Design of Mechatronic Systems
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Lecture 47
Case Study: 3D Micro-printing via Bulk Lithography

We will now look at another case study, I mean, we are looking at 3D Micro printing as a case study thing, we look at a different technology in 3D Micro printing now. So, what we have seen is stereolithography based micro printing in the last case study. Here, we are talking about some different technology, but using similar kind of mechatronics for the systems, okay, so, we will do that now, okay.

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So, let us get started with this. So, if you see what we produced in the last study, micro printing technology is these components which are having this layered kind of structures, okay. So, these are at a macro scale, see, this is a 1 mm kind of distance here. So, in such a small kind of a distance you can print now various kind of components here, okay.

But you can see that the slanted surfaces will have this stepping effect, this is because we are stepping in the Z direction every time okay. So, the stepping in Z direction is the characteristics of this all these micro printing methods or the methods which are currently there in the market for 3D printing, most of them also are dependent upon layer by layer kind of a fabrication.

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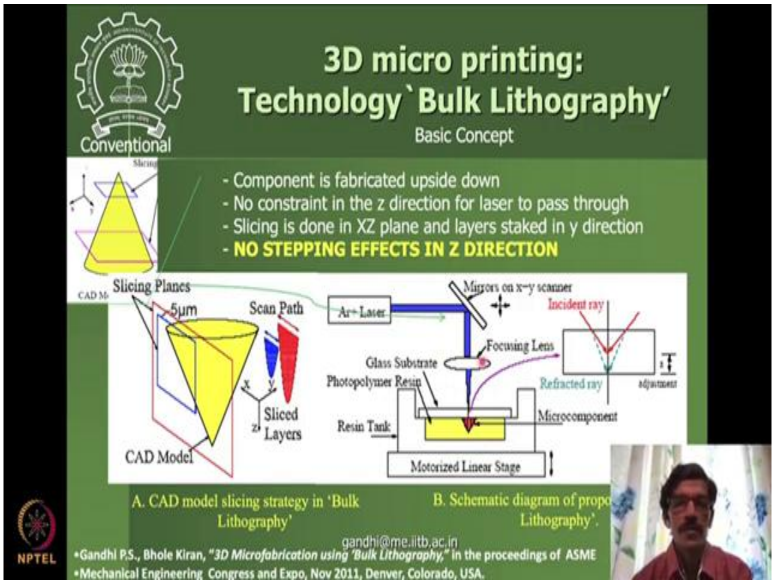

So, we thought we will do something different about it and then we started thinking that okay, what if we, what if we produce these components such that the photopolymer vat here has no layer, okay. So, that means this is complete volume here, it is complete volume production volume of the photopolymer is there and then we are, and then we are focusing the laser beam on the photopolymer at the, and the focus is matching with the bottom side of the substrate.

There is a glass substrate and the component is getting fabricated upside down inside this glass, inside is photopolymer vat on the glass substrate. Okay. So now if this is so, what will happen? Okay, if you can imagine, like this laser light, which is getting focused on the bottom substrate is going to form, it starts photo polymerizing indefinitely in the downward direction, will it continue forever? Those are kind of kind of issues that we will have to see.

And what if we start moving this laser beam when it is getting photo polymerized, when the resin vat here is getting photo polymerized. Okay, so while it is focused on the bottom surface, if we scan it further then it will form this kind of a wall, okay, so this wall is getting formed. And if I want some shape to be given to the wall, okay, normally, if I do not change anything in the system, I just focus a laser beam, it starts penetrating down, and I scan it in one direction, it will form some kind of rectangular wall.

If I want to change the shape of this wall, then I just like I have some acousto-optic modulator to change the intensity of the laser beam. So then I use that, as we saw in the last presentation there is acousto-optic modulator is a switch, but it can have also possibility of changing the intensity of laser beam, okay, so when we change the intensity of the laser beam, we can start forming the shape to that wall, okay.

And that is how one can have a fabrication, where now the stepping effect is little lesser than before, of course, when you go for the next scan, there will be some kind of a small stepping effect, but now that stepping effect will be much lesser than what will have in the Z direction because Z direction stepping effect is governed by the liquid layer thickness, okay.

But here now, there is no restriction of the liquid layer thickness kind of we are fabricating this entire volume of the liquid here, okay. So, that is a difference that will happen in this process. Now, if you see the mechatronics of this is again similar kind of mechatronics that will have to, will be using here.

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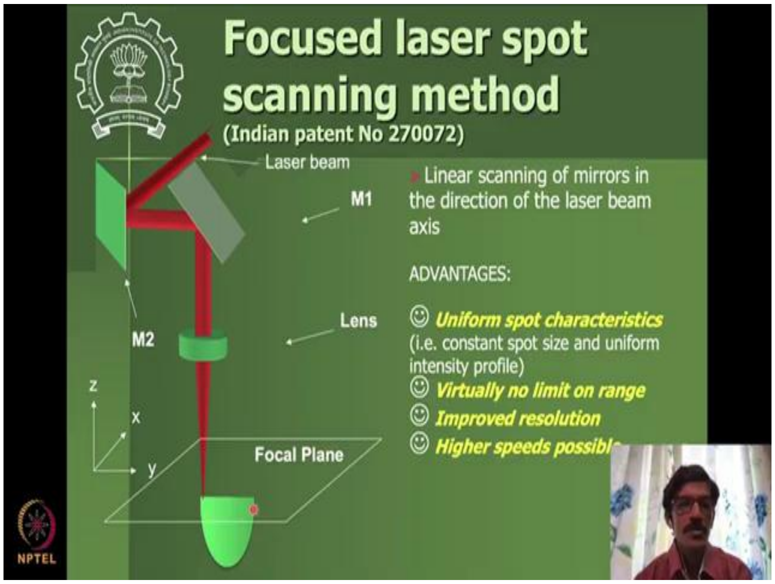

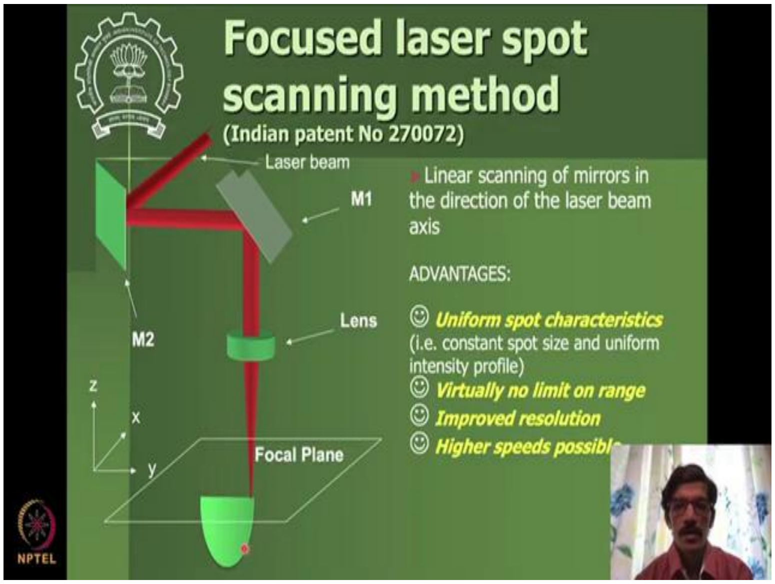

So, let us say the scanning system now is same as what we had before also, but now the technology is little different, we are not doing anything layer by layer now, so what is happening is when this is getting scanned, you start for fabricating something below the focal plane, okay. So below the substrate you get some formation happening here and there is no constraint for the beam to stop fabricating okay. As much as it can penetrate, it can fabricate, okay.

So, this kind of a way of doing things is going to produce some interesting kind of a components that we will show, okay. So, only thing difference here is the technology and now how do we move these laser beams in the same kind of accuracy fashions; is by using again know that compliant mechanisms in this case also, okay.

So, build compliant mechanisms around this technology, then like no build your now tank will be different, z stages is not there in this case at all. So, z stage we can remove and then there is no tank, there is the tank is different, the tank is filled with a liquid photopolymer and on the top there is a substrate glass, okay, and at the bottom side of the substrate you are going to get component fabricated. Okay, so we will see how this is put together now here and will look at this video, okay.

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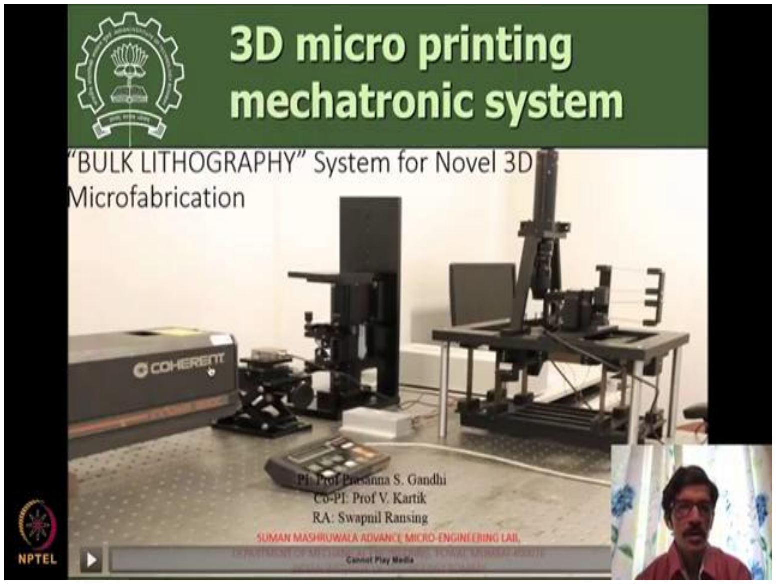

So, this is again we are using the same laser all other things are same. So, here is your coherent like the laser is there it is be steered by some optics and then it will be falling here on this cell system setup. And then you are going to kind of have the fabrication done by using some kind of motion of this XY stages in the compliant mechanism kind of way. And then there is this observer, the camera through which we can observe how things are getting fabricated and things like that, okay.

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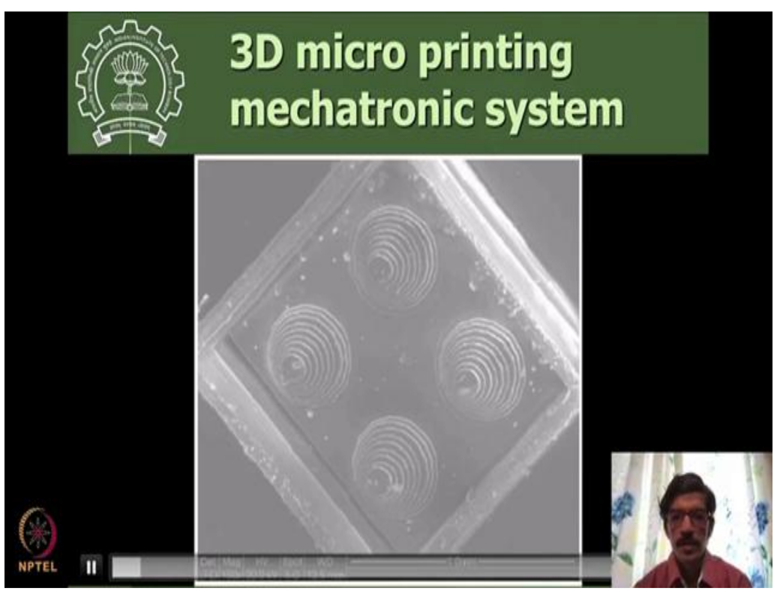

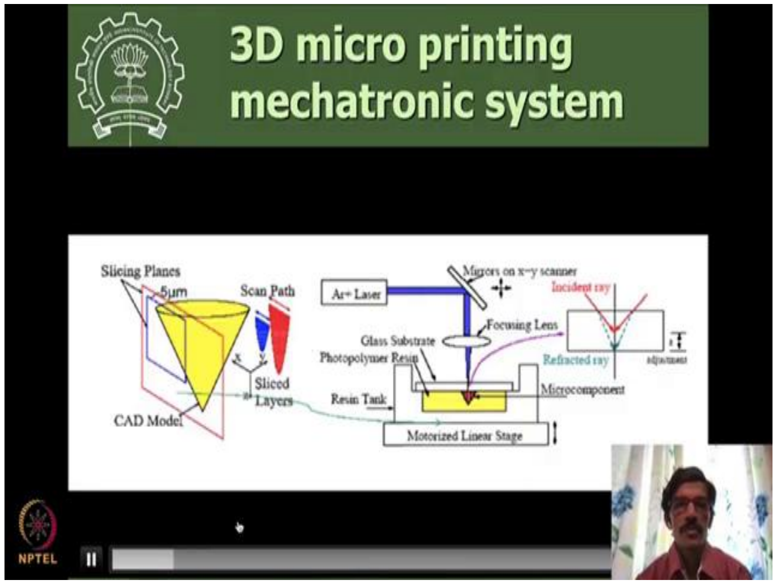

So, let us see that okay, you can see these are like components which are fabricated with the stepping effect in the previous technology and that is why this technology as I explained will be of help here, okay.

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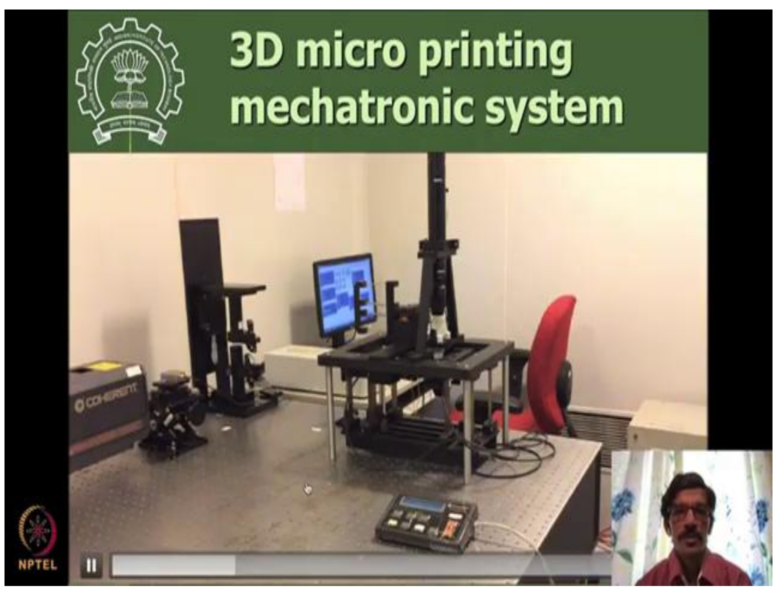

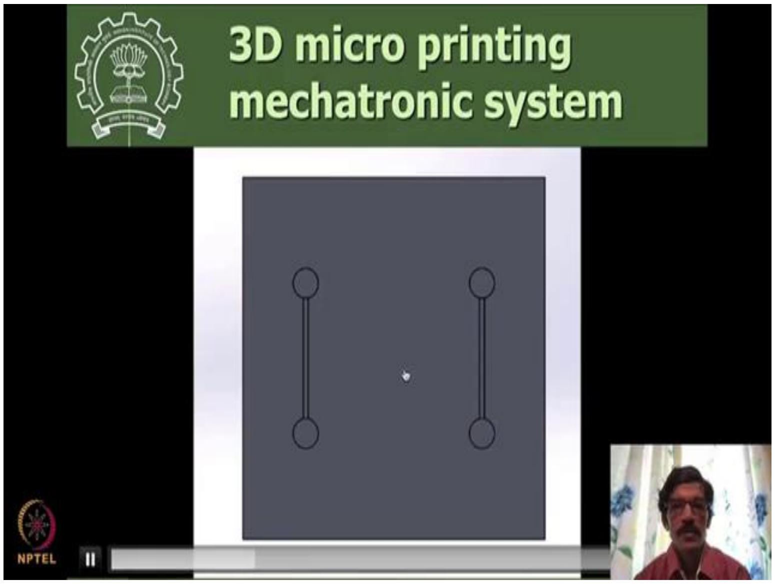

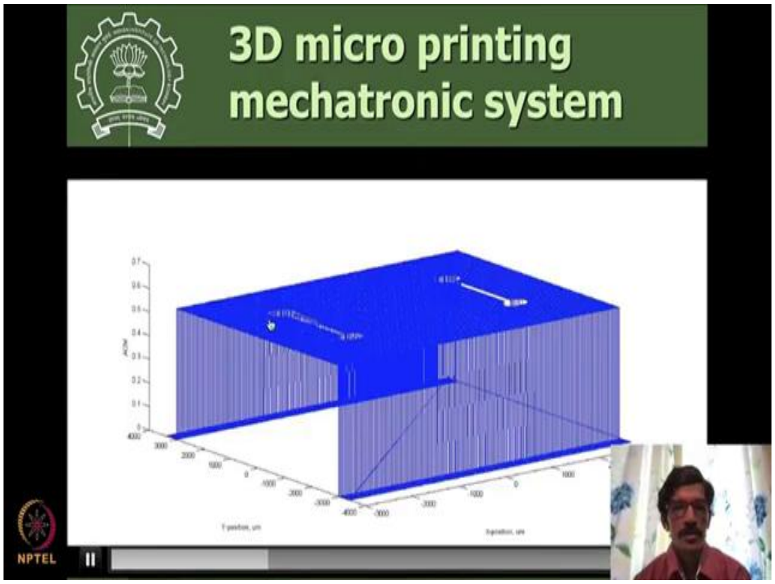

So, you can see the system here and the system this is a laser control panel, then you have, say suppose this is a component that you want to fabricate then there is again some kind of a MATLAB program that is written to get that slices done and the laser intensity mapping done.

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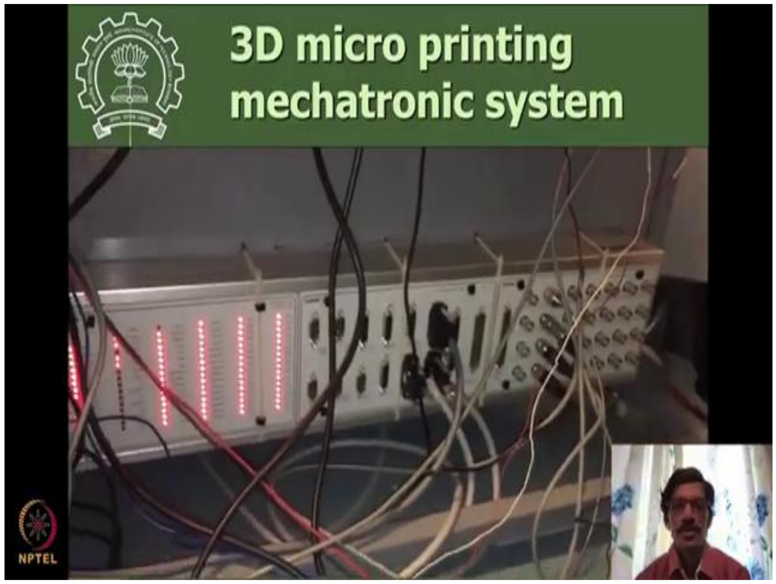
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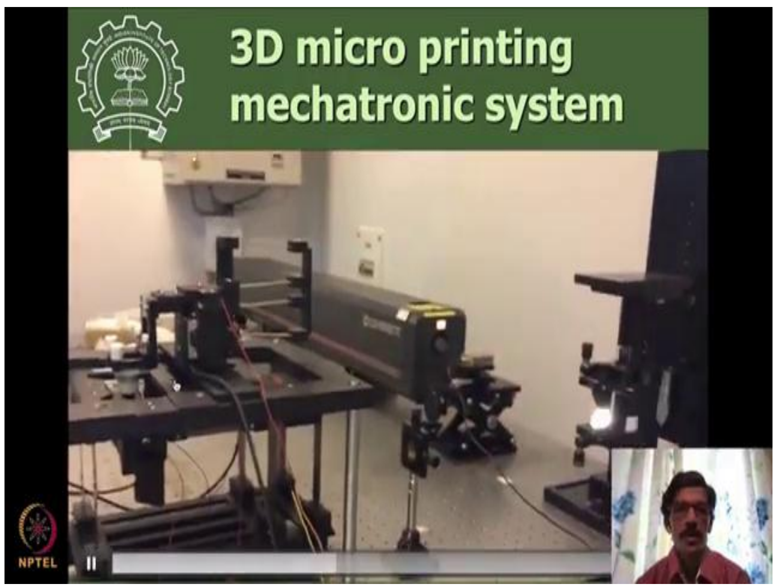
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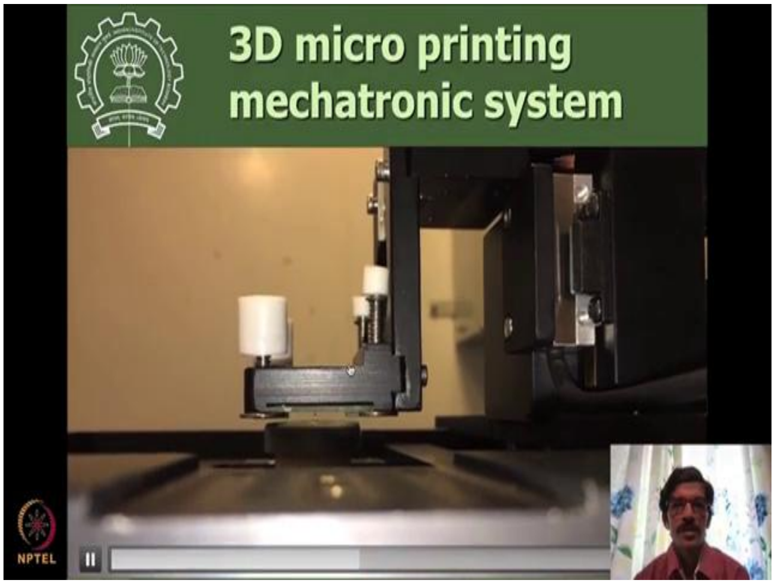

All these things are done in the software and then you put together all these in the system this is a dSPACE controller, then there are these voice call amplifiers in their power supplies and all these things are operating this system here, the voice coils are there inside and then this is a z stage. Now this z stage is stationary here is only some small adjustment if you want to do for focusing purposes the z stage will be moved.

Otherwise it is going to be completely stationary okay and the beam is coming and falling on the stage like that okay. So, this is how it shows how the stage is moving. So, you see that this operation happens here without any noise, okay there is no friction, no lubrication required and there is no noise in the system as well okay, because of no fiction okay.

And it is very silent operation you will find these stages are operating is acousto-optic modulator unit here laser comes out of this and it falls goes through this acousto-optic modulator and then falls on these mirror system steering mirror system. And then finally the moving mirror said it goes to through the pinhole, okay.

And that is how things work here, it comes out of this small lens here and it gets focused on the bottom of the side of the substrate and here it is what you are seeing here, it is scanning now, you cannot see the substrate is also transparent and then the photopolymer is also transparent and you can finally see only the component that is getting fabricated, okay.

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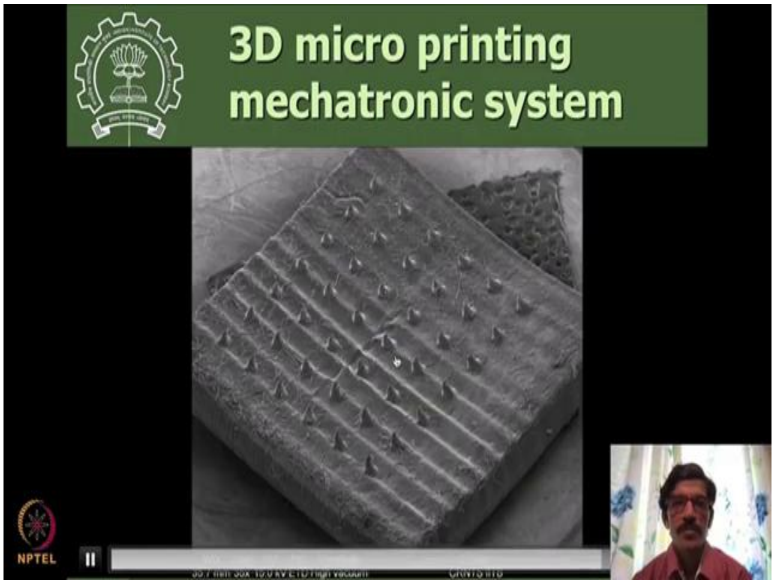

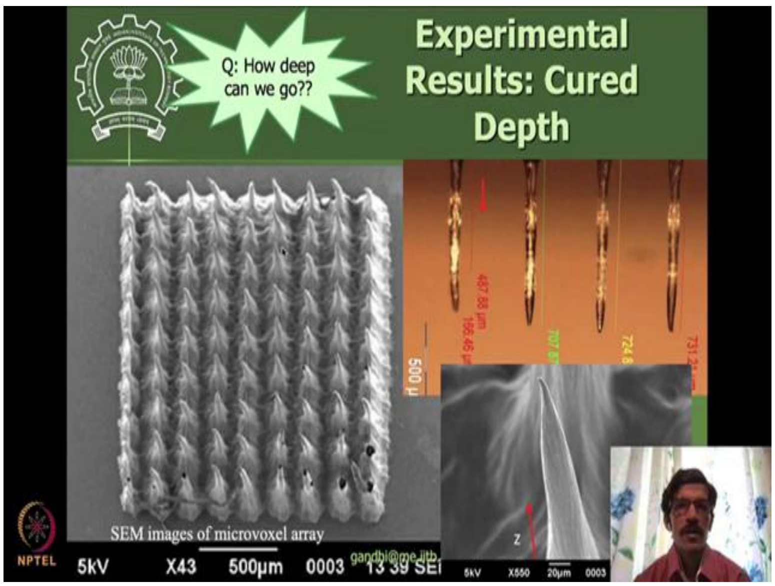

So, these are like micro needle like patches structures can be fabricated very-very easily by using this bulklithography system, okay. So you can see some more kind of components fabricated here where you have this needle like structures getting fabricated very-very easily. And there is some kind of typical nature that you will see here. You see there is some kind of a necking happening here, and then again bulging and necking and again bulging and necking that kind of formations are happening, okay.

And there is some reason for that, okay, we explored these in the mathematical way by studying its modeling, okay, modeling of these phenomena. Okay, I will show some results about that, okay. So, from Mechatronics perspective, what do we need to control is like okay well, if the laser comes at one spot, how long it can stay there?

Okay, that is one kind of a control that laser, if it is staying longer time, then this penetration will happen to more depth and you will have this longer and longer needles coming up, also the needles will increase in their width at the bottom. And if you want very tiny needles, you just do this, like you go to some spot and get the laser focused only for a short duration and then you will get a smaller needle, okay.

So, like that you get a very good control over the size of the needles that you get out of this process. Okay. And this will be very useful for generating the micro needle patches that usually are now nowadays used for drug delivery into human system, instead of like we have big needle pricking your skin, these needles were which are very tiny, they you do not feel that they are picking, okay, but it is still there, drug can be delivered to these needles, which is by coating the truck outside these needles, that is it. We do not need the needle to be hollow in many cases okay.

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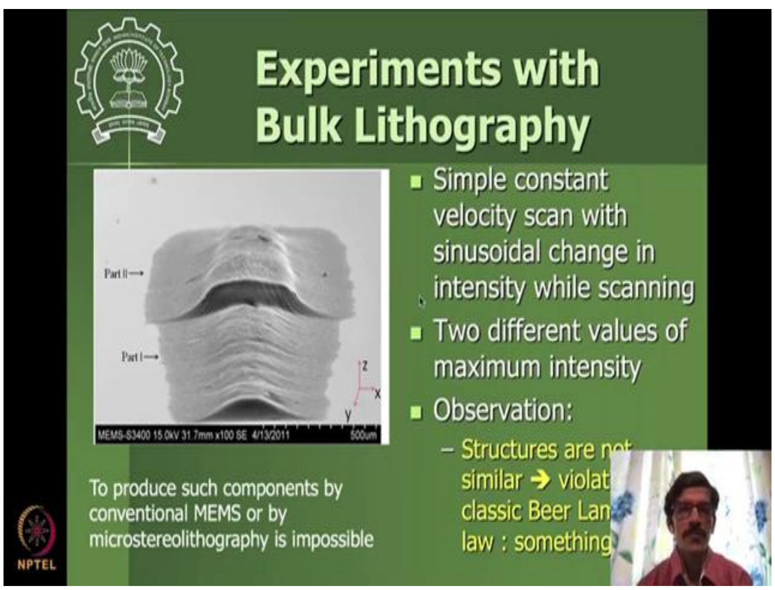

So, so, these are when we start scanning you get this kind of a very smooth changing patterns and the stepping effect you can see in the y direction still there is a small stepping effect, but it is quite less here and then there are more kind of a finer observation that, okay, if we increase the intensity, the same kind of speed, the pattern does not repeat itself, okay.

The pattern is completely different here than here. So, then we started investigating into these details and then we make use of all the sensors to sense the data and start finding out okay, what is the reason for such a kind of behavior and that investigation leads us to some kind of research findings, okay, that is how typically the research goes, okay.

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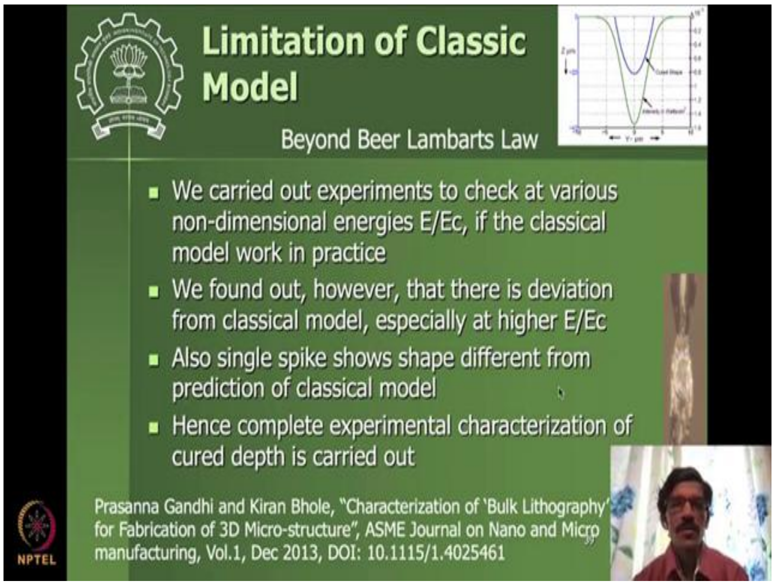

So, typically, there is a law that is governing the penetration of the system called Beer Lambarts law and Beer Lambart Law does not predict this kind of behavior necking pattern happening, nor the behavior that we saw here like it has some kind of a saturation reached here that happening that is not predicted by this law. So, that is how like you start looking at now, new kind of phenomena, what is happening here and what is leading to formation of such patterns which are having like know very strong necking behavior observed here, okay. So, that is all is explored or investigated further to get to some kind of interesting findings, which are published in the literature, okay.

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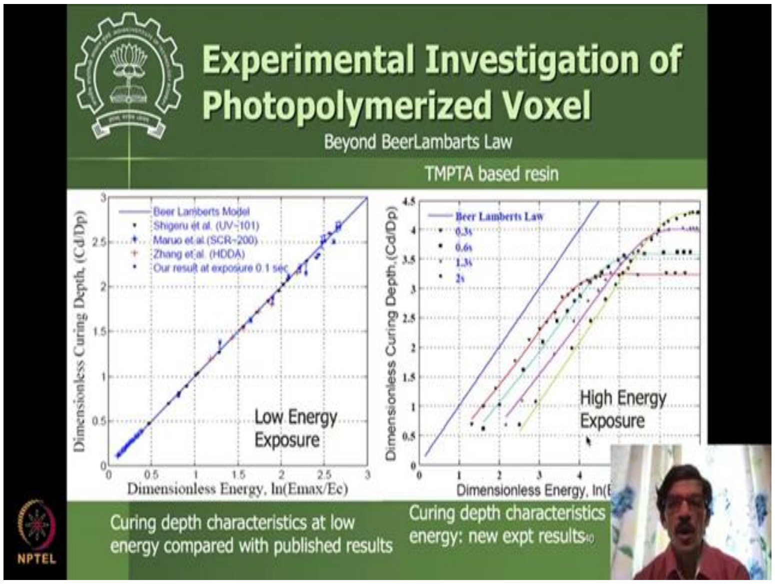

So, these are the details of the plots, how this Beer Lambarts Law, how our results match with the literature Beer Lambarts law results, and they are falling in the same straight line, but we have carried out some results beyond some like exposure levels. So, higher energy exposure, when you do there is some different very completely different picture that is observed here. And that is what we characterize further and model further.

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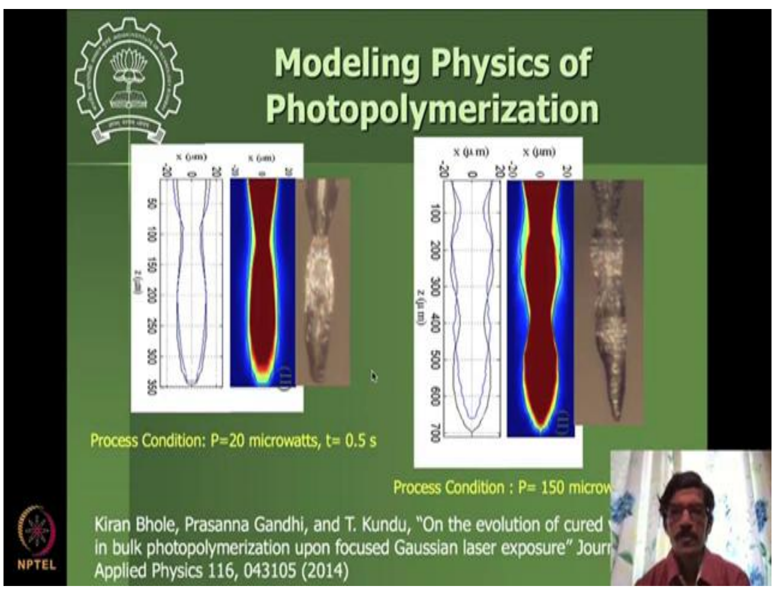

And you see that there is a if you model this by our model and compare with the experimental data, it gives very similar kind of results and this very interesting finding. And these are useful for the cases of if you want to have the needle to have this kind of a necking at the bottom that needle will be better gripping the surface of the skin that it is applied on, okay. So, those are the kind of application areas one can think about.

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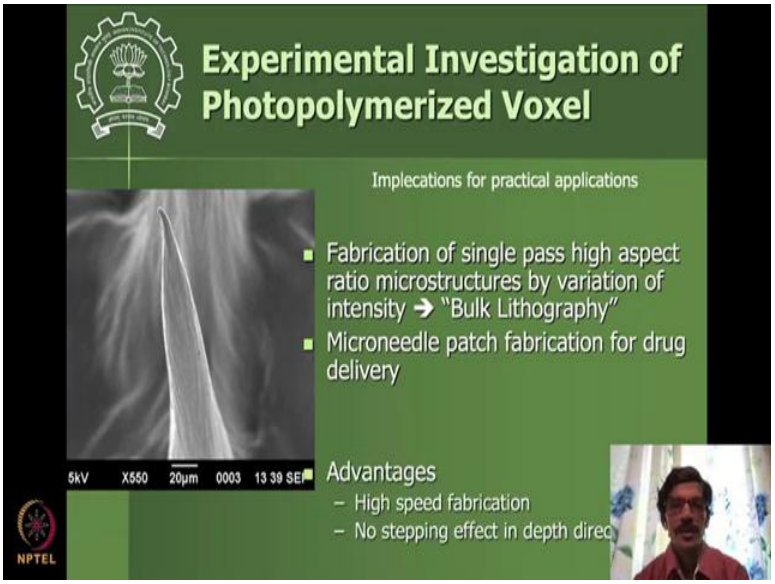

So, these are like we study this implication for the practical purposes for microneedle patch that I was talking about for drug delivery, okay. And then some micro lenses systems and things like that, okay.

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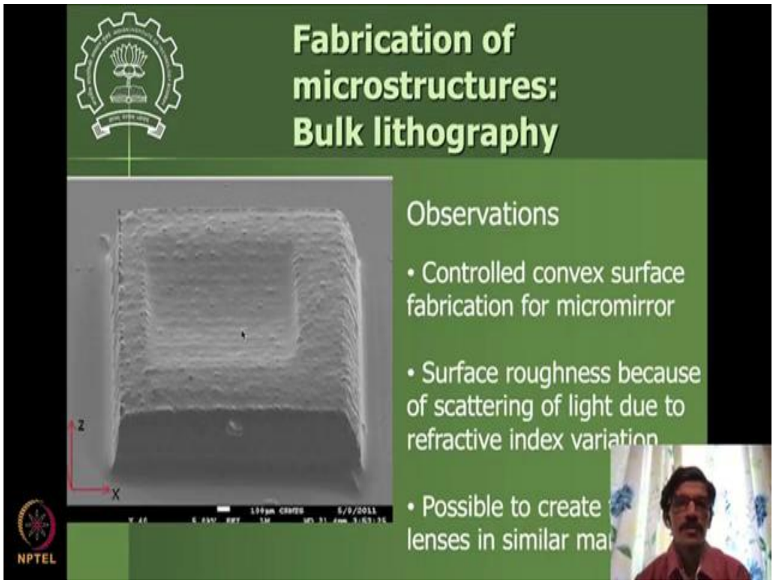

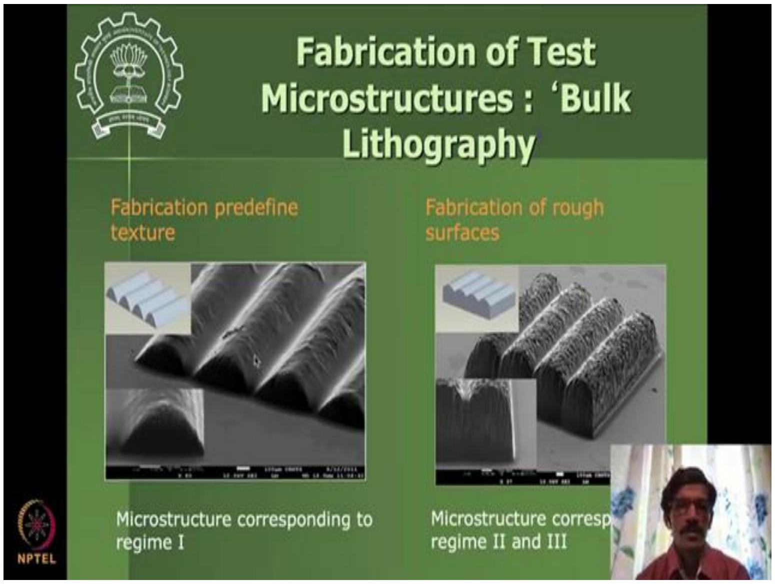

So, there are different-different micro structures fabricated by this process. And you can see that you know, at very small scale, we are able to do interesting structures possibility there are this lens array kind of structures here okay.

And here, we do not have these undulations from the CAD model, but because of very high intensity kind of exposure, you get these very rough surfaces on this and they may be useful for some sensing applications and things like that.

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Okay, so, these are like again, we conclude this part saying that we have these different technology and different kind of a little bit different mechatronics for such a technology, where we still have compliant mechanism based scanning systems, but now control and the positioning of these for different components fabrication is different, okay.

And again, these can be converted into a product for specifically targeted to micro needle patch fabrication by using some kind of embedded programming for microcontrollers, and having some kind of a human interface, human machine interface HMI given by some kind of a touchscreen or some buttons or things like that, okay.

And then this can be other product, which is, through which we can produce different kinds of micro needle patches for many different applications to come. Okay. So, we will stop here for this application, and we will study, let us see any other cases in the similar way, so one can mean what one I can see, say that, you can look at these case studies from the perspective of that, okay.

Look, if I want to get my new kind of a system developed in a similar fashion, okay, it is not very difficult to do that, okay, it is just a matter of like, you know, you are looking into things in a different way and see, okay, well, I go through this training that has been received in this course, in terms of having different sensors identified for this particular process that I am thinking about, what are the different actuators I should identify.

And then how would I put together these things to make them work; and wherever you feel that okay, well this particular area is of not your expertise, you can always borrow expertise from other places and start putting things together and realize your dream applications in this way, okay. Thank you very much. Will close the session for now.