Microsystem Fabrication With Advance Manufacturing Techniques
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Lab Session-04
Laser Machening Process

A very good afternoon to all of you I am Shantanu Bhattacharya, and today I am actually going to demonstrate physically how you are able to generate micro channels with in p m m a material using the laser, and graving process in our lectures, earlier we have a made detail study of how laser machening works is basically, based on a beam mater interaction there is a surface a which if attracting with the beam would absorbed the beam,, and because of the absorption coefficient there would be a local heeding. So, there is a photon to phonon or a vibration bond vibration conversion, because of which there is a local increase in the heat, and the heeding goes up to an extend that it starts to locally a vaporize, and melt the material, and there is a change on the solid density a a in that particular zone of interaction. Which goes into a the particular material, and this is really the process of engraving.

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So, today we have with us this small laser, and graving, and cutting system which is from company called epilog this tool is working on the principle of a small ton micron spot of laser which scans, and raster the surface a that is grading the engravement or the formulation of the microchannel within soft, and hard polymeric material. This is a the machine cover, and you can see on the left corner left upper corner here of the system there is a small lasing head, which actually is a c o to laser, and the the head is assisted mechanically of rather electro mechanically to move in a manner. So, that it moves like a inject printer head on the top surface of the machine, and rasters the machine in a line by line manner. So, the red actually the the red laser spa the c o to laser spot moves around in a linear manner line by line manner, and scans a the whole surface at a resolution of about fifty microns between the two lines.

So, if I go to divide this surface by scanning it into lines of the print a different types, and natures the minimum spacing between two such lines is about 50 microns, and this really defines the way that the laser a is used for cutting on soft, and hard polymeric materials. So, therefore, we are really limited on to the process of getting resolution up to the extent of 50 microns. Therefore, anything above 50 microns can really we extend formulated using this particular machine a there are other systems of laser and. In fact, I am going to talk about that a subsequently in one of the presentations were, you can see when higher accuracy lasers, which can go up to a spot size of probably an micron, and a superfine resolution achieved by series of demagnification a techniques which would eventually be able to right, at 10 micron by 10 micron feature arrange on to metallic surfaces as well as polymeric surfaces.

But in this particular application as we are intending to show you way to fabricate of microfluidic channel for a microfluidic devise, we really a can limit ourselves to this resolution of about 50 microns our channel sizes in the correct application at we are not a less than 100 microns. So, you can easily use this lasing machine for such a application. So, the substrate that I am going to use.

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A for doing the whole process of laser machening is a polymethyle mithecriled sub straight, you can see you say clear flexi glass a substrate of thickness about two millimeters from the edges you can make that, and this is a material for actually doing replication, and molding of sub polymers like p d m s etcetera if you can change the surface form position a little bit after the process is over.

So, today throughout this experiments. I am going to take a through series of steps we are we are going to for a h the microchannel on to the system, and then with this h microchannel I am going to from modify the surfaces in a manner. So, that it can act as a molt micromold, and then in another part of experiment, we are going to use a polymeric soft polymeric material called polydimethyl siloxane. Which can be its like a epoxy rubber which can be poured on to the top of micromold with some suitable release agent which you are fly to the surface, and you are able to separate that later. So, that whatever a channel line features or other structures you have embedded on to the system is replicated the negative of that is replicated or casted on to that liquid material.

This process incidentally is also point a with a terminology micro replication by double inversion or m r d I process. So, coming back to the lasing business a as you know here as as I already defined this laser spot needs to be a calibrated properly as to the extend a focus that it would have on the sheet, and the step by step a approach is that you first up all put this substrate lasing ne below the lasing head on the laser on the on the cutting bed of the machine, and a you had first switch on the machine, and try to be able to calibrate whether the focus a of this laser is matching, and for that you are using a sort of jig which has been provided by the system manufacturer, we should talks about the exact that from the lasing torch to the surface were it is a change were the focus would be right, about a for the lasing action we have one thing you had to remember is that the p m m I surface is highly shiny in nature. Which would create a lot of power loss, because of reflection, and our group here as formulated a diverse amount of strategies were such optimizations can be performed corresponding to the different cutting parameters. So, that a by minimum usage of power you would be able to generate a very fine finish or fine surface.

And I am going to detail those optimization experiments in a later presentation module, a which eventually would come after this a experiment. So, I am going to now put this jig on to the system here you can see it is magnetically assisted. So, it basically goes, and clubs on to the laser mounter a laser mount, and a this kind of gives you have feeling of how much depth of focus it really needs to achieve for the laser to have a good focal spot, and what we are going to do is to calibrate our system by taking up this bed by suitable distance. So, that it start just about touching this point here a while leaving a not very high pressure on this particular jig. So, that you can actually put it on the focal spot of the lasing surface I switch on the machine, and it will take some time to initialize you can see there is a controller here, of this machine which has been a built in by the manufacturer, and there are several options on this controller which says different a or which is row different aspect like go stop resets peat power set home x y of job focus down up a pointer. So, on. So, forth.

So, what I am going to do is to first calibrate the system by turning on the focus spot here, and the movement, I say that we will see that a the lasing head has now come on to a certain point which is probably the x y zero of the system, and it is going to now a able to a set of the focal spot of the laser. So, I can move the lasing bed up by the z motion control there is a motor on a slide in this direction, and you can see this bed coming up clearly till the surface of the work piece touches just about touches lower portion of the jig. So, this is actually a still not touching. So, we can actually go a little further ahead, and this is right about the focal spot of the laser that it has achieve you may just try to recall that if the surfaces are various thickness, you may use thicker substrate or the thinner substrate accordingly the zee motion would be different, and therefore, this motion, and this calibration needs to the somehow incorporated on the system itself.

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So, what I am going to now, do is to sort of take off this jig, because the purpose of its focusing is over, and there is again if you look at the control panel here on the controller there is a, and indicator called pointer. So, if I press this pointer system is going to generate the spot a which is actually. Now, very much visible if you look from the top here, and are the lasing is like this. So, it is at a certain angle, and I can actually see that there is a very well focus spot that is formulating on the top of this acrylic slide, and one more aspect is that the point to this use not only for checking the focus, but also see how the rastering action of the laser head happens, over the surface of this acrylic sheet. So, supposing if the pattern that, we are eventually going to generate through a software a is not readed properly by the machine. There has to be a way to find out what is the track or modality that this lasing head is following or whether it is different, then what ever pattern was intended to be engraved on to the surface of the a p m m a sheet.

So, that is why this pointer. So, I will just now as if now close this pointer, and will turn it on later you can see there is a red dot off command which comes on the top this controller let me make it very clear that, this controller here is mostly a for manual applications the machine as an interface with a software, and typically is driven by the software. So, whatever a formats are generated which actually are drawn in a package a computer designing package in this case it is coral drop a that that basically converts into a numerical data, and there is a format like data exchange format or p d e s product data exchange pacification format, which is followed. So, the date is translated on to the controller here, and beyond that the controller executes set of commands to the various motors, and the various slides which are present within the system. So, electronic data or numerical date comes on to the system, and a makes the controller to execute different motions along the different stepper, and a analog motors which are available, and the drives there in. So, that all this mechanical action of scanning rastering etcetera can occur of this head on the top of this whole work is surface.

So, I am going to now close of this led, because we are kind of done with the a formality which is here the only other a command that we need to use, because it is an automatic control that I am teaching today is the go command which will be used once our software is process, and we are able to draw a feature which we want to engrave on to top of this a flexi glass slide and. So, we just need to forget about everything else regarding this controller which is used in case there is a manual job which you are process.

We are now going to a illustrate the way that use a computer aided design package for a printing material or different shapes, and features which are useful for our microfrotic devises using this a lasing system or a laser engraving system. So, here we are using this package coral draw x five a we go into a the package an open a new blank document, and the document shows a reference size which automatically gets its a default size which has been certain to the system a which is not same as the size of the acrylic sheet that we have put in the lasing engraving system. So, I am going to actually change the template size here to the size of the block a by going up here, and making at 609 m m which is which is what the length of that block that, which is put in the engraving bed is, and the width of that particular block is about 300 m m, and we get new set of template size which is similar to the block.

The advantage of this a process that we at is initialize process that we are doing is that we are trying to make a high through put production, and the idea is to be able to judiciously utilize the whole a acrylic sheet that we are going to get a engrave using lasing and. So, just as in silicon based lithography we have a concept of bi size here also each devise would be contained, and a certain size or certain domain of this wafer which is not be totality, and it is called one die. So, we are having multiple options of printing is dice on to this whole template. So, that in one engravement you can a various shapes feature sizes etcetera engraved o n to the system, and then we can actually use either c n c milling or some other process even banked. So, based cutting to cut these dice sizes out off course it will not have that fine resolution as a silicon processing would have, but in our applications here I think considering the faster speed of the process, and also a you know the need of going beyond under microns a we can easily manage with such a system to be able to produce secured enough for our applications.

So, here I am going to now, first a introduce the dice size by selecting this tool on the left corner a in this particular zone here is called the rectangular rectangle to, and I am going to actually layout this rectangle a in one corner of this template were I would like to position this not at really the edge of the of the acrylic block, but at some distance away a in order to ensure a proper template size be machine a with flat edges, and what I am also going to do is to sort of change the units here little bit.

If you focus here on the ri on the center co center a spot of this screen you find out a set of commands call units were your here different units which are use we are using the inches a scaled here particularly for the dice sizing, and the referencing. So, therefore, we will just change this to inches, and then the idea is I can do the selection tool on the left side again, and try to select this block, and this window on the right. Call the transformation window it pups up, and what you can do is you I can change the size into conventionally used dice size of 2 point of two inches a horizontal by one inch vertical a template size, and once the side has been said you can apply. So, that the feature has now a been converted into the template size indicated, you can once again do the selection of this particular feature, and try to take it to a the same spot as before leaving some allowance between the vertical edge, and the horizontal edge of the template.

Now, this dice size is very small a for application of a trying to layout some features here, which would eventually what encourage what down go to use the central curser of the mouse here to zoom up, and again go a line myself to central of the template a central of the dice crated, and we can draw feature that he want in this particularly zone here to should an graved, and dice the idea that, there is two approach the lazing up the fallow one is called vector scanning where only through cutting action in initiated, and then there is rastered scanning where whatever feature your trying to engrave on the inside of block gets initiated. So, these two feature is we can cut completely a dice size, and in graved in dice size very easily, and let, us make microfluidic small channel simply that we were talking about, what I am going to do friends circular reservoirs go to the left corner here select ellipse tool, and bring in to back dice, and a actually after laying at here scale again into millimeter through this tab central tab here, and there again tried to the selection of this particular ellipse, and make two m m bye two m m. So, because earlaps you have of question of major, and minor access.

So, here major, and minor access, because talking about circular reservoirs same to each other to make it two meter diameter apply this. So, actually gets formulated somewhere in this block we can actually pick this lips move it round to block where when necessary. I would like plays is somewhere this central of this block in the interest of final replication, and molding process we will do, and create the copy of this file again the same system, and move this copy all weight on other end of dye, and would generate an interconnect between the two reservoir circular reservoir by using again rectangle to now here the rectangle channel is intended to have a size of about let say close to 1.5 inches. So, I am going to change back the units again back to inches and. So, I am going to convert this rectangle which should be had here into 1.5 inches length converting the units into inches again making the selection of this rectangle go back here, and make one point five inches applied. So, that at goes to that particular length, and then again actually change back the units once more back to m m, and go further selection here, and do size. So, the vertical there can be point one mm or microns. So, this is how the channel real looks like I mean a I can now try to again select back these two features. So, that they can be moved to a both ends or both edges of this channel, and then we will see how it looks like in magnified a view of the assembly. So, we just go to this finer level, and look into how the circle is going to make an attraction with the channel you can see here clearly that there is some kind of a edge of the channel sticking out of the circle. So, I am going to know sort of move in a line it by making a selection of this circle, and moving it back to about this point, and similarly a trying to match a to accurate a stent extent all these different features, and do a similar job towards the other end where the other second reservoir is being placed here.

So, here I can again make a selection, and try to a line it more or less with the center of this change and. So, we have now a feature which is like a input output a microfluidic channel of about 1.5 inches length, and hundred microns diameter. So, once we have a set on all this we can actually a use control, and cut control the. So, what we are now going to do is to a make a selection. So, that we can combine a both the reservoirs, and the channel. So, once is whole a feature is selected I can go to the I can make a right click here cut combine make a right click here, and combine all these images together as a single entity. So, now, these all three a different geometric features are been combine together as a single entity, and what we are going to also do is to place or grab this, and place it somewhere along the center of this particular die, and again combine the die along with the whole structure by selecting on it, and a combining the whole thing together.

So, now, if I am able to a move this whole combine imagery, it we you know it work works as one group, and it can move as one group to were ever you place it. So, once we are done with this basic processing a we are kind of left with a lot of other space on this particular template as can be seen from the size of the block that, we had actually initially estimated, and you can actually copy a one of this blocks, and repeated multiple time; however, while doing that you do not really have a control on the positioning of these different dies across the whole screen, and so, there is a very convenient option which is a available here in the edit mode which talks about step, and repeat. So, what can be done here is that you basically, take the selection of this whole feature here, and go to this step, and repeat option. Which creates a window on the right here at pops up a window which says horizontal setting a, and vertical setting and. So, as the step, and repeat option means that either the copying would happen in the horizontal manner or the copying would happen in the vertical manner, and both of them not be together. So, in one of them you have program, no upset another you can actually have spacing defined between the objects, and it will simply copy.

This particular case let say, we want to copy this one die size vertically to all the way to from one edge here right here to the other edge a somewhere here, and that we were we want to fluid the vertical spacing of this one column which has been generated in a row wise manner. So, what I am going to do is to a provide no upset to the horizontal setting a tab, and then provide a spacing between objects to the vertical setting tab let say the distance between two such blocks is about one mm a. So, I just formulate this a, and select this to set it to about one mm, and the direction of selection can be either upward or downwards in this case, there is space left in the downward direction, and I can apply.

So, many number of copies in this particular case, because this is about an inch why. So, they can be about a this size about an inch which is about 25 mm, and there about three hundred mm a vertical spacing of the initial die size of the initial a a a p m m a block size the acrylic block size which has been use.

So, I can go with about nine or ten such features place to one below, and other. So, I just do 9 features here, and a I can actually apply this selecting the group, and it will actually copy a all these 9 in a vertical manner a let just look at the spacing, and just seems to be a one mm spacing between them I can actually go to a further higher size a to just see a you know whether this can be a spaced at a little more distance between each other. Let us make it about four mm, and that way we just limit ourselves to about close to seven such features let say, and we apply. So, here you can see that all this features are copied in a very nice manner across this in a in a columnar manner here.

A you can probably fluid many features in to this whole template, and then go for the machening operator. So, now, a you have multiple features here on this acrylic surface as you can see, and we will all a together print this on the acrylic surfaces in the engraving system. So, for doing this what we have do initially do is to save this file in a certain format in the certain name let, us call it advanced manufacturing process for microsystems fabrication this is name of the file save it on the desktop, and I can go, and do control p to get into the print menu were you can see the different options here. So, we select the printer as the epilog engraver a when 32 based, and we can also going to the preferences option here to set of the parameters that, would be needed for the printing. So, basically a you know you can print add about twelve hundred d p I, and these are some things which have been already optimized by our research team a through various design of experiments a protocols, and one such optimization will be shown subsequently in a a presentation power point presentation later after this a whole process is executed.

We set of the a operating speed to the sixty percent of the maximum speed, and the optimum power a to be about forty percent of the maximum power which is available a for the system, and the power, and speed maxima are mentioned in the a manual the service manual related this or any other system you had just see how much percentage of the maximum values you are using for your particular operation you have do also set the a total template size which in our cases about closed to 600, and 9 a millimeters by 300 millimeters which amounts to about 24 inches a horizontal by 12 inches vertical. So, its all preset here, and then off course a you can a after setting all this you doing this engraving direction top down a. So, therefore, you know it is option has to be selected there is also a bottom of approach which can be done in some other laser, and this particular machine operates mostly on the top down approach, and we make it. So, then we are now ready to set a the system. So, what I am going to do is to apply the settings to the a the controller of the system, and use the print option the movement I do the print command here the particular file name advance manufacturing process would be displayed on to the a else the a the monitor the lcd monitor of the controller.

So, I am going to now to the print option here, and o over to the machine. So, as you can see here the job one reads advanced manufacturing processes which means the corresponding file which was a transported from the software as now been receipt by the controller of the laser engraving system. So, probably the d x f or the p d s whatever the specification format comes in a the numerical data transported in the same format. So, now, the machine has read the drawing, and should be able to print just as a inject printer

So, all what we need to do now, just to switch on the pointer to see how the laser spot fa rasters over the surface, and whether it is doing the job properly, and then a do the go command the movement there is a the go command is executed the laser head would start rastering, and scanning on the surface. So, it is a pretty fast process you can see a features being formulated one channel as already been made in this particular area, and this particular zone as you can see, and there are many multiple channels which are being in printed, and a very high rate of machening, and this itself shows that how high through put or how I yield this lasing processes a, and it is similar to the yield that conventional lithography process would reduce, because you have to remember that in a lithography there is also time associated with making of the mask in the chromium a a coded glass plate where there is substantial amount of this laser time which is there for the mask to be made all the lithography is a one shot go the light falls on to the through the mask, but mask making is identical process here.

Here a only one shot the whole engravement happens on to the surface, and once it happens we are done with all other steps we do not need any other chemical steps following that you can now see also you can actually here the a sound of the system . So, you know seen that the rastering action is happened, and all these different features have been printed on to the p m m a surface.

Now, we have to actually do the better action meaning there by that these individual templates need to be removed from the acrylic piece by piece, and for that the common or the way that we proceed is more or less same we do control p, and go to this epilog engraver option here do preferences, and the only other option that we have do certain is the different cutting parameters as we know in this particular case it is going to be a more amount of well time, and higher amount of power. So, therefore, we have to reduce the speed, and also increase the power.

So, here what we are going to do is to basically go to the vector mode, and now do the power speed standings here take the speed to about close to 8 percent of the actual maximum speed, and let the power go all the way to for 100 percent of maximum power. So, you have more duel time more power a. So, that you can actually penetrate through the two mm sheet, and be able to cut it vectorially, and you can increase the frequency of the laser all the way to about 500 huts 5000 huts. So, once. So, these parameters again have been based on lot of design of experiment studies done by the research group, and we are going to a represent all these how this optimization has been done later on eventually.

Right now I am just going to show you the machening process. So, you make this, and then apply the settings to it, and then do in similar manner we do the print command and. So, automatically the file will now, be able to go back into the controller, and start cutting vectorially. So, you can actually see now job number two here which is the same file essentially, but the here we are changing from the raster mode into the vector mode. So, that the each individual die can be separated. So, it is actually a die there, and what we have going to do here is to just press this go button. So, that now you can see that how a the lasing spot is able to h of vectorially the die template of each feature, and structure and. So, therefore, you will have a series of these die is coming out at the end of the day a which would formulate the bases for all our application in molding process in the next the step of this experiment .

So, we are now going to unload the machine of the work surface our piece as you can see here the individual pieces which are formulated as engraving on the center by the rastering action, and a full scale cutting on the sides which makes, it of die size a two inches by one inch, and I am going to now pick of this acrylic sheet, and leave back the material which is actually cut, and which can be uses template. So, this for example, is one such template that, you can see were the edges are vectorially cut, and the center member here is rasts a you know rastered or raster cut I am going to use this further for application process whether is going to be a liquid polymer which will create negative of this, and will take another step were will create a negative of that negative which will exact same engraved channel on the topic that polymer which would using for our further microfuidic applications.