Introductory Neuroscience and Neuro Instrumentation
Indian Institute of Sciences, Bangalore
Lecture 20
Introduction to 3D Printing

Hi, welcome to this module. In this module, we will look at 3D Printing. Now, 3D printing is a part of additive manufacturing. And the importance of 3D printing is, is enormous. We will see the theory and we will also see a video that is recorded by us in my lab, on how to use a 3D printer. And we can design a casing when you talk about the electronic signal conditioning circuit for EEG and you can also design and fabricate electrodes for capturing or acquiring EEG signals. Those electrodes would be metal electrodes and if you want to print metal you require 3D metal printing.

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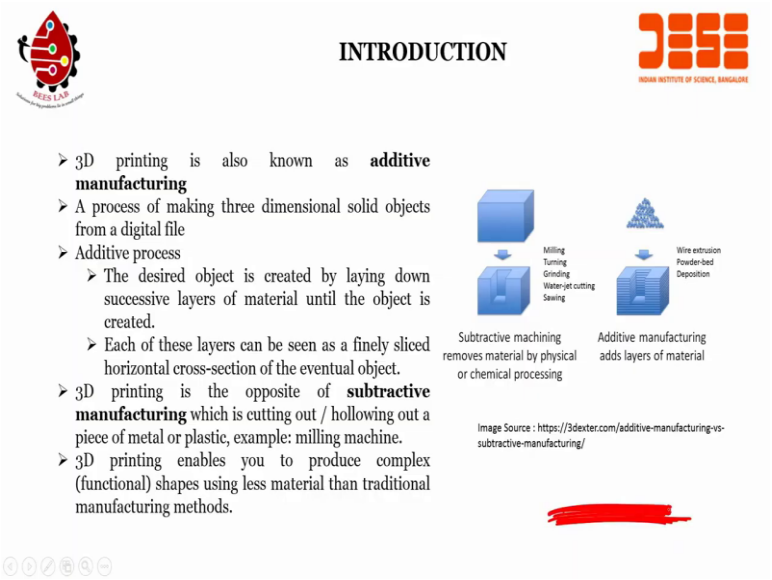

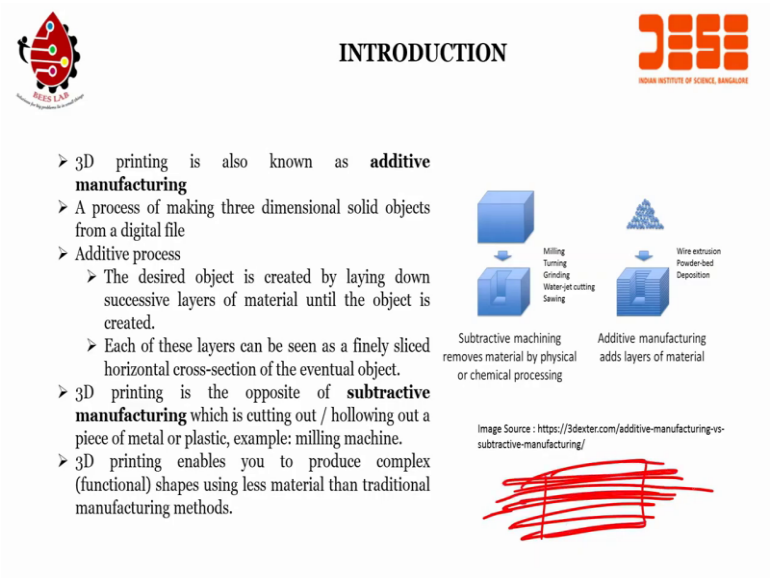

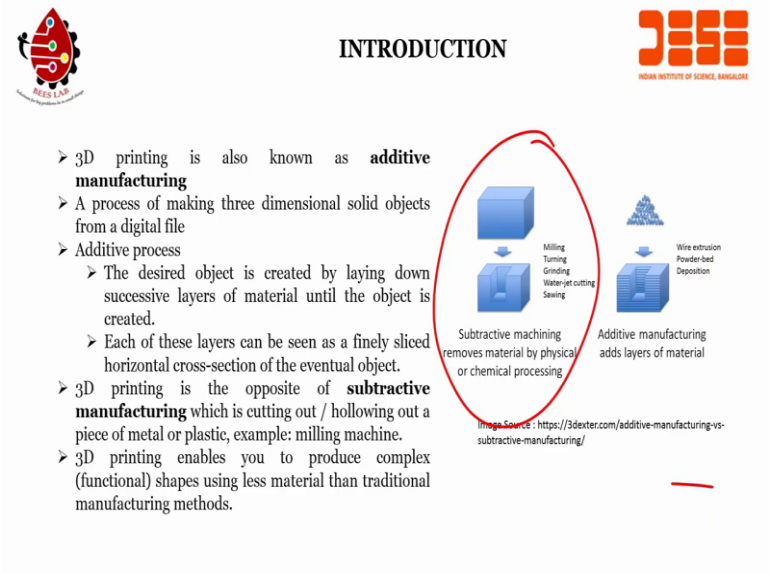

So, let us see what exactly 3D printing is and we will take it over. If you see the slide, 3D printing is also known as the additive manufacturing process. Why additive? Because it will add the layers to the substrate. While there is another machining technique called the subtractive machining technique. Where the material is removed by physical or chemical processing.

So, the process of making 3 dimensional which is 3D solid objects from a digital file is used in 3D printing, is a part of the additive manufacturing process and that is why the desired object is created by laying down successive layers, layer by layer, one layer, second layer, third layer on it and then you create a structure. Of course, there is no gap in the layers, just it was my just drawing mistake.

But you see one layer, second layer, the third layer, fourth layer, fifth, sixth, seventh, eighth, ninth and you can see the slowly the material is adding to the base material, that is why the structure is created. This is the way the layers are created. Each of these layers can be seen as finally sliced horizontal cross-sections. So, if you want to make a box and then this box can be made by stacking several layers, so, it is like a slicing of the layers that are attached to (for) formulate or to form this particular box that is what it means.

3D printing is the opposite of subtractive manufacturing. We can see here, this is an example of subtractive manufacturing which can be, you have seen the machining like milling or turning, grinding, water jet cutting, these are all subtractive manufacturing. So, the 3D printing examples for subtractive manufacturing of course are the milling machine. While 3D printing enables us to produce complex function shapes using less material than traditional manufacturing methods.

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So, what you have seen in the video is how 3D printing kind of works.

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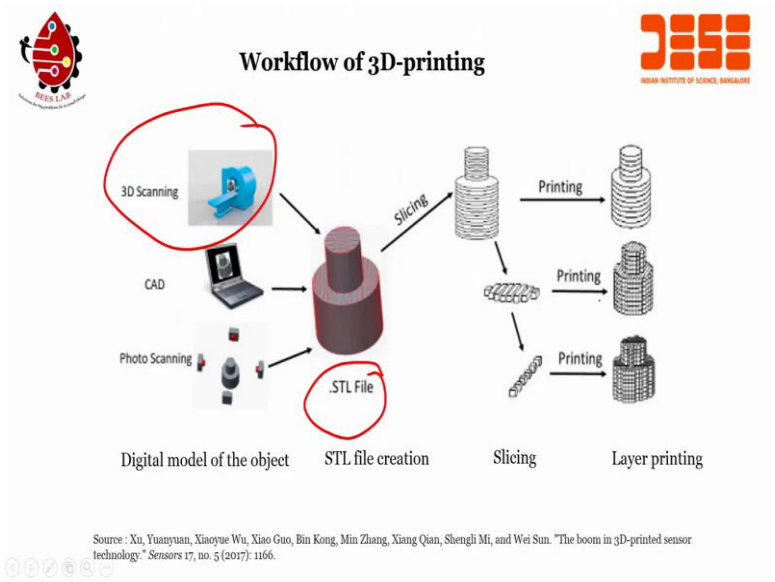

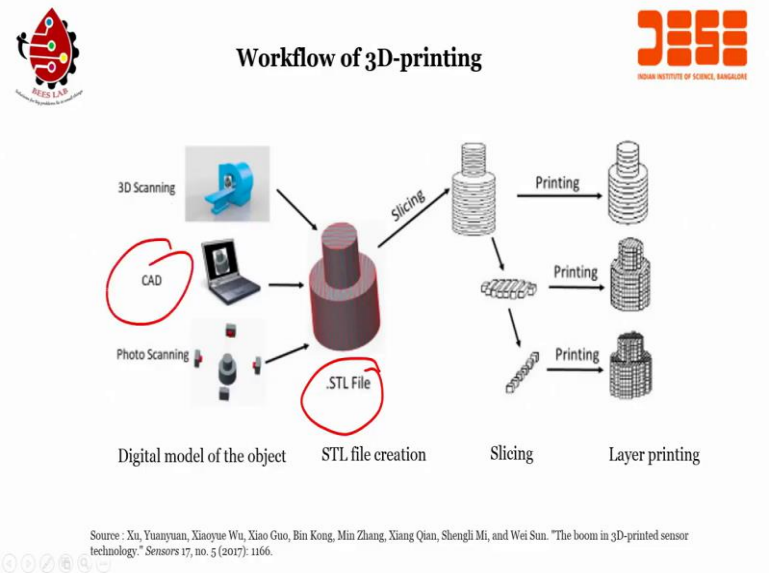

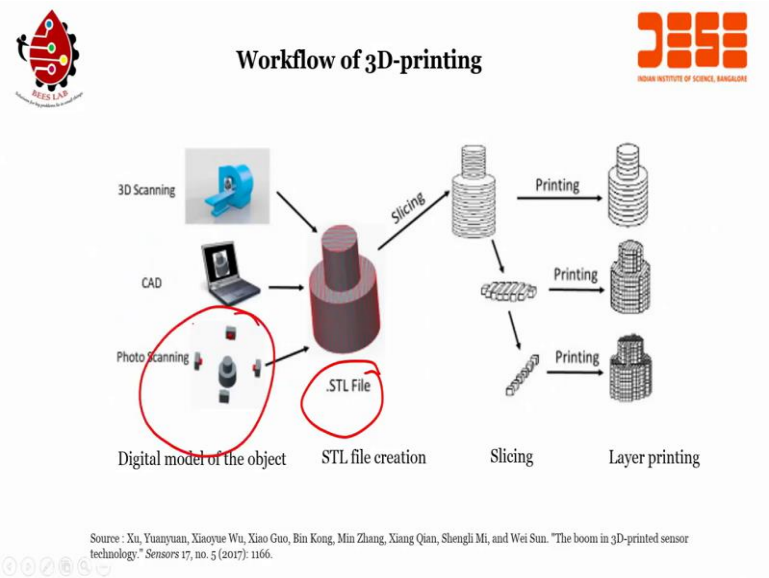

So, let us see the slide now. What is the workflow of 3D printing, if you see the slide you will be able to see that first is you have to, you can scan, so 3D scanning can be done. Either by scanning you can generate an STL file, this STL file is used finally for printing purpose. Or you design your model using CAD, or you can do photo scanning. You take a photo and you can send it, make an STL file. So, this is the digital model of the object 3D scanning CAD or photo scanning. You prepare an STL file and then there is a slicing and layer printing.

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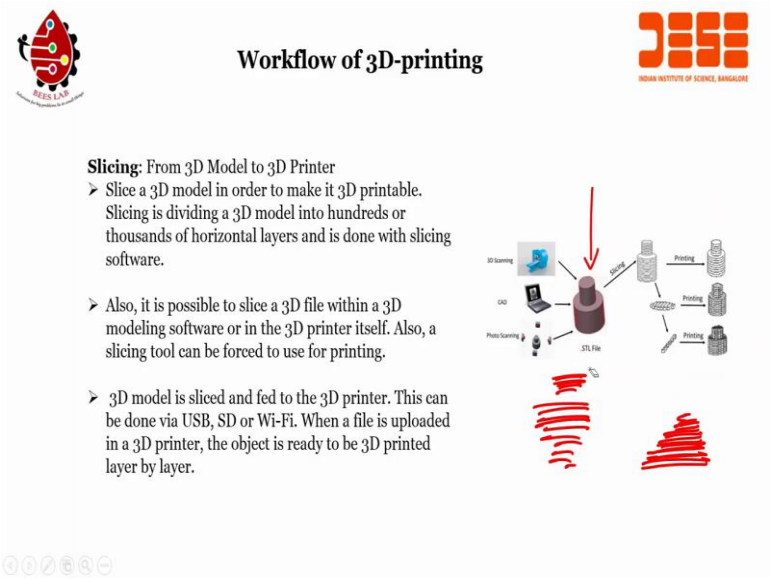

So what is slicing? from 3D model to 3D printer, slicing or 3D model into, to make a 3D printable version we need to slice the model and is divided into hundreds or thousands of layers. Suppose this is what means to print then it is the first slice in many many many parts and then it goes on slicing and then this parts slice by slice this part is been made to recreate your object as you are desiring, which is the slicing process. The 3D model is sliced and fed through a 3D printer. This can be done by a USB, it can be done by an SD card or Wi-Fi and when the file is uploaded in a 3D printer, the object is ready to 3D print, layer by layer.

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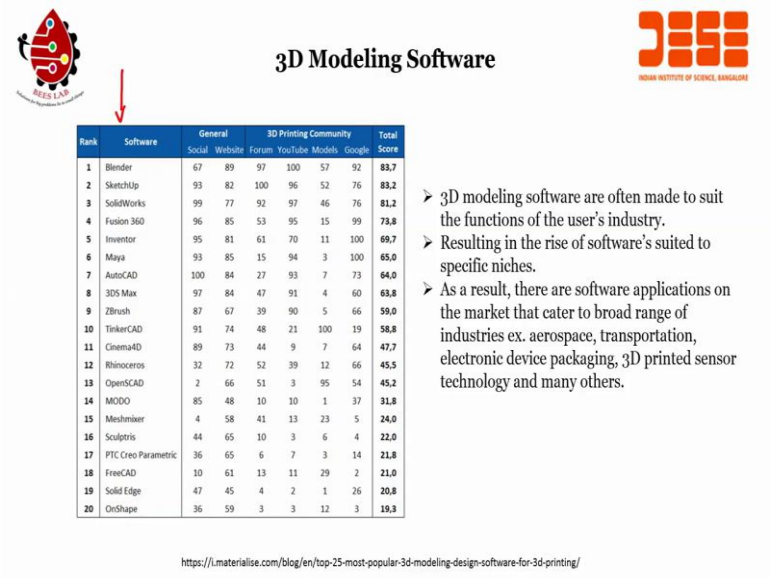

Rank	Software	General		3D Printing Community				Total Score
		Social	Website	Forum	YouTube	Models	Google	
1	Blender	67	89	97	100	57	92	83,7
2	SketchUp	93	82	100	96	52	76	83,2
3	SolidWorks	99	77	92	97	46	76	81,2
4	Fusion 360	96	85	53	95	15	99	73,8
5	Inventor	95	81	61	70	11	100	69,7
6	Maya	93	85	15	94	3	100	65,0
7	AutoCAD	100	84	27	93	7	73	64,0
8	3DS Max	97	84	47	91	4	60	63,8
9	ZBrush	87	67	39	90	5	66	59,0
10	TinkerCAD	91	74	48	21	100	19	58,8
11	Cinema4D	89	73	44	9	7	64	47,7
12	Rhinoceros	32	72	52	39	12	66	45,5
13	OpenSCAD	2	66	51	3	95	54	45,2
14	MODO	85	48	10	10	1	37	31,8
15	Meshmixer	4	58	41	13	23	5	24,0
16	Sculptris	44	65	10	3	6	4	22,0
17	PTC Creo Parametric	36	65	6	7	3	14	21,8
18	FreeCAD	10	61	13	11	29	2	21,0
19	Solid Edge	47	45	4	2	1	26	20,8
20	OnShape	36	59	3	3	12	3	19,3

So, there are several modeling software available that can be used based on the application or function of the user industries. There are software applications in the market that cater to a

broad range of industries example for aerospace, transportation, electronic device packaging, 3D printer sensor technology, and many others. And you can see here several software available from Blender to SketchUp to SolidWorks, Fusion, Inventor, MAYA, AutoCAD and many till you go to 20 which is OnShape software.

And you can see that there are several things based on the general score like social website Forum, YouTube, Models, Google, and based on that the score that is given to Blender is highest compared to other. However, we can take any one from the first seven if you want to start working on 3D printing. We will show you how to use a 3D printer as I said.

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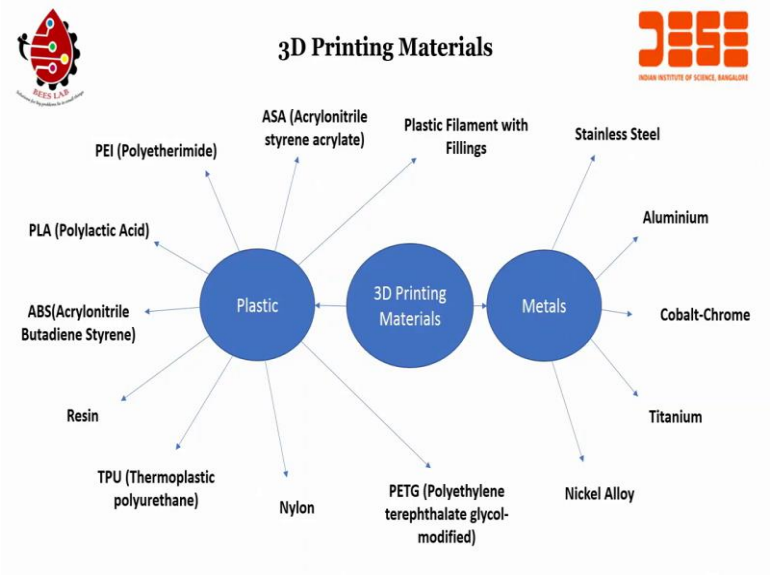

And then what we have, we can use several materials for printing, it can be plastic, it can be metals. So, a metal 3D printer is separate from the plastic 3D printer. When you talk about the plastic we can use PTG, we can use Nylon then you can use thermoplastic. You can use ABS, you can also use Resin. You can use ASA, PEI, PLA, and so forth. Finally, if you want to go for metal it can be nickel alloy, stainless steel, aluminum cobalt, chrome, and titanium. So, these are 3D printing materials that are used.

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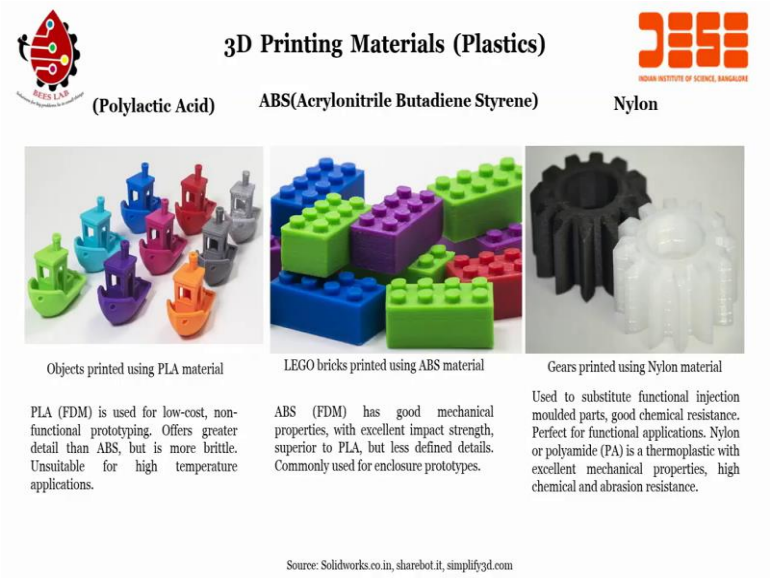

You can, you can print several objects as you can see here in this slide. If you want to go for polylactic acid material, you see the object printed using PLA material is, this is used for low-cost non-functional prototype, offers greater details than ABS but is more brittle, unsuitable for high-temperature applications. So, again depending on the applications that you want to use, you have to change the materials. If you want to go for ABS, then you can use it because it, can give you good mechanical properties, with excellent impact strength, so you can make LEGO bricks, but less defined details.

It is better than PLA but in terms of the minute details, it is not as, as great as PLA. And generally, it is used for enclosures. While Nylon can be used even for gears and is a substitute functional injection moulded parts, good chemical resistance, perfect for function applications like thermoplastic with excellent mechanical properties, high chemical and aberration resistance. Thus the Nylon can be used as a material for several applications.

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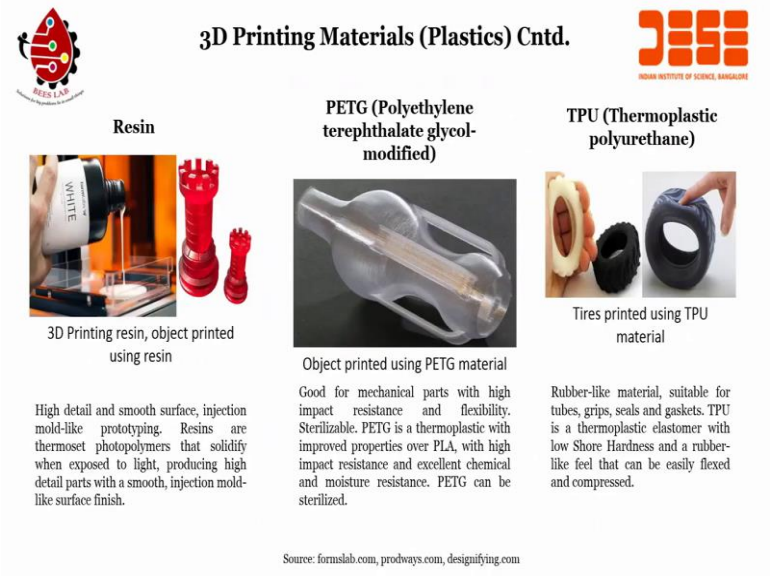

If we talk about resins and PETG and TPU, then you can see here that the high details and smooth surface injection mould like prototyping we can use a resin. Resins are thermoset, photomers that solidifies when exposed to light, producing high detail parts with a smooth injection mould. When you talk about PETG, PETG is used because it has good mechanical parts, particularly when you want to design a mechanical part PETG is a better material.

It is a high impact resistance with flexibility. And if you want to go for TPU then TPUs are generally we can print tyres using this material, is rubber-like material suitable for tubes, grips, sills and is a thermoplastic elastomer again, with a low shore hardness and rubber-like feel that can be easily flexed and compressed.

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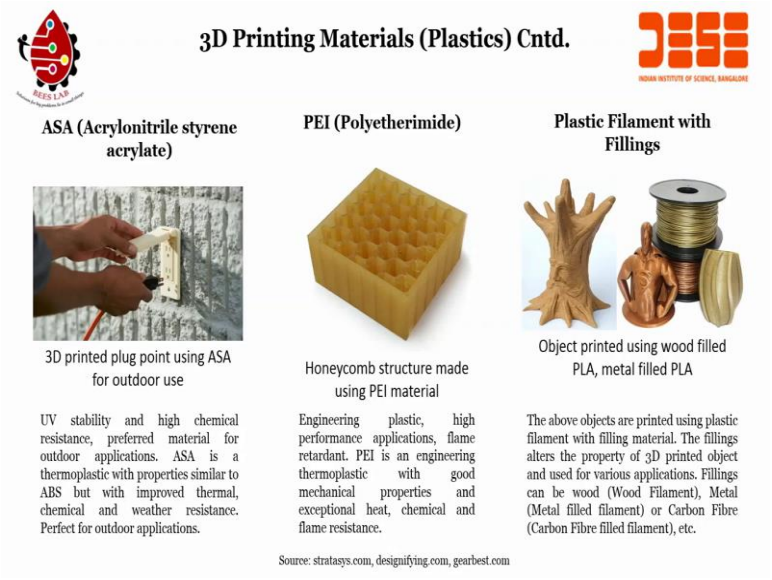

So, like I said you can, the choice of material depends on the application. Fewer materials are there which are ASA PEI and plastic. Where the plastic filament with filings or fillings are used for, for several applications like you want to fill, can be wood, metal, filament, or carbon fiber. Where if you want to use PEI, you can use it for honeycomb structure, this is just an example.

So, it can be used for engineering plastic, high-performance applications, flame (retardant) retardant. PEI is an engineering thermoplastic with good mechanical properties, it can also resist heat chemicals and flame. While if you talk about ASA it is a UV stability and high chemical resistance preferred material for the outdoor applications and ASA similar to thermoplastic with properties or to ABS but with the improved thermal chemical and weather resistance.

So, perfect for outward application. so anything like you can see here a power cord or connection can be, can be fabricated, or can be printed using a 3D printing technique. When you want to go for an engineering kind of solution or complex solution, you can go for PEI. Where you want to use it for filing, you can go for plastic filaments.

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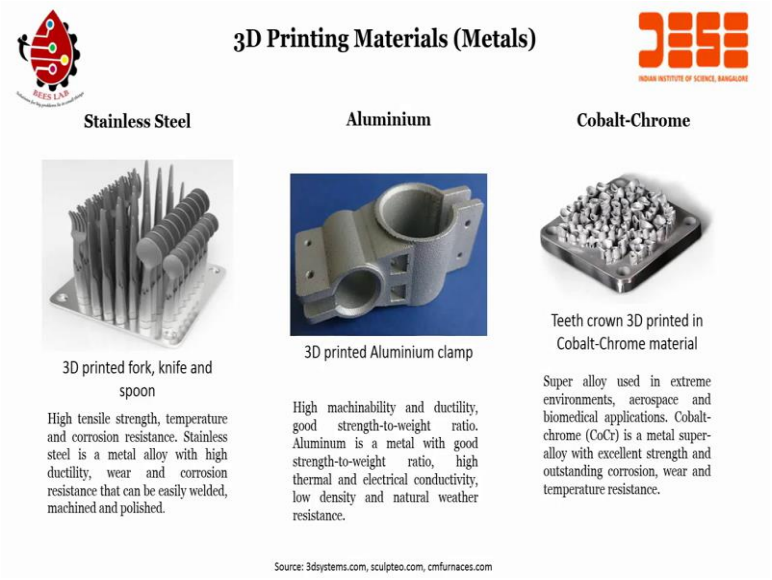

Then we have metals, so we have stainless steel we can design or print fork, they can design and print knife and spoon. While the importance of stainless steel everybody knows however just to, for the sake of just finishing this particular 3D printing stainless steel part, let me read it. So, you already know stainless steel has sensor strength, temperature, and corrosion resistance.

It is a metal alloy with high ductility, wear, and corrosion resistance that can be easily welded by machine and polished. So, stainless steel as we all know is extremely useful but is heavy material compared to aluminum. And aluminum has high machinability and ductility, good strength-to-weight ratio, aluminum is a metal with good strength-to-weight ratio, high thermal and electrical conductivity, low density, and natural weather resistance.

However, we need to understand the aluminum will get aluminum oxide and, and compared to steel it is not, it does not have that great mechanical strength. However, the weight is extremely less compared to steel and that is why it is preferred. Also if you see cobalt chrome, then it is used for teeth crown. So, super alloy used in extreme environments aerospace, biomedical applications generally cobalt chrome is used. It can, it can withstand corrosion wear and temperature resistance.

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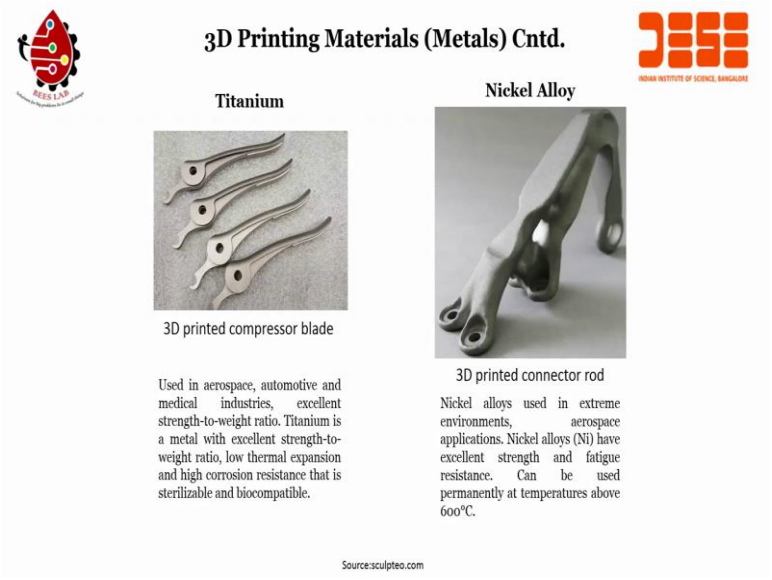

Titanium and nickel alloy. Titanium is used for a long time, is used in medical industries, it can be used for implants, it carries an excellent high strength-to-weight ratio, is low thermal expansion, high corrosion resistance and it is biocompatible. So, generally, the blades are used or the implants are used, are made up of titanium.

Nickel alloy at the other side is used in extreme environments, aerospace applications and has excellent strength and fatigue resistance. It can be used permanently at temperatures above 600 degree centigrade. That is at a very high temperature we can use nickel alloy. Some of these are some of the materials that are used in 3D printing.

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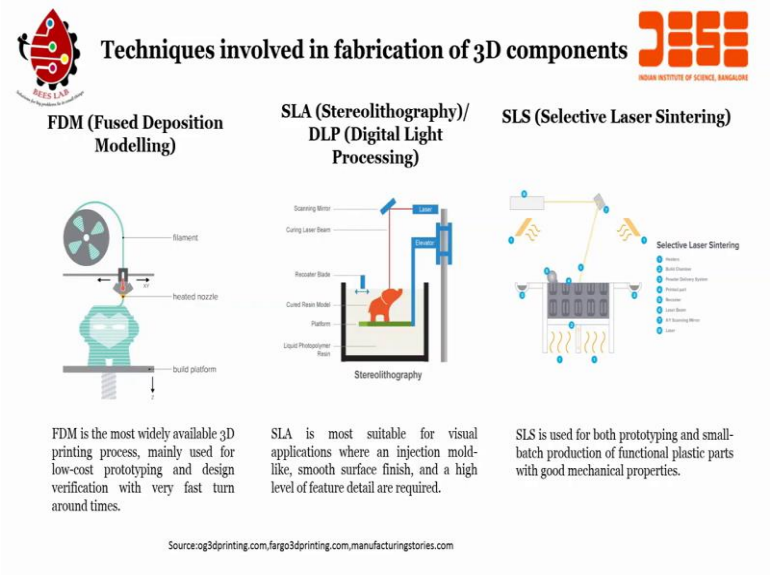

Now, we should understand what are the techniques used in 3D printing. And there are 3 techniques generally which are extremely used. First is called Fused Deposition Modeling, then we have Stereolithography or Digital Light Processing, and finally, we have Selective Laser Sintering. So, in FDM it is the most widely used 3D printing process. Mainly it is used for creating a low-cost prototypes. And just to quickly know, whether the designs are correct, so verify the designs.

While the SLA which is Stereolithography based technique is most suitable for visual applications, where an injection mould like smooth surface finish and a high level of features are required. While SLS which is called Selective Laser Sintering is used for both prototyping and small batch production of functional plastic parts with good mechanical properties. If you talk about the technologies then also let us see the techniques involved in the fabrication of 3D components.

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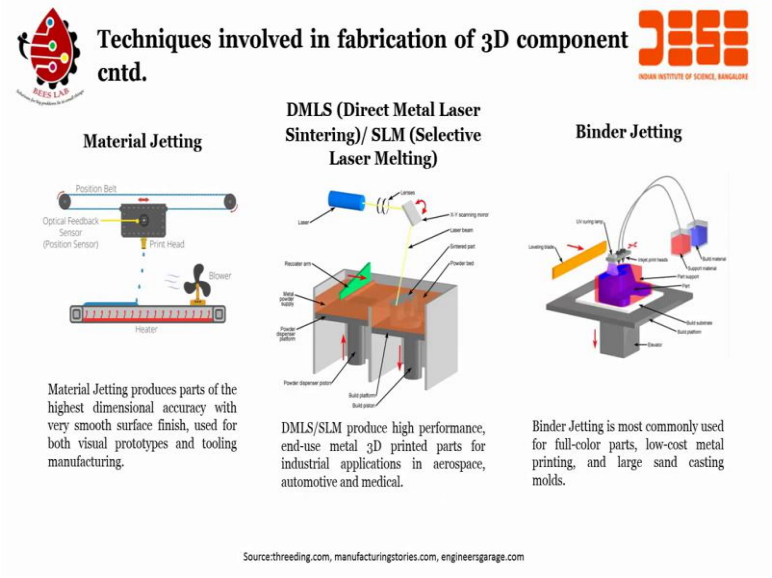

So, if you see the slide we have three different techniques. Material Jetting, Binder Jetting, and Direct Metal Laser Sintering. So, in Material Jetting, the Material Jetting produced parts of highest dimensional accuracy and you can see here there is a blower which will blow and, and dry the material. There is a heater on which the, the material is printed using the printed head.

And there is a positional belt so it can move in either direction. And there is an optical feedback sensor for understanding the position. So, it is used for producing parts of the highest dimensional accuracy with a very smooth surface finish, used for both visual prototypes and tool manufacturing. While in the case of direct measure laser centering it is

used for metal 3D printing, generally in the aerospace industry and automotive, as well as medical.

And in this case, as you can see there is a powder metal dispenser platform. Then we have powder dispenser piston, we have recorder arm, metal powder supply, and the laser is focused through the lens on to the powder bed where the material is sintered. And it can be, we can, we can move it with the help of XY scanning mirror. Then, we can position the laser in that particular part.

So, there is a built platform and there is a built piston while there is a powder dispenser piston, so this is the details about it which we are right now not interested in because our intention is, how we can use the 3D printing for EG kind of application or for, for the casing of the electronic modules. Finally, we have Binder Jetting which is most commonly used for full-color parts low-cost metal printing, and large sand casting molds.

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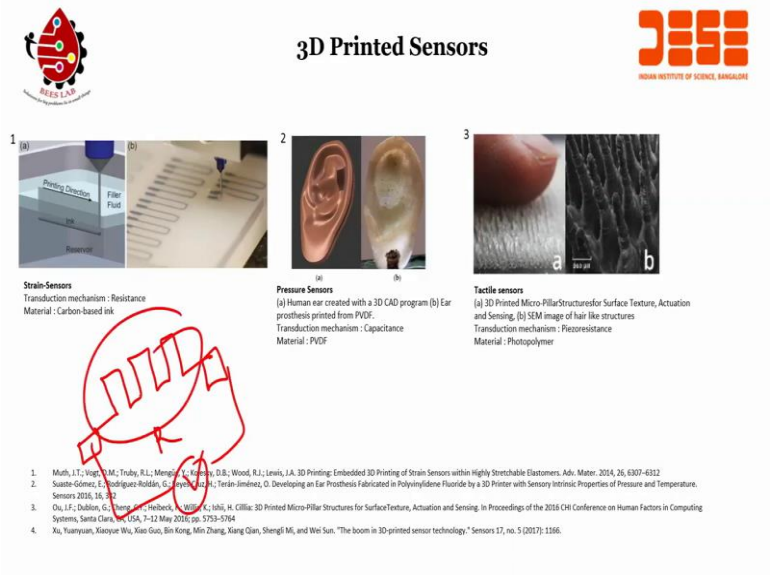

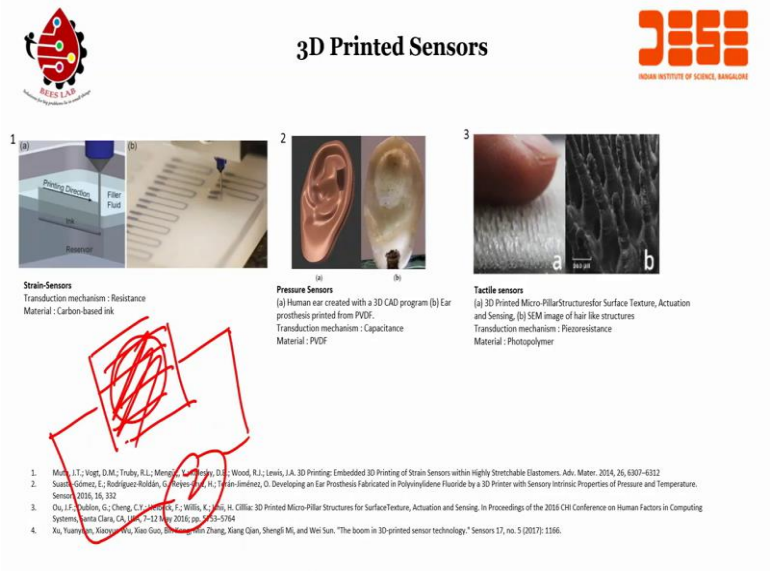

But the real application of 3D printing will be in sensors, will also be in casing the electronic modules. And you can here see that we can directly use 3D printing for fabricating sensors. For example, if you want to print carbon, carbon-based ink then you can create a resistor. For example, if I move my 3D printer such as I can print the carbon, carbon ink then what I have?

I have this resistance, now if I apply a voltage, then this will heat and this might becomes a heater. Same thing we can create a inter-digitated electrodes. See like this, you can print like this. And if I measure impedance, if I, if I put a tissue on this, then I can measure the different impedance of the value of the tissue. So, there are several applications of this 3D printing a particularly when it comes to sensor design.

Recently people also have started creating pressure sensors. And also for (human) to creating human errors, human ears. So, the human ear is by printing the tissues right and it is a very complex process, right now we will not go into details of how the printing is done for creating biological tissues but, but yes one of the applications is for printing biological tissues. Then we have also seen the application of 3D (printer) printing in micropillar structures for haptic.

So, to convert the force into a haptic is very important, to get the feel, the feeling when you operate equipment, the feeling of touch, like for feeling of how much pressure you are applying to a system, this can, this is called haptics. So, the haptics can be, can be integrated if you have a tactile sensor or a force sensor that can be printed using 3D printing. So, these force sensors or tactile sensors can be printed again with the help of 3D printing materials or, or techniques.

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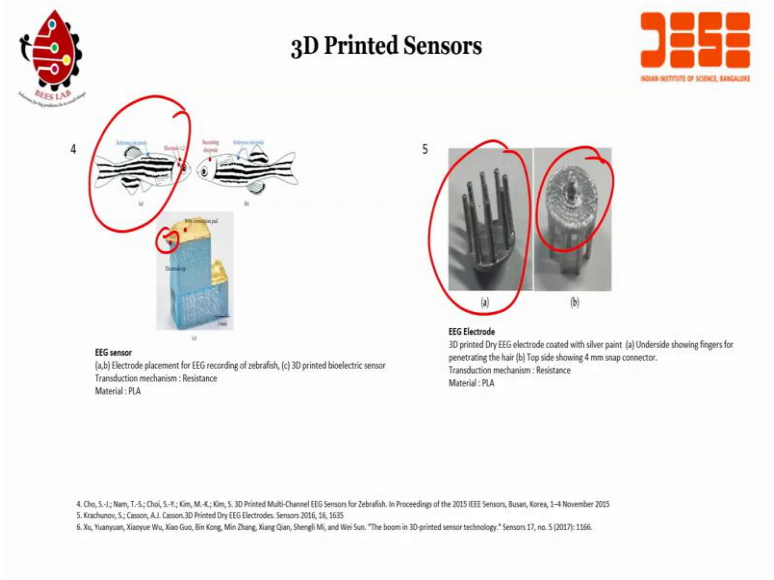

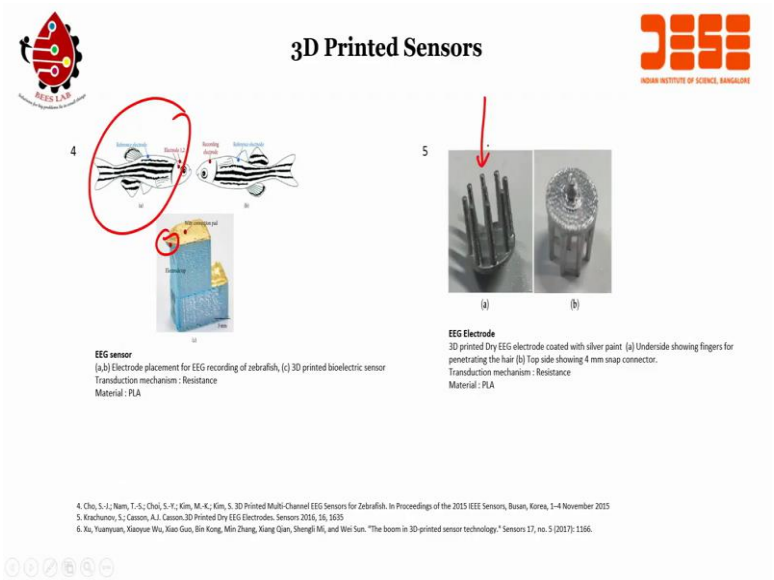

Even the recording electrodes can be printed and that is our idea for EEG recording electrodes. While there is an electrode cap, you can see here and above there is a wire connection pad, it is tested on the fish. And the same thing, you can create the electrodes with spikes, with the metal printing. You can see here also, so the top sides showing 4mm snap connectors, while this one is showing the fingers penetrating the hair. So, this is kind of dry electrodes that we can print with the help of 3D metal printing. So, there are ways like I said.

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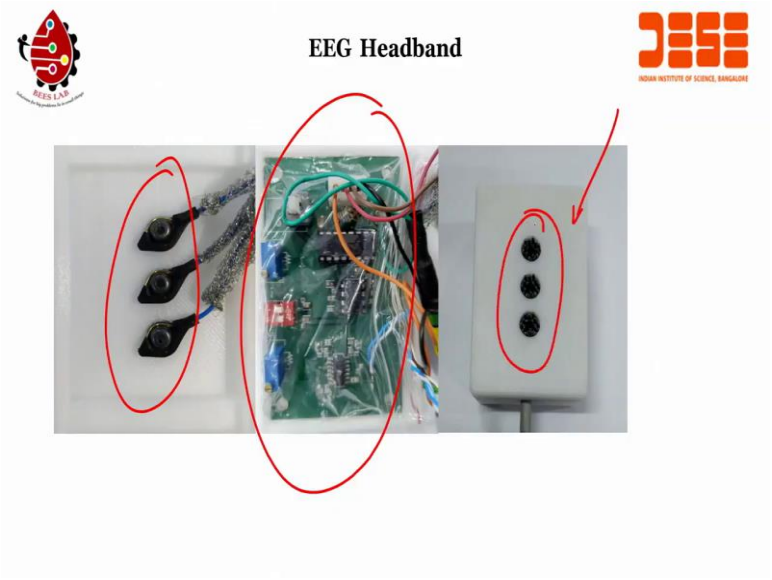

The application as, as I was talking about, you these are the EEG electrodes, recording electrodes. And this is the electronics that are used to process the EEG data. Now you want to cover everything in one box, then you can print this particular 3D printed casing, and you can cover it. With these 3 electrodes, you can place it on the scalp to record the EEG signal.