Lecture 14
Inject technologies
Drop on demand

So, we continue with our, Digital Printing Lectures.

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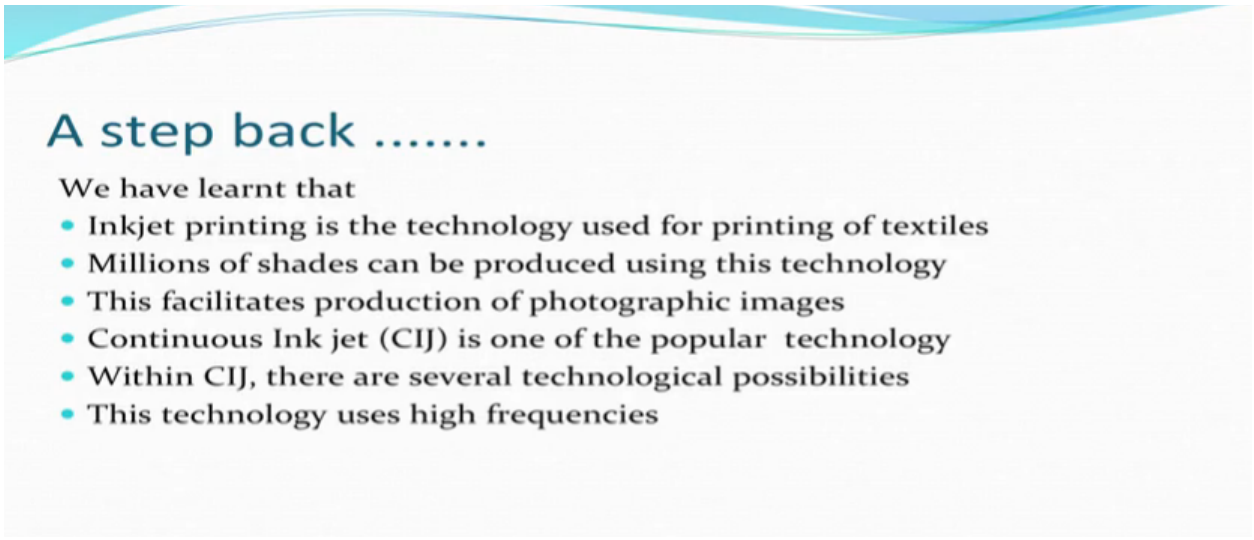

So, we learnt, till now, that Inkjet printing is the technology used for printing of textiles. Unlike for paper where, LaserJet also is used. Millions of shades can be produced using this technology, this facilitates the production of photographic images, continuous inkjet, delivery is one of the technologies, within that continuous, you have several possibilities, this technology generally uses high frequencies, because continuously you're supposed to generate drops.

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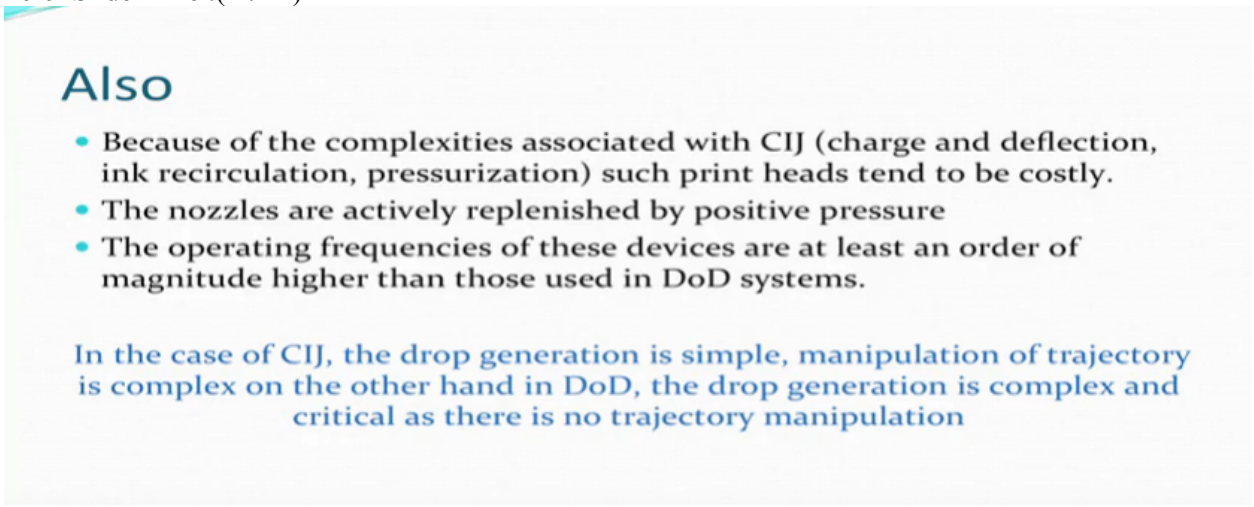

So, because the complexity is associated, with the continuous inkjet, charging of drops deflection of drops, ink recirculation because you are putting part of the ink in the drain and pressurization. So, that the continuously there is a positive, pressure it keeps on replenishing itself, as I said operating frequencies of these devices could be at least an order, higher, in magnitude than those, which may be used in drop on-demand systems.

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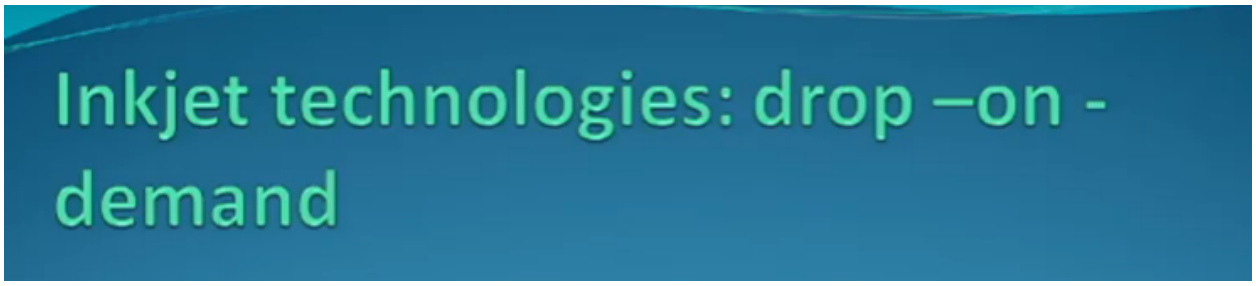

So, we will see some of the things for the inkjet, technologies like the drop on-demand, what therefore it means is that you do not. Continuously keep generating drops; you generate a drop when required. And so, if the design does not require any ink to be used, then there is no drop generated. So, therefore you do not need to have any drain, any such thing and recirculation of the unused, ink.

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One of the material that is used, to excite and the ink surfaces or the bulk. So, that the volume within the chamber, is changed let's say by squeezing, a large number of piezoelectric systems may be used, for generating drop on demand process. So, piezoelectric material is B one of the transducers.

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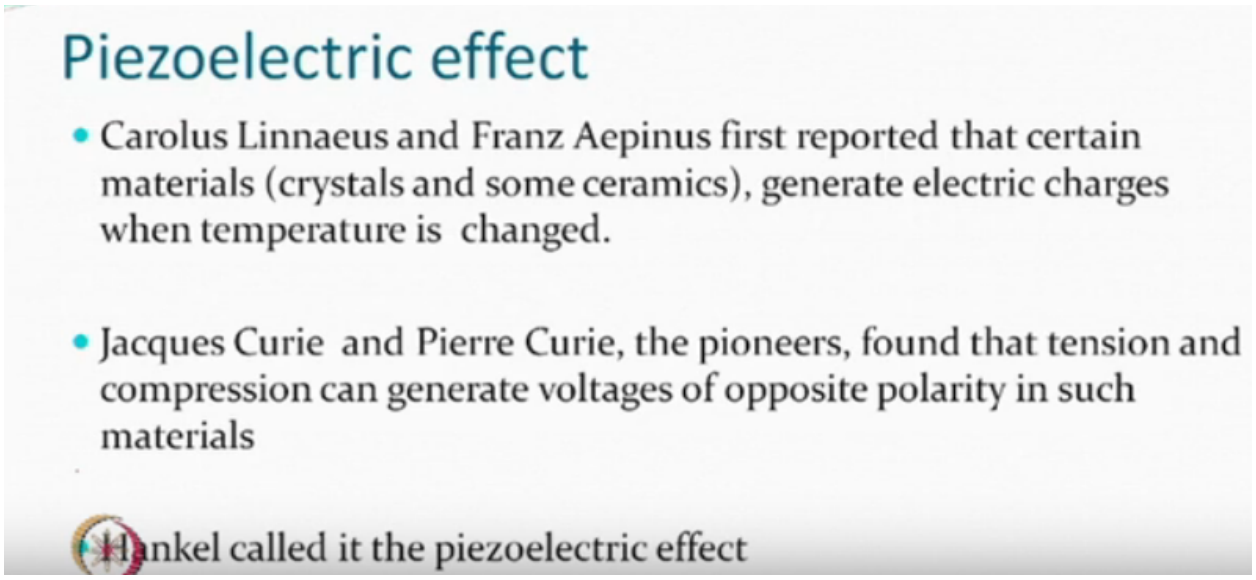

So, historically we do not, we have to understand it somebody, in the early days, noticed, that some materials, some crystals, some ceramic, material generate electric charges when temperature is changed. So, the observed change in temperature can generate, some charge, in some of the materials and which was interesting enough. So, you begin. So, these are notices and people noticing things happening, then two brothers, Jack Curie and Pierre Curie, known as the pioneers, they found that the tension or compression can generate voltages of opposite polarity, in such materials. So, some polarity if you generate when you pull and the opposite polarity is generated when you compress. So, that means, they saw the potential of such type of materials being used, as engineering materials which can drive things, another scientists Hankel, term these kind of effects as piezoelectric effects, that means the crystals, if you deform, them in one way or the other electrical impulse could be done and it was also seen, that you can have the reverse, effect that is, if you pass electricity or subject them to electrical field, then based on the polarity, you can see expansion or contraction of these type of materials, because the effects, are very small and that's the reason, why small things when have to be done, these type of materials will be used, we are looking at some Pico liters, of drop being generated, that means we are not really looking at a very, large deformation in such cases, only such type of materials can come in handy, if you try to do, any other thing, which will be always larger very, difficult to control. But, so these materials became very important.

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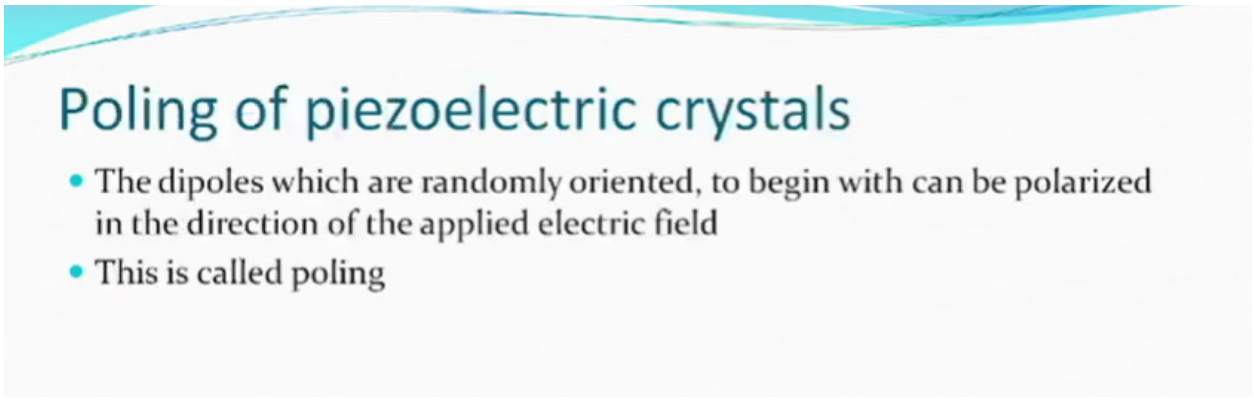

Other than the crystals there are people found other, materials that are called the, 'Ferroelectric Materials'? Which also show and exhibit, their in crystalline, stays is different phases and domains, which can be polarized and so, you can create different structures, in polarization, that means there are some elements within the system which are polarized, electrically and so, they have positive, negative they respond to, a positive side or a negative field that is created and therefore, they also have some properties which are similar properties and exhibit piezoelectric effect and these type of material today, are considered that is the ferroelectric materials, an important class of engineering materials, of course, you can use, non Ferro materials also.

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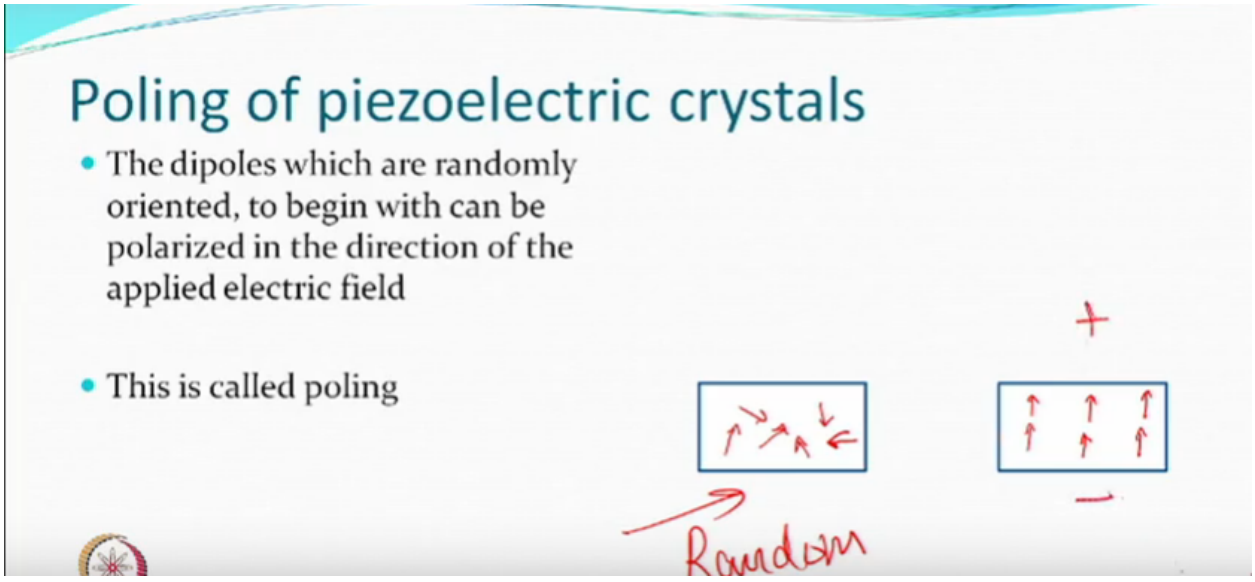

There is a process which is called, 'Poling' that is you orient the poles, in the piezoelectric crystals, what therefore it means is, like in magnets, you try to work around so, that north and south, pole elements, are oriented aligned along a direction, similarly the dipoles, can be which are randomly oriented, can be polarized and this process is called, 'Poling'. So, that they are pointing in one direction, if you consider that, crystal or such object is a three dimensional object, this poling can be done, on any direction, X Direction, y direction or Z direction. This would help people to Design, Systems how, to pass the current

and where will they see the result of expansion. So, the behavior, of the such type of crystals, can be modified by poling. So, you can theoretically, pass, on a current or apply a field which is parallel to the poling direction, you can apply a field which is perpendicular to the poling direction and you will see changes in different directions and that way, you would know where to put the material and which direction you want expansion to take place in case you give the field, either permit dick Euler or parallel and so on so, forth. So, it gives you a flexibility, in design of any system. So, this is what exactly, I said the dipoles which are randomly oriented, to begin with can be polarized in the direction of the applied, electric field, like for example, you have a randomly oriented entities, they can become polarized, if you have let's say, a field getting created. So, you will have a material which would, then be oriented. Now, this orientation, when the field is applied has one. But, what it means is? If you apply the field for sometime which is called, 'Poling', could be called, Tuning' that this, these poles at least almost get oriented in this direction. So, this type of material, which has been already, polled where polling has been only done, can be used, although when you remove the electric field some, part disturbance can take place, the alignment may shift a little bit. But, it does not become random; you know if it does not become random that means you have a material, which would respond, to electric fields in a manner, which may be desirable, at any given point of time.

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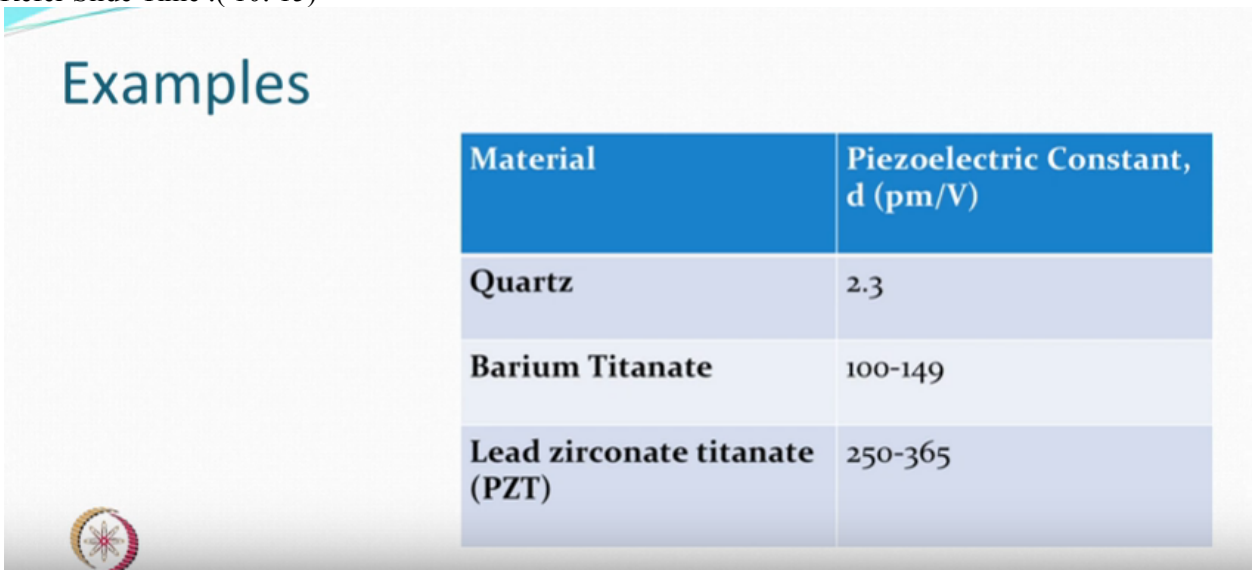

So, some of the examples, are like quartz, barium titan ate, lead zircon ate, titan ate, which is also known as PZT, very interesting material and the property is that when you change, one volt how much dimensional change you may get, you're talking about very, small changes let's say in quartz, Pico meter. Al right? Which is very small change? But, these small changes so, in the PZ T, the change is more than the quartz. So, different materials therefore, would have different let's say the D or a piezoelectric constant and so, you will use them according to what you desire? Most of the engineering applications may be using PZ T, based sensors.

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Examples

- It is evident that the level of strain generated is not so massive, but good enough to be exploited in engineering applications

Material	Piezoelectric Constant, d (pm/V)
Quartz	2.3
Barium Titanate	100-149
Lead zirconate titanate (PZT)	250-365

So, from the values that we see, per unit voltage that change in dimension, is not very significant, is small. Right? But we can still exploit it, wherever for example, our drop on demand type of a situation, where we do not require, very large displacement of the volumes, similarly such type of materials could be used, for example in, transmission electron microscope, where you want to change the or you raise, the platform or the stage, you want to raise it by a few nanometers, there is no other way, you can raise the platform by a few nanometers, other than using some of these materials and by controlling, the electric field that is the voltage, you can control the displacement and that's what we would like to see how, the things get used.

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Drop-on-demand (DoD) piezoelectric

- The piezoelectric crystals can be used as displacement tool by impressing suitable voltages
- The transducer could be attached to a membrane that forms the ink chamber wall or this itself can act as a wall
- When an electric field is applied, chamber volume is proportionally reduced
- Ink drop is ejected

So, piezo electric based, inkjet printers which are also, drop on demand type, once we know that this particular sensor, is going to display so much and accordingly, you can design, theoretically to begin with. So, the piezoelectric crystals can be used a displacement tool, by impressing suitable voltage. So, as a displacement, the displacement could be in any direction, in the X direction, Z direction, Y direction, depending upon what are we done, the transducer, can be, may be attached to a membrane, that forms the ink chamber. So, you have ink chamber saying, chambers of wall, the wall is made of some membrane, which is flexible and so, on one side, on top, on the side, at the bottom, if you add, any such crystal then after passing the suitable voltage or the flying off we'll field, you will get displacement and so, that much part of volume, could be ejected out. Sometimes, the sensor itself, act, may act as a wall. So, you can appreciate as long as the, chemistry of ink, is not such that this is going to destroy, then you can, use that as well. But, that is obviously dependent. So, the volume will be proportionally reduced, when you apply the electric field and then, ink drop will be ejected. So, so it appears that if you take control your voltage and you have. Right? Kind of circuits, then the drop size can be controlled, drop on demand as we said, only means that, you are ejecting when you need. So, restive circuitry, contacts and a software, which communicates.

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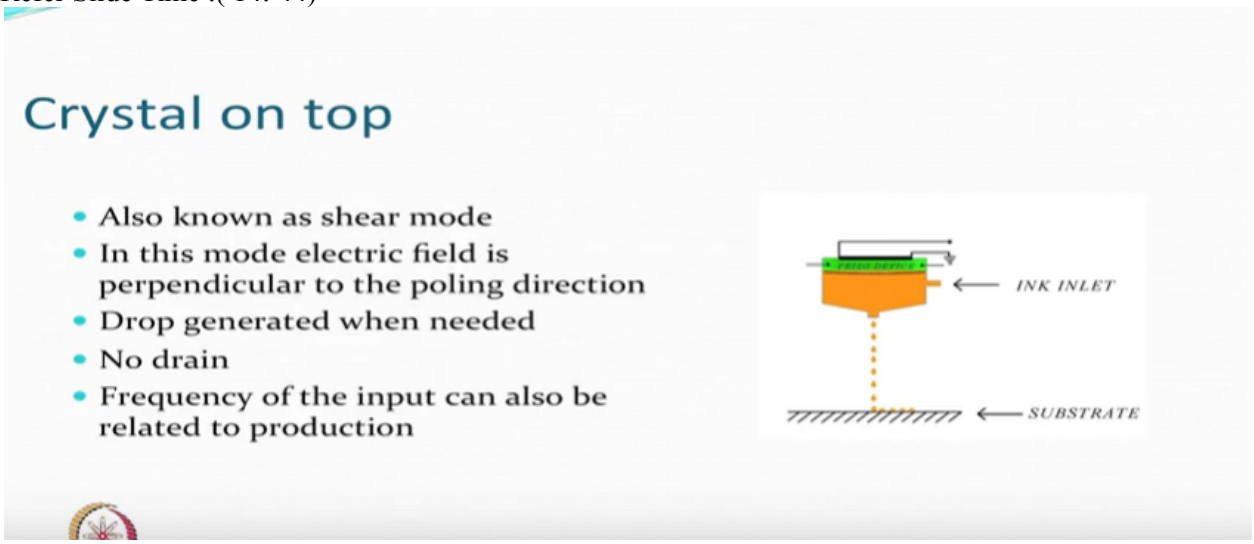

So, some of the things can be, simply like what you see, here a piezo device, is put on the top. So, either which you call a, 'Crystal or a Piezoelectric Sensor'. It's put on the top, of a chamber, which is suitably connected. So, that you can apply the field and if this changes, the dimension in any manner, becomes larger then you will have a push and you would get sometimes they may, only shift and share either in this direction or in this direction and that itself, will cause some change, that some change is interesting teen, they can share, also this mode also is called a, 'Shear Mode'. Crystal on top, in this the electric field is applied, perpendicular to the poling direction. So, you have material, which has been pulled in a direction and electric field is not applied in the direction, of the polling or opposite to that, it is at perpendicular. So, their shares are obtained also, drop obviously as I said generated when needed, no drain is there. So, you don't need a drain, so theoretically it can become a smaller in size, the frequency of the input, can be varied and this frequency will definitely be related to production and production in inkjet, would be

considered how many drops have been produced, in time. Al right? That is the production, we can always say that the production is in terms of how much ink has been consumed and so, the frequency with which it is going to be operating, in some way would finally decide, what is the operation, people can so, they normally would describe the production as how many, square meters of the fabric, has been printed, rather than what is the speed of machine? The speed of the machine may change, if your area of print is large and so, frequency is one of the parameters, which would determine, the production also.

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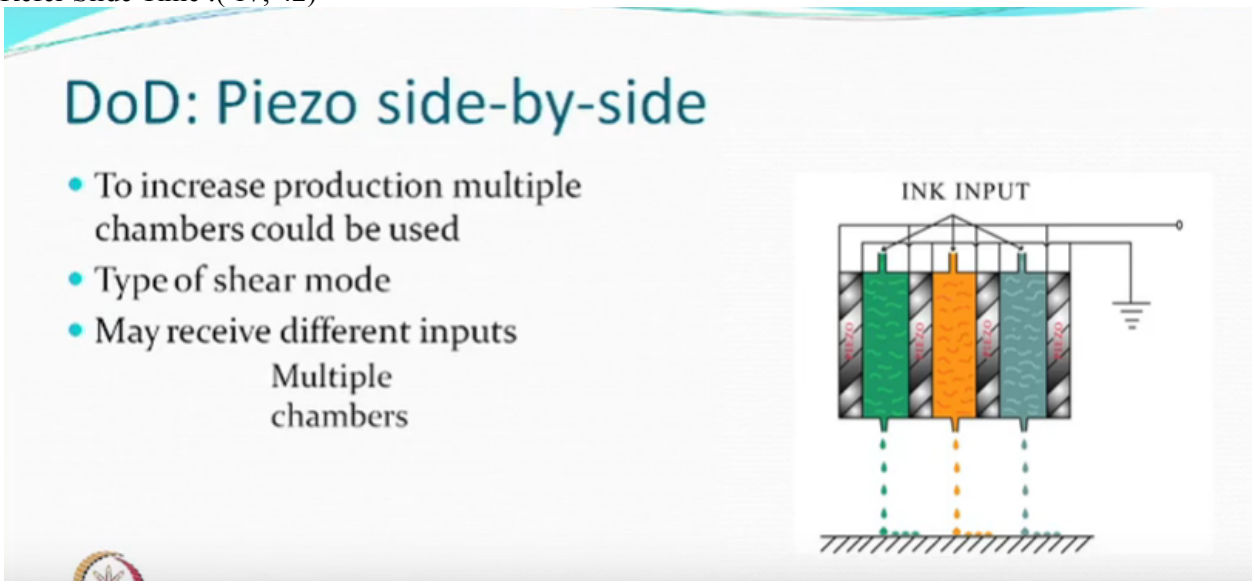

So, instead of having one chamber, one piece of device, you can have multiple piece of device with themselves are acting, as displacement units, as also may act, like chambers that is their wall, is the part of the chamber itself, the wall is the sensor itself, it could be they also, can act in a shear mode, as if you're just pushing the oil to or pushing the ink, to go in forward direction. So, they may receive different inputs, at different times, all of them can be simultaneously, if the whole area requires the same color and so, you fire all of them, if you feel no less number of drops have to be generated there so, you generate only one or two you can that means, it has more control, one control obviously, the frequency other control is the voltage. Now, if it is possible, to change all of them but, normally frequency may not be changed very easily, because frequency generation system is a different system. But, the software may, think of changing voltages, in case that is not there, you can always make sure that some are fired the others are not fired. So, you can have multiple chambers, working side by side and so on, so forth. So, let's say in this case, let's say this one is not firing. So, it may come, you can control, if both of them fire, then the volume could be different one of them may fire the other two don't fire. So, squeezing could be in any of the directions then one can think of.

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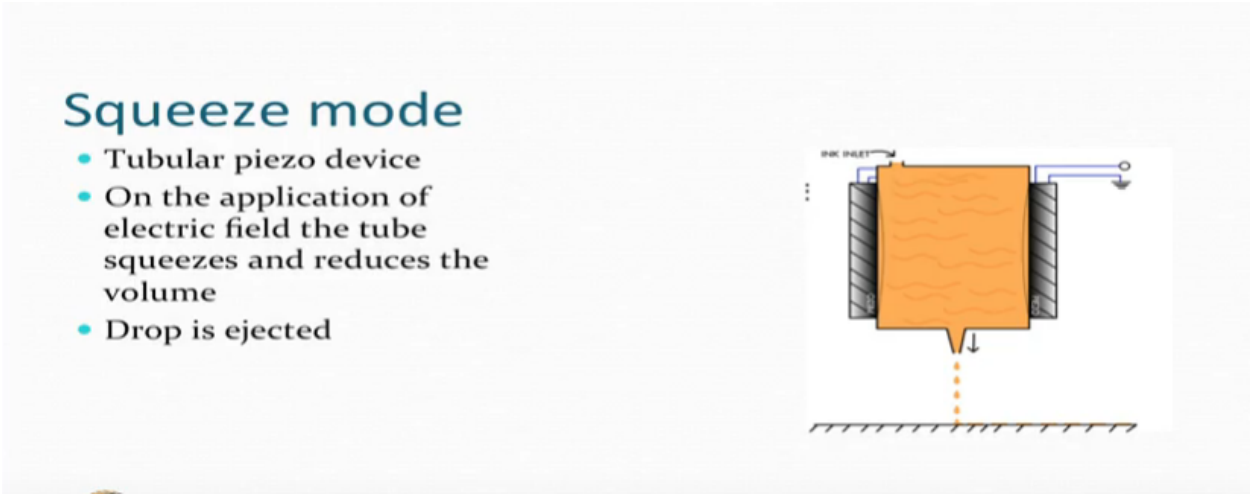

There is a squeeze mode, that the whole sensor could be a tubular sensor; there may be a membrane, which is holding the ink. But, the whole sensor is a tubular sensor, annular and so, the tube will shrink or expand. So, one can, have some of these types so, therefore once you know, that there is a possibility to push, reduce volume and interesting is when it comes back, when there's a pulse, let's say it's expanded, when the pulse is stopped, obviously it will go back, when it goes back vacuum will be created and so, there is a ink reservoir, from where it will get filled. So, somewhere the ink will keep coming and so, whatever you remove, once it goes back, somewhere, because some positive pressure may be there and ink will just come in, here we control as you know, the viscosity of the ink and the orifice, the diameter of the orifice, is such that it by itself, cannot fall. So, that viscosity and surface tension will make sure, that unless you push, ink will not come, like in printing otherwise conventional printing also unless you put a squeegee, the pace doesn't move, where the viscosity is much less, compared to the viscosity is in there conventional printing, still there is viscosity, which is enough, the surface tension with caustic properties enough that the drop will not come out, unless pushed.

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So, there can be the jetting, of the ink sometimes it's known as, can be by the method that we have talked about, above or methods this could be simple push, when the direction of the poll polling direction and the electric field Direction, are same, it will be generally a push mode and you can get the things.

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Within the DOD, there is another, mechanism which people use for generating drops, which is not based on piezo sensor, there are reasons some people obviously would appreciate, those reasons also, thermal, you may have heard, some time there used to be, a term called, 'Bubble Jet Printer'. So, bubble jet printers in some way, are thermal inkjet printers, where a bubble is created, by heating. But, obviously you have a control, when to create a bubble, if you pass the current, then there is a heater, which will get heated, if you don't pass, then it will not do that. So, that control is with you, how much energy you generate? How much time, you pass the current will also remain so resistance, which can which is like a heater. So, you can do that.

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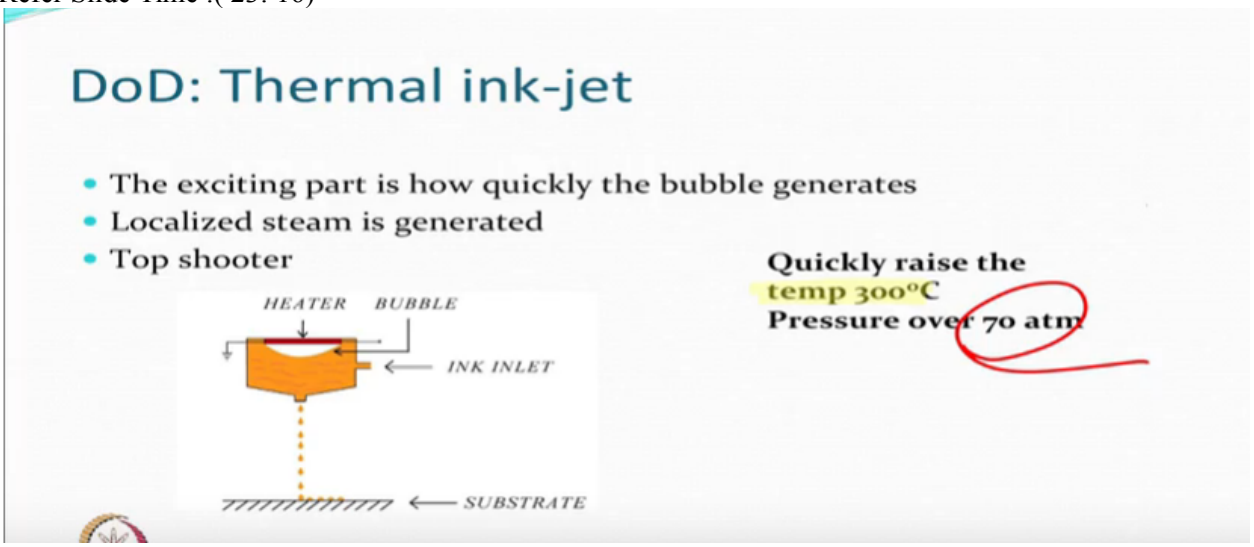

So, very interesting, technology is this, the bubble generates very, quickly and so, you can appreciate the temperature of the ink, within the small chamber that we are talking about doesn't change much, because if temperature of the whole, ink changes the viscosity will drop and you will not know, what to do, it doesn't happen, because most of the inks are aqueous, based inks, it could be any solvent for that matter. So, localized, wherever there is a heating for example, there is a heater here, it gets heated and just around this point, the temperature rises very quickly, say quickly means, in fraction of seconds, you are at somewhere around 300, that means water obviously has got converted to steam and bubble is formed and based on the size of the bubble, which would depend on how, much time the current was passed and the

temperatures are achieved, same amount of drop or similar, drop size may get ejected, interestingly the pressures as, high as so much, you can understand what we're talking about. But, it's a very small area, very small volume, the moment the pulse is off, there is no current passing, the drop has also been ejected, the rest thing is quite cool, the steam it's gets converted to water condenses, immediately there is no bubble, there's bubble created, bubble is finished. So, bubble doesn't go anywhere, interesting. Now, these type of heaters which are very quick, heating very sensitive, to things are used in many devices, for example, your DSC, the small cell, is there, where you have a polymer, on a crucible, you put it on top of heater and efficiency is very, high and so, it immediately gets heated. But locally, the total amount of energy is low, but so, what but still, what is happening is around that point, there is heating, then there is cooling and heating and cooling and heating and cooling. So, this type of an arrangement, is called a, 'Top Shooter' that the heater is fixed, on the top of the chamber and so, bubble is generated, below that and obviously it is being pushed.

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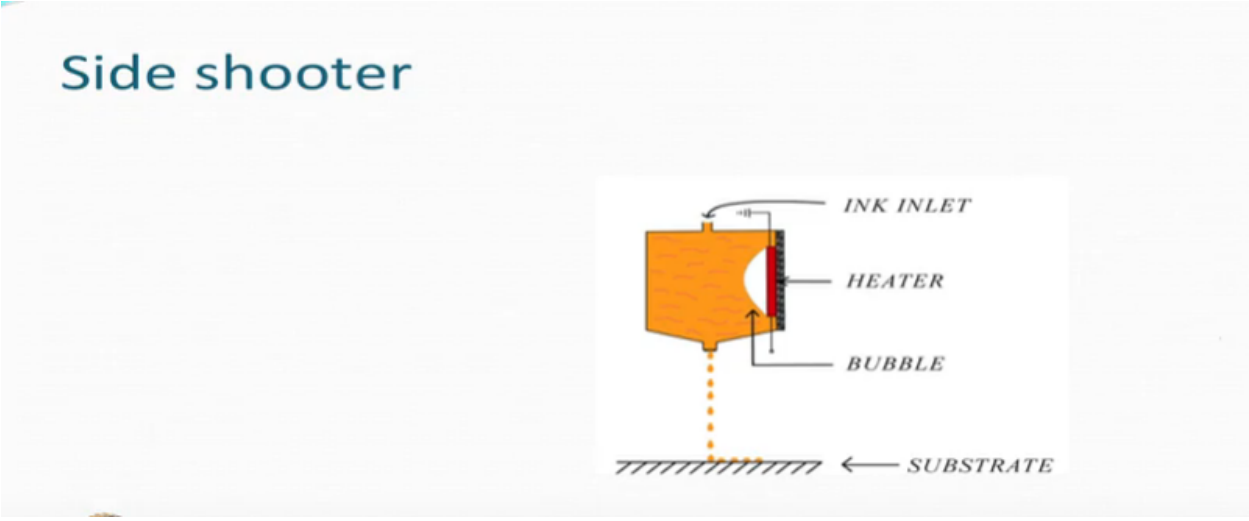

The same arrangement can be done the other way, for various reasons people may say well, it is easier for us to have a side shooter. But, it can still, form the drops, in the same bands. So, once you know? That there is a process, available then you can keep making, designs which may suit your, requirement.

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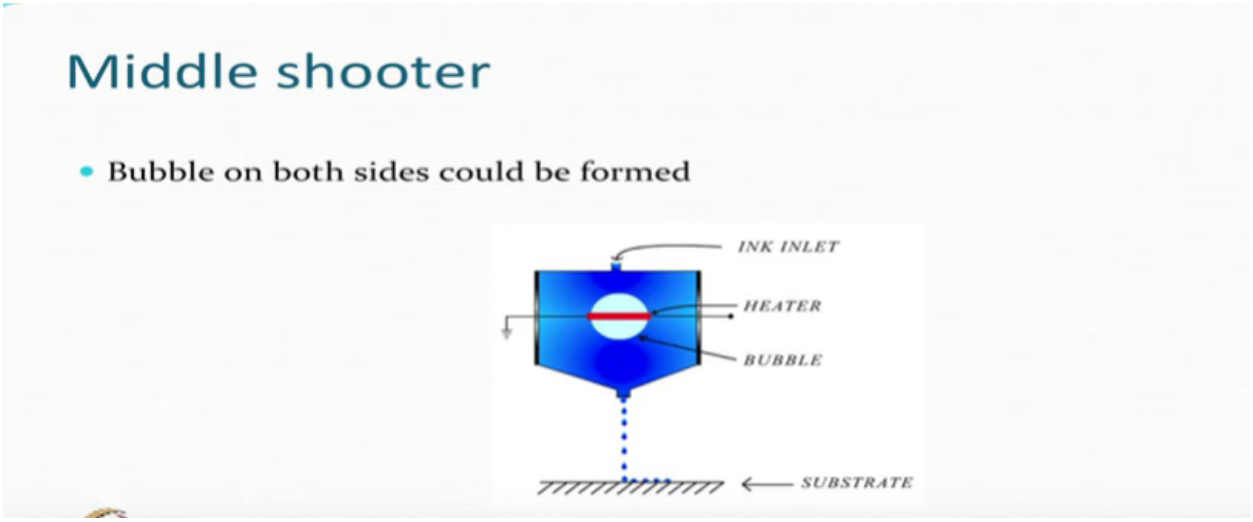

So, suspended heaters are also there, a suspended means that it is, both side the ink is there and so, you apply a field and suddenly there will be bubbles and one can get the same effect. So, here what are we controlling again there is only voltage control, that is interesting, that you do not need a displacement, transducer. So, it's a, concept like a different but, it is also some companies are using, thermal inkjet, is called, 'Thermal Inkjet', printing the other one is called the, 'Piezo Based System'. But, both are being used.

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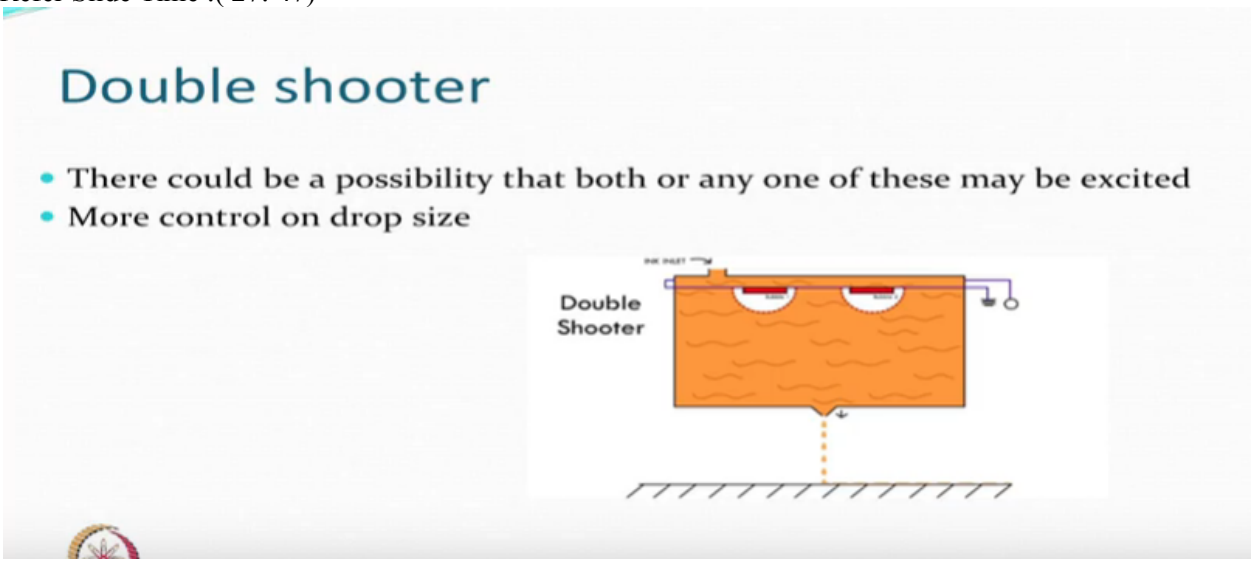

One can have double shooters also, either at the top or at the bottom. So, the bubble size can be controlled because your area, of the heating element may be different, if you need more volume both of them may operate, if you need less volume only one of them may operate. So, you have another, control which can work on which kind on the you know, control the size of the droplet.

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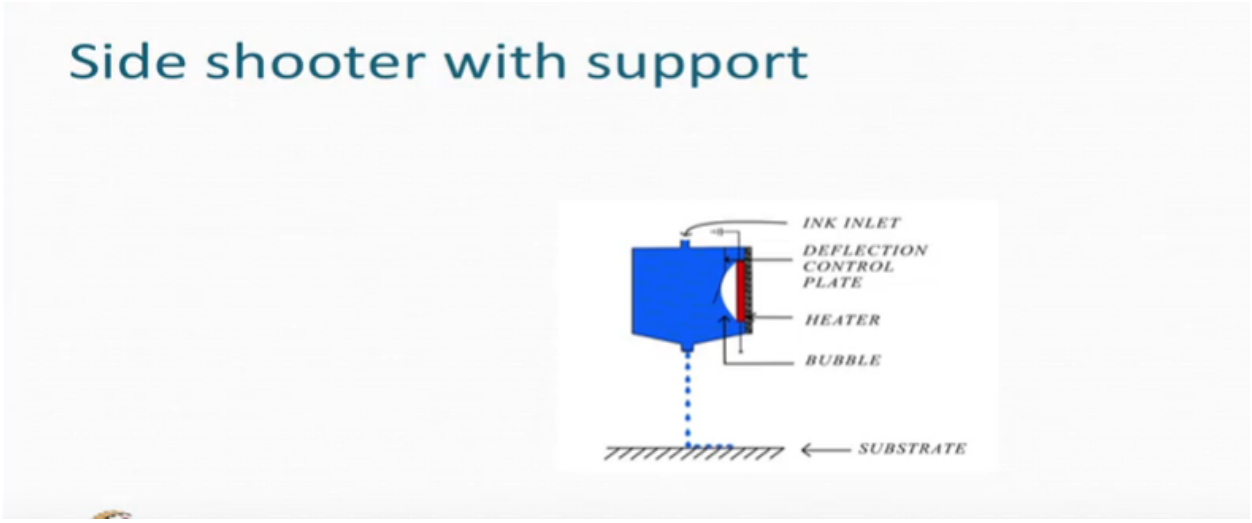

There also some of the companies use the same concept. But, there is a deflection plate. So, basically, because this is a moveable component. But, obviously it has some amount of rigidity of its own. So, in some way, you can control the size of the bubble and how much is going to get generated. So, the pressure control or the, the control where the force, is going to be pressure is going to be transmitted from one point to the other, instead of it going and striking the other wall, first the wave you stopped it here and so, it goes towards the nozzle. So, nozzle could be interestingly, placed at a point where, with less of work, in gets in deflected I mean ejected through that hole, it may be center, it could be side. So, that is way so what you say? Is once you know, a technology exists and you can generate, a bubble and therefore I think you can place these things anywhere and keep doing your job.

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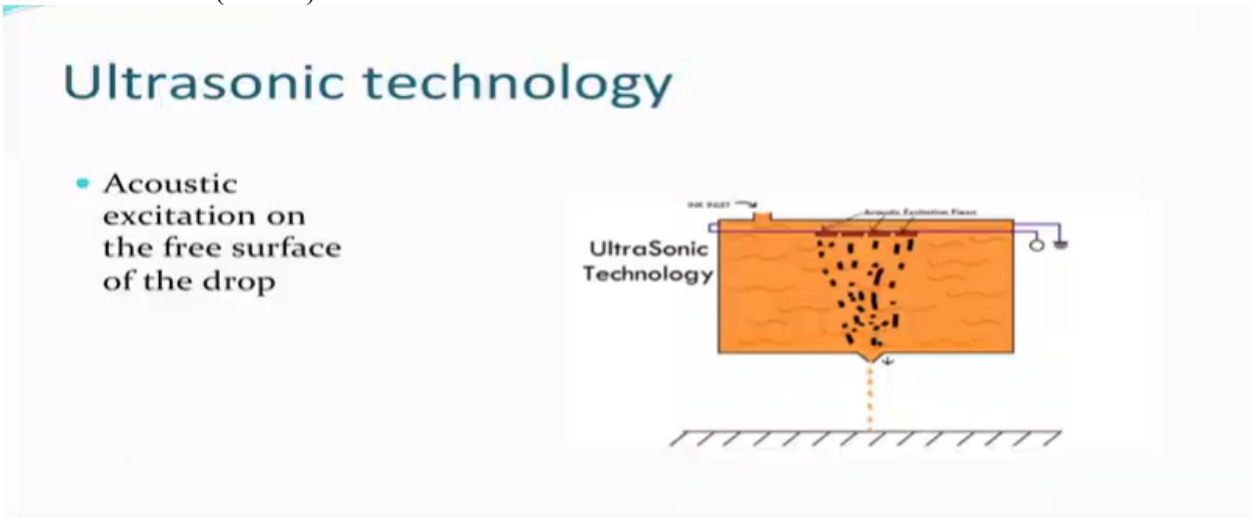

Other technology which also has been used to create drops is acoustic excitation. So, you create instead of a bubble creating the wave, pressure wave, you have the sensors, which can generate, ultrasonic waves and so, the pressure can be put on the top, of liquid surface and then, this can come, it doesn't matter that all the technologies that have been pushed or all the possibilities, that have been shown will be utilized,

not necessarily, people will use whatever, is good and whatever is good means, that you've got to put large, number of nozzles, large number of chambers and within a small volume. So, the, the size of each, one of them is so, small that fabrication itself is a challenge, this is not like what so much large diagram that are made, where acne is very, small and if you want, X number of nozzles in one area, let's say which can be more than 200, then you are looking all of them, have to place in that and nozzle, because should generate a drop when required. So, that means so many chambers are also, there and everyone, has to be controlled. So, the everything is complex now.

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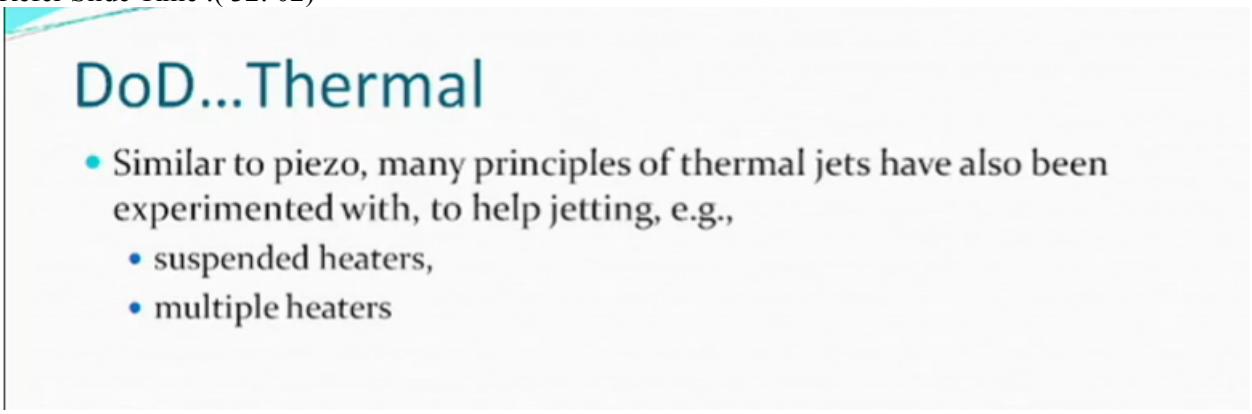

So, thermal drop on demand, if we summarize is similar to piezo, many principles are there, which have been experimented with, to help the jetting of the ink, they suspended heaters, multiple heaters we have seen, two heater that could have multiple heaters and one can work.

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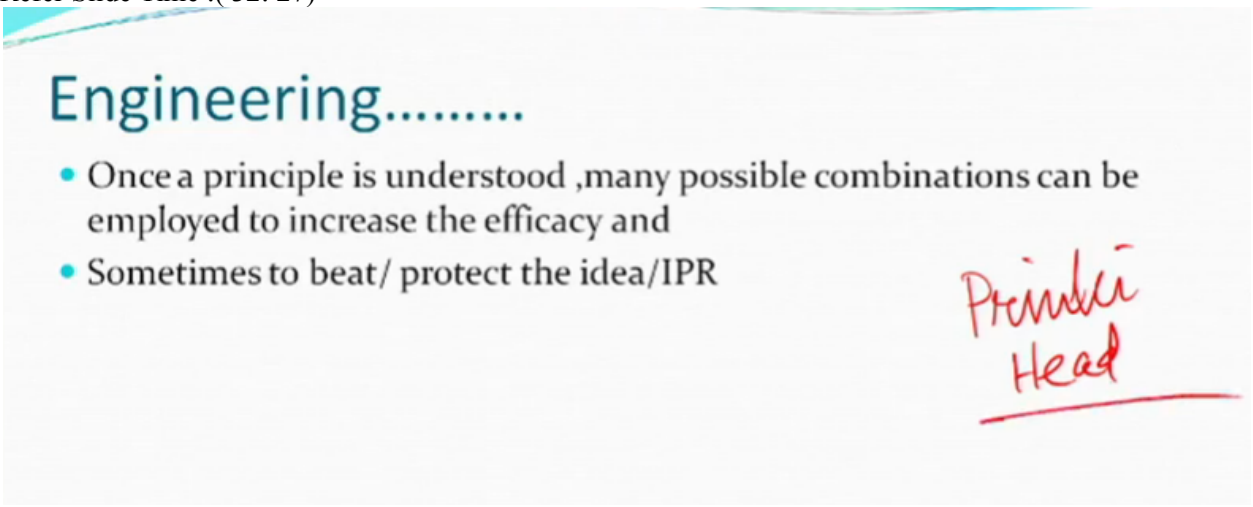

So, the bottom line also, that once a principle is understood, many possible combinations can be employed, to increase the efficacy, of the final product which is a printer head. So, R product is a printer head. So, they'd head, moves from one direction to the other. So, how many, such small nozzle come chambers can you generate, fix in one head, it's a challenge, always. Some of the technologies sometimes are used, because the other, possible technology and the combination has been patented. So, once somebody has patented you cannot use it. So, the only thing that can happen is, that I you generate something which is different then and not covered on the pad patent and may not, really have too much different advantage. But, it is different than therefore you can make a machine, make a sensor.

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So, till now what we have also learnt that, drop on demand, inkjet technology uses, either generally, piezoelectric, transducers or thermal excitation based transducers, these are two major, others are available but may not be used, to such an extent.

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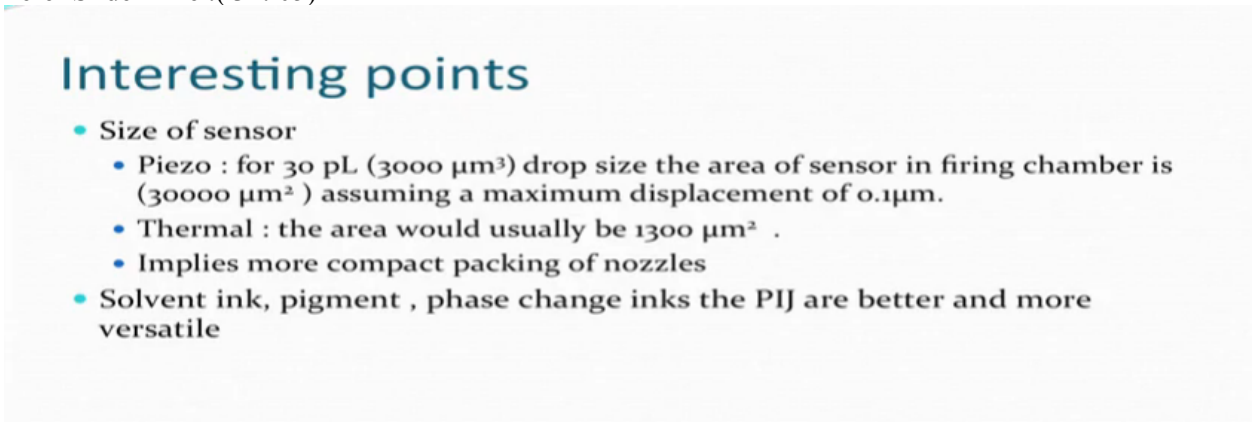

So, let us be looking at a piezo, size of a sensor, we said in the beginning that the displacement is very small. So, for generating something like a 30 Pico litter, of a drop size, volume area of the sensor in the firing chamber, is approximately, 30,000 micrometer square, assuming that the maximum displacement, is 0.1 micrometer, for one pulse, that's the maximum. So, if you generate, you want to get a thirty Pico liters

of a drop, should have, closed to the area which is30,000 micro meter square, thermal printers, require much less area, on an average there could be 1,300 to 1200micrometer square, that means a smaller size and if the element which is the resistor, which gets heated, it does not get corroded very easily, this will be the cheapest way, to make, inkjet printer. So, the piezo sensor also means that more compact packing of nozzles, have to be done how much compact they can make the nozzles, that is the part of a design, which always has a challenge of something or the other, solvent inks, pigment-based inks, phase change inks, the piezo electric, piezo inkjet heads, are considered better and also considered more versatile. So, obviously you can appreciate that the area, of the sensor is not going to be changed every time, you design a sensor the area will remain the same, the only thing you can say, either to fire or you don't fire or you control the voltage, if you can control the voltage, you know? The total displacement can be considered. So, there is some advantage of piezo also.

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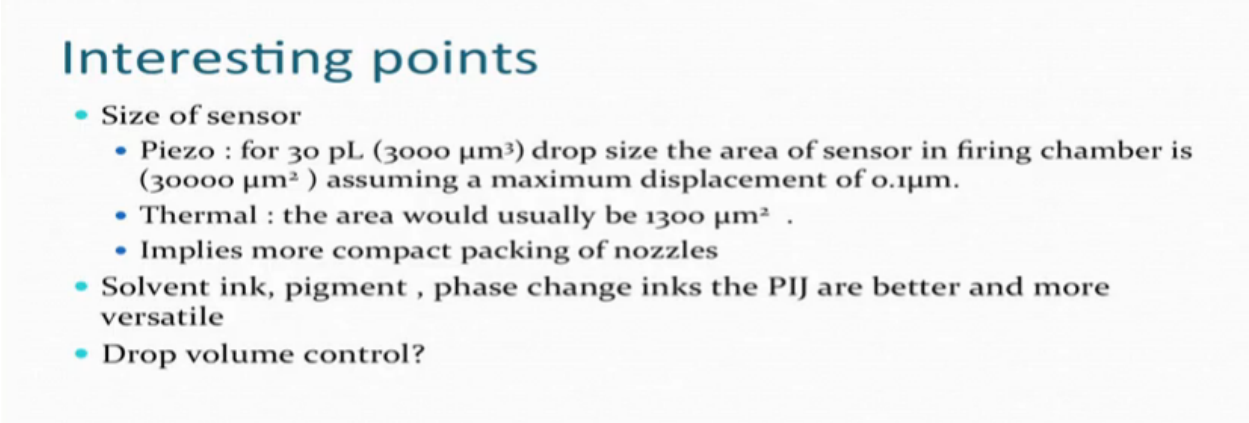

And therefore drop volume control can be done; by relatively, easily because the dimensional change of a piezo is fixed, based on the voltage that is applied.

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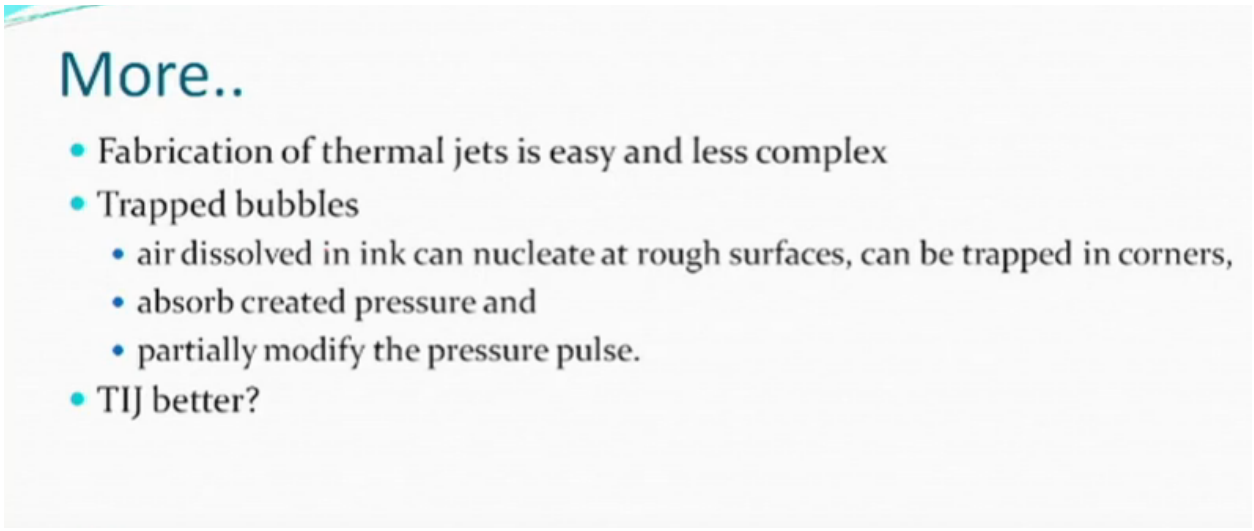

On the other fabrication of thermal Jets is easy and less complex and so, people you may get a large number of thermal Jets also. But, there are issues, air dissolved in ink. So, one is there is water, which becomes steam. But, you may also have dissolved, air which can, cause some problems, if you pour any liquid, in any container, you see on the side you see, some bubbles. Right? Unless is very, you can see. So, corners, asperity, irregularities, can create, some air bubbles also and they can be somewhere else also, not necessarily where you are interested and what it means is that, they can absorb the created pressure. So, you have created a certain amount of volume and you expected a certain amount of pressure to be created so, that a certain volume of lick in could be ejected, if there are in the corners and somewhere else, pressure absorbing systems. So, air can be compressed. So, your total pressure which is available at the point of ejection at the nozzle, can get reduced and so, there can be few but, because of these things, some control may be less, that you were hoping that the control will be so much, but it may get less or more depending upon how much the air was dissolved or was a trapped, clean, not clean those type of things will come and with time they will, keep reloading so, these are some of the interesting things. So, it looks, thermal exam may be better. But, everything cannot be done by them, for example, these days, the pigment-based inks, after a lot of research; the binder is added in the ink. Now, say what cause binder can cause problems and choking, in the nozzles. But, nice binders, are available, the question somebody can ask you, why can't we do, a pretreatment, with a binder and print but then where do you, do the pretreatment the binder should be there, exactly where the color is, you don't want the binder everywhere else, then the binder cannot be washed away, because when you fix, it get fixed, that is what's supposed to do the binder, is supposed to make a film. So, it is not like a reactive dye, where you have pre padded with some alkaline solution, after printing you can wash, the Alcala will get washed, from the areas where there was no dye, wherever there is alkali an get washed. But, if you there is no other way, actually of doing a pigment, based exact printing, without adding a binder. So, if you have a thermal, inkjet and you have binders also, then choking can take place, they may polymerize, during this bubble formation and heater, viscosity may change and you can appreciate, if there is a choking, of these type of printer heads, you have tore place them, you will not be able to clean them and which is obviously not cheap, because it comes all along with the circuitry, this is not something that you replace one, chamber which appeared to be blocked and let me just remove, there may be just one single plate, there are

nozzle's, on top of them there may be chambers and so, it's a complex design. So, for pigment-based inks, piezo base sensors will obviously be preferred, which do not, do any heating.

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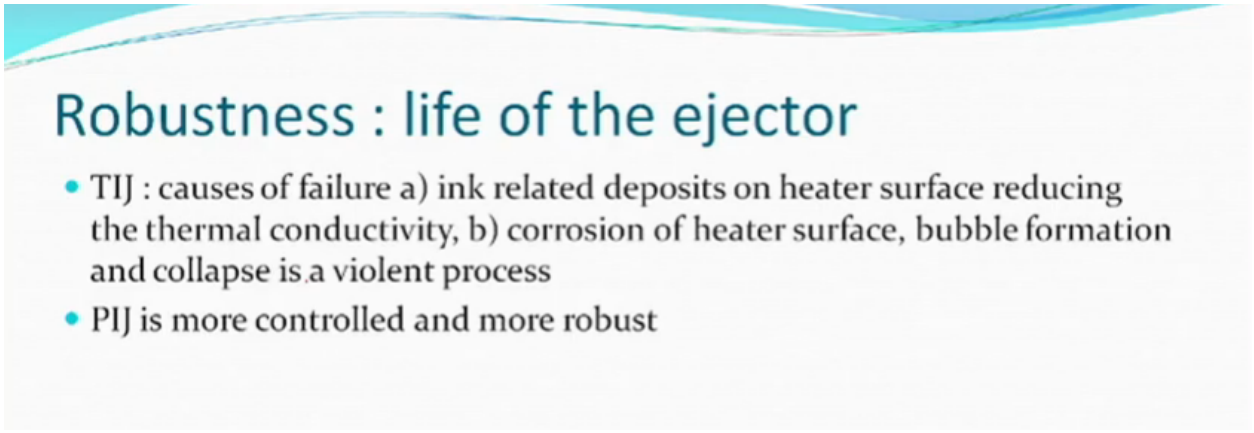

Robustness, life of an ejector, thermal inkjet, can cause, failure due to the ink related deposits on the heater surface, reducing the conductivity, that is the heat generated is being blocked by something which has been deposited on the surface of the heater, because heating, we have seen, have you seen those, immersion heaters, when you boil anything, you see surfaces are obviously, something get deposited. Once it gets deposited, obviously the conductivity from the heater, to the outside is not the same and this depends only on that and so, that would be interesting one is it, corrosion can take place and the bubble, formation and collapse is a violent process and therefore the life, may not be so, high. It's simple to design, less complex to design. But, may be less robust, while the piezo based system, is more robust and relatively, easily controllable. So, there is some comparison. But, you have companies today, using both, technologies and trying to make their things better and one of them will be cost competitiveness. So, if you have to require a change, doesn't matter, it will cost the same. To of this will be equal to one of that don't worry. So, that type of a thing people will do, but we must appreciate, that both of them, are difficult options. So, I think we'll stop here. And pick up, next time.