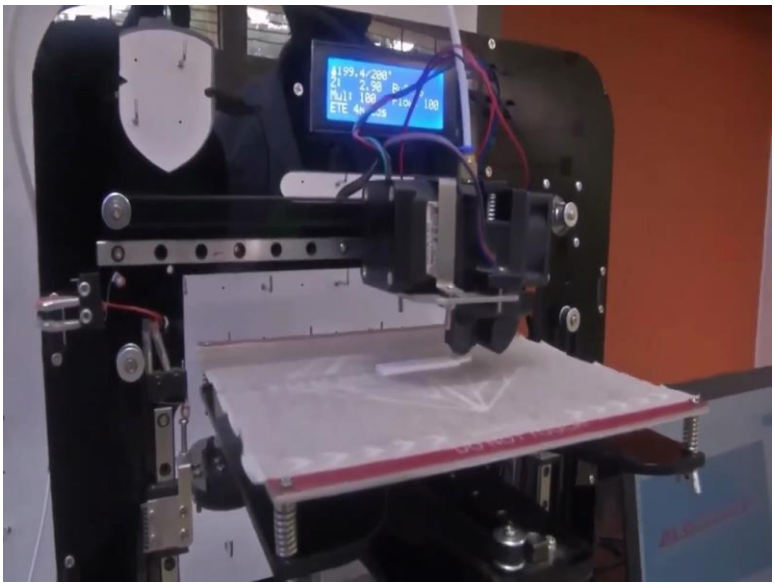

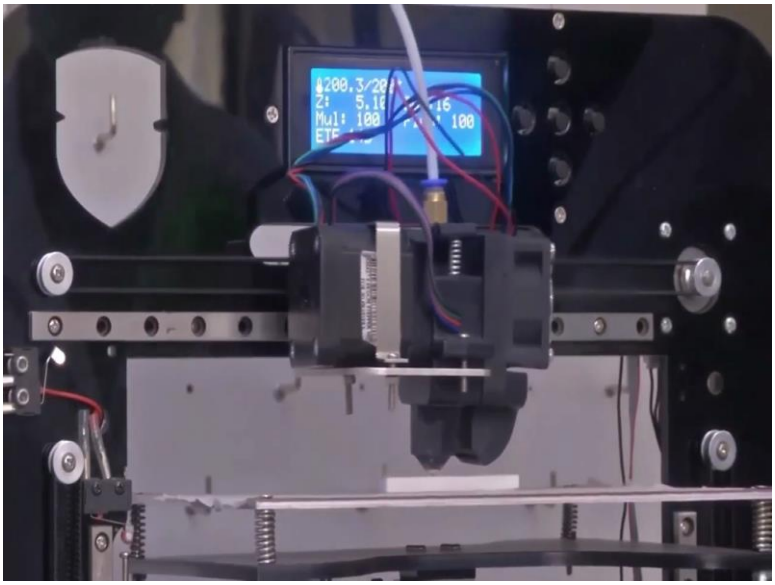

So now let us look at, how the printing is progressing. So you can see that the intender is slowly getting formed and the estimated time is around 4 minutes now. 5 minutes, 4 minutes 58 seconds. So in another 5 minutes, this printing will get over. So we can see it here, 4 minutes 47 seconds are remaining. So the extruder is printing very fast. So this is, this is a 3D printer that we have assembled in the lab.

We have procured it, the individual components of the 3D printer, and the enthusiastic members of our lab have assembled the 3D printer 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 available 3D printers. So it is getting printed. Now we, now earlier we came close to the machine because it has formed enough. We 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 is, so you have seen that the (material) it is getting deposited as 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, so whatever 3D printer prototype that you make, they may not be of a single part, you might have to fabricate different parts and then assemble them.

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, you can print, get your multiple products, print it 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 to print the multiple parts of your design, so you might have to use the same material for all your parts. We can also go ahead by printing integrating different materials, but you would need those different types of 3D printers. So the only cost would be a (criteria) 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 2 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 this course. And they are very fragile, brittle and all, and they need to be handled very carefully. So the packaging of sensors that you have seen till now is very important.

So once they are packaged, as I have told they have to be nicely enclosed and they have to be introduced to any potential customer most aesthetically. So for that, a 3D printer is very much important in any lab. And labs in India are slowly gaining their, trying to understand the importance of having 3D printers within their lab spheres which is a good thing.

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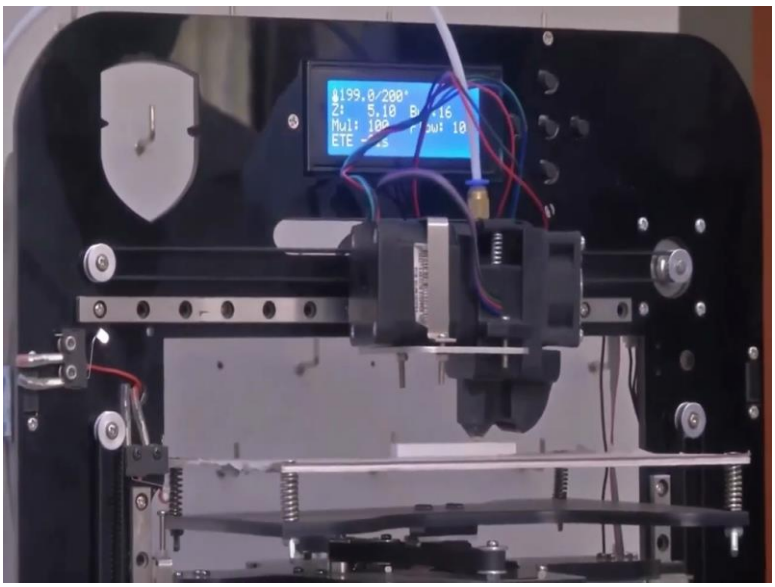

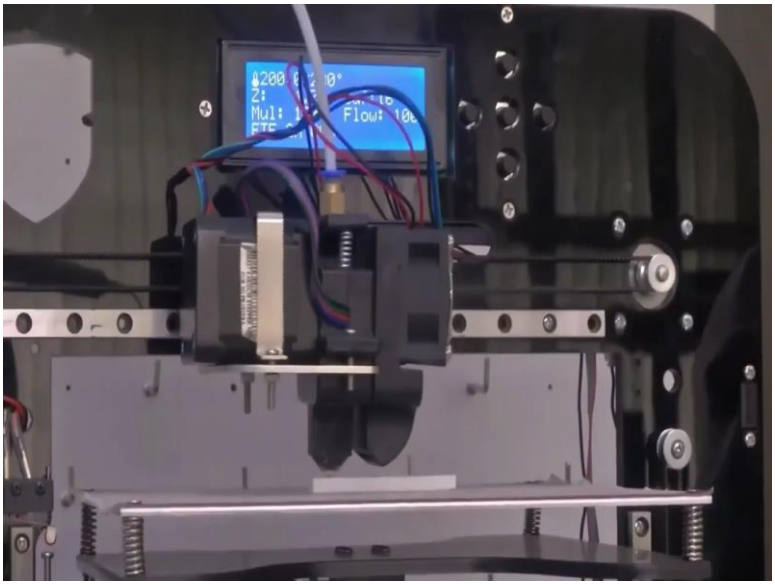

So now we can see that almost the structure is formed nicely. The same intender which we (show) saw in micromanipulator is here. So in another, under 2 minutes it will get over. So once it gets over, you should observe. So immediately once it gets over, the extruder goes up the platform, not extruder goes up, extruder stays there. The 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 the supply goes while it is getting printed, it does not have a memory to restart printing. So that is one shortcoming. So higher grid 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 the thing. So I hope this video showed you how important 3D printing is and the versatility and utility of having such equipment within your lab space. It is just, I think it is just going to get over. Let us just see it. The printing is about to get over now. It is around 40 seconds away. So you can see that it has nicely formed like milky bar white colour and so it is about to end. Just, let us wait and watch now, I will not speak now. So as soon as it is over, the platform will dropdown.

And the control system in the printer makes sure that always the material gets melted at 200 degrees Celsius around and it gets deposited. So those are all control system details. So it is about to end. In 8 seconds, it will get over. It is doing the finishing touches. If you see the outer surface now, it has made it smooth all out the surface. Inside when you had seen, it is

all meshy-meshy. Now that mesh structure is not there on the out surface. So it has fallen out, the printing has ended.

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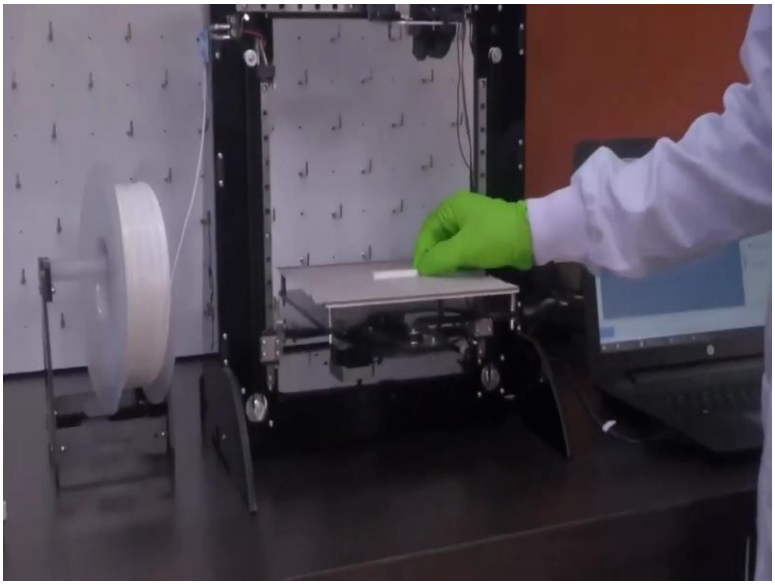

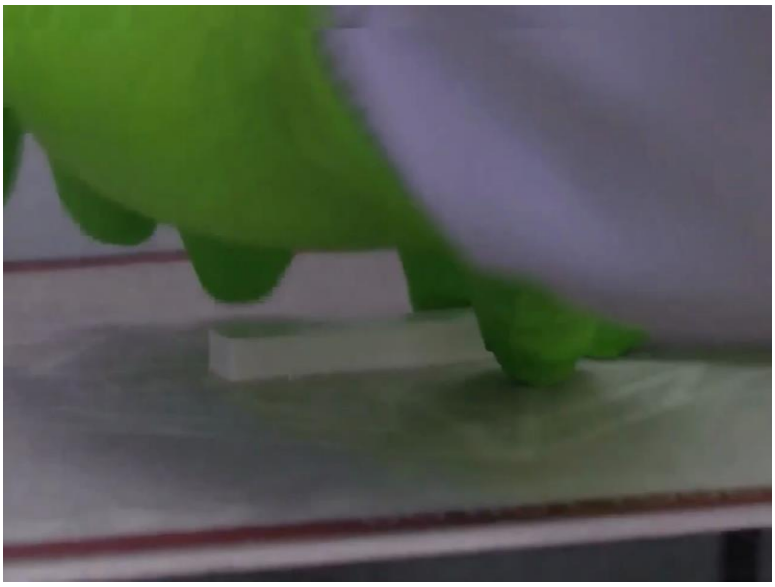

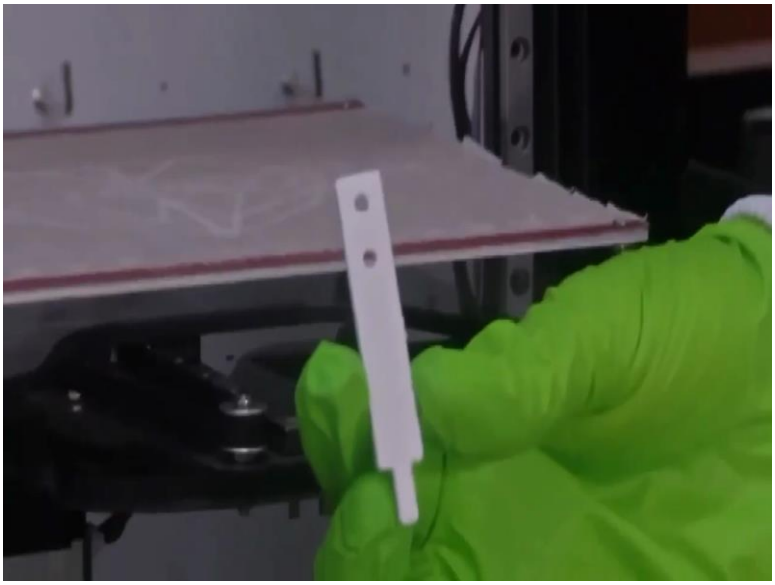

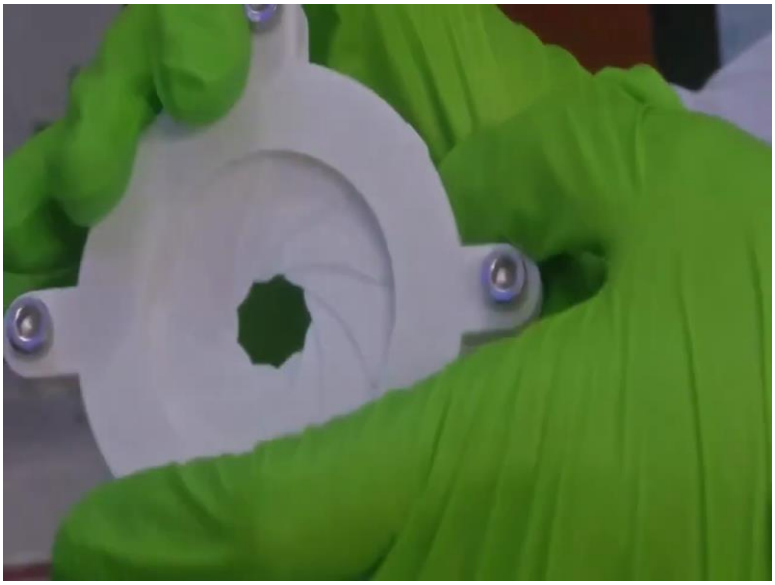

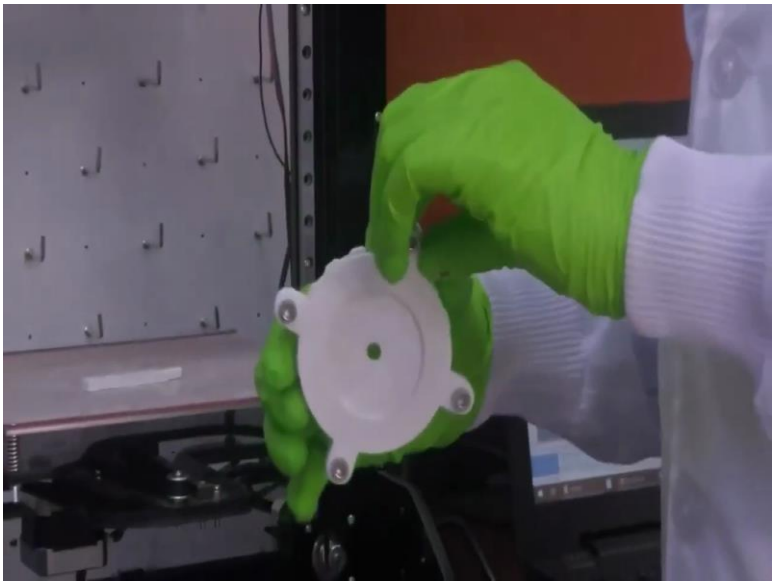

You can see that the structure is formed nicely on here. Now it is stuck to the platform. Now we have to remove it. So let us see how he removes it. So it is removed. So this is how this is our final 3D printed intender. This is the same intender that we saw with our micromanipulator. In another 10 minutes, it got printed. We have something solid in our hands which we can use. It is very solid, nothing will happen.

To a reasonable extent, it is very strong. So you can handle it with good roughness. So I was, so let us see one more thing that we have printed here. I was telling you that we can use multiple parts, multiple parts to make a 3D printed system. So this is like the, it is a mechanical aperture. So you might have seen similar mechanisms in camera lenses. So if you rotate it here, it will open up.

If you do this, it will close up. So this, let us see how many parts are there in this. This top part is there, the top circle that is one part. In the same way, there is a bottom part, a second part. Then there is this controlling lever mechanism here which I am rotating, that is the third part. And there are leaves here inside. If you see it closely, there are leaves. There are 9 leaves which have been printed separately.

So a total of 9+3=12 separate parts are printed on a 3D printer and then 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 the course on fabrication. So during this, during the journey of this course, we have seen several microfabrication techniques.

But if we look at it, this is also a fabrication. But this is not microfabrication, this is you can say this is a macro fabrication. You are fabricating stuff. Physically (feel), you can have stuff that you can feel just like your microfabricated 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 about fabrication and fabrication need not necessarily be microfabrication.

But that is the focus area of our course. But fabrication is a very general term. You can always have microfabricated components that will house 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 society as final products which they can 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. Whatever research you are doing has end value to society and you can make the world a little bit more a better place to live. Thank you.

Professor: So in the video, you have seen how we have used 3D printing and you have also seen as a live experiment what kind of 3D printing material we can print. You can print several different designs. Again, if you have more questions on 3D printing or which kind of parts or material you have to use for your particular application, feel free to ask us. We will help you out. It is very easy to learn CAD models. Generally, I prefer SolidWorks, however, there are several software that is available as mentioned in my previous slides.

Feel free to use whatever is comfortable for you. The point is it should create an STL file and we can send it for printing purposes. Again, 3D printing is a very small part of the overall course. It is just to give you some understanding of the technology available for (designer) designing a casing for the instrumentation. So we will see different modules about either sensor or on the lithography or on, on the cleanroom environment that we will, we have already seen how the cleanroom looks like and what are the processes to follow when you enter the cleanroom.

We have also seen the silicon wafers and silicon dioxide, how it can grow on silicon and what is the use of the substrate and we will take it further. As I said, we will be stressing more on the experiment side where I will be showing it to you or my TA will be showing it to you. When I say my TA, they are my students. So these TAs are working with Doctor Mahesh.

So they will be showing you how the electronic instrumentation can be used in real-time and we will show you, by acquiring the signal, EEG signal from the scalp and showing you on the display. So this entire focus on the experiment side is also there in this particular course that we will be looking at. You, you again look at the videos. Any questions, feel free to ask us. We will help you by answering through the NPTEL forum. Till then you take care. Have a nice time. Bye.