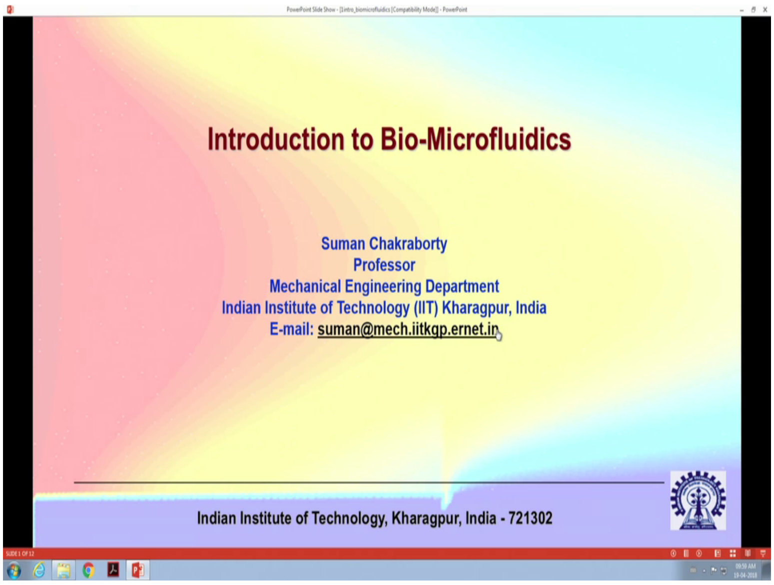
Introduction to Biomicrofluidics
Prof. Suman Chakraborty
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 01
Introduction to Biomicrofluidics

Biomicrofluidics is a very fascinating aspect of microfluidics.

(Refer Slide Time: 00:20)



I can understand that some of the participants of this course are not very familiar with what is microfluidics and therefore before getting into Biomicrofluidics may be it is important to spend our couple of minutes on talking about what is microfluidics. So, microfluidics as we can say is all about studying fluid flow in devices for which the characteristic length scales are of the orders of microns or even less.

The question is that I mean is it a scientific way of describing what is microfluidics, clearly the answer is no and the reason behind that is that microfluidics is actually a buzz word, it is not at all scientific terminology. So, microfluidics essentially does not represent anything from pure scientific terminological considerations. So, there is also another terminology called as nanofluidics and just like microfluidics commonly talks about micro channel flows nanofluidics talks about nano channel flows. However, because of similarity in physical paradigm there are many situations in nano channel flows where the considerations the analysis of micro channel flows becomes equally applicable.

So, instead of getting into the deep scientific issues of microfluidics and nanofluidics we will broadly keep in mind that we are talking about fluid flow through nano channels. Where surface effects special effects at the surface like for example, electrification, surface tension all these effects are much much more important than the volumetric or the body forces which are important over large scales. So, with this little bit of background we will get into the topic of biomicrofluidics, but before that I would like to create a motivation that why are we going to study biomicrofluidics.

(Refer Slide Time: 02:56)

So, the first important consideration forget about biomicrofluidics, forget about whatever is the specific application we are going to talk about small devices. So, such small devices why are they important, I let me give you one particular example whatever is written in the slide of course I can read out. But, I think it will be much more effective if I first give you some example and then go through the slide, so that you can relate the descriptions given in the slide through with some examples.

Now, let us say that there is somebody who is suffering from fever. So, when the person is suffering from fever the person is usually observe for sometime, may be couple of days and normally paracetamol type of medicine is given and observations are made that what is happening or what is the pattern of the fewer and all these. But after sometime when the fever is still there is of course a compelling need to go for medical diagnostics and very commonly the blood tests.

So, these blood tests are routinely done by drawing a large volume of blood by large volume, I mean at least one syringe full of blood for each test and then that blood sample is taking to a sophisticated pathological laboratory where some pathological analysis is done. I would elaborate later on that you know what are the plows and cons of this method, but just for sake imagine another situation in which instead of this large volume of blood you are required to be pricked in your finger and in the process you just give one drop of blood.

So, you might argue that you know it does not I mean except for the mental comfort factor it does not create any difference because, eventually will giving one syringe of blood or one drop of blood we will not matter that much. But what matters more is you know of course behind the phobia and all those thing of giving blood, what practically matters also is the volume of reagents which is used to analyze the blood.

If the blood volume is large it will require large volume of reagents, if the blood volume is less because, there is proportionality between the volume of the blood and the volume of the chemical reagents. So the volume of the reagents will also be less and because the volume of the reagents will be less you will actually require much lower cost to perform the test. Of course, the cost of the test does not always come from the reagents it comes from several other sources, but so far as the contribution of the reagents is concern it is definitely are going to result in low cost device. So, we can say that because of miniaturization one can minimize materials as well as sample consumption this is the first point which is highlighted here, second point is reduction of power budget.

So, if you have a large device say a large centrifuge or large big big machines kept in a pathological lab, to run that lab forget about the ac environment in addition to that even running of the devices itself is expensive because it consumes power. On the other hand instead of that kind of a device if you could have a handheld miniaturized device then the power requirement is going to be minimal, the power required to run a small device is usually going to be much much less than the power required to run a large scale device.

The third point is exploitation of favorable scaling laws, so exploitation of favorable scaling laws it means that you know there are situations where the forces the scaling of forces become favorable when you come down to small scales for example surface tension. I will give you a practical example, let us say that we are trying to see that how by surface tension of fluid can be transported we will see later on in this course that that forms a foundation of medical diagnostics in many low cost devices.

So, now if you want to transmit the fluid by using surface tension, then you are no more using a volumetric force. So, you have to come down to a scale where the surface forces are much more important than volumetric forces and that scale is a small scale device. In a large scale volumetric forces will dominate because, volumetric forces are proportional to L cube where L is the length scale of the device and surface forces are proportional to L square

So, surface force divided by volumetric force is proportional to 1 by L. So, if L becomes small surface force becomes much larger than volumetric forces. So, one can use favorable scaling laws typically the effect of surface forces to a large extent and finally exploitation of new effects, that is there are certain types of effects where I mean which are due to very typical interaction in small scales, like for example electro kinetics which we will study later on.

So, or many effects of Van der Waals forces or several very very small scale interactions these kinds of effects. These are new in the sense that these are not new in terms of physics, these are new in a sense that these effects are normally not realizable in the large scale devices not that they are absent they are present but they are not important. So, miniaturization gives a lot of practical as well as physical advantages as compared to you know the deployment of large scale devices.

When do we use miniaturization of course, we do not use miniaturization for all cases for example if you are trying to supply water to a city you will of course never use microfluidics because, it is a large volume of supply that needs to be made. So, you have to understand the prospective and the applications very carefully and based on that only you have to figure out that when you can use microfluidics.

For example, microfluidics is routinely used when the application demands handling of very small volumes like ink jet printing. For example, as a historical note ink jet printers are among the first industrial devices fabricated out of microfluidic principles. However, in those days possibly the subject was microfluidic the subject of microfluidics was not known in that terminology, so I mean it this historical development was missed by many later on. But ink jet printing is a very important area the other important area is drug delivery, so sometimes you know you require to handle very minuet small volumes of drug very precise quantities what they have to be delivered in an targeted fashion to that part of the body where you know the elements are physically located.

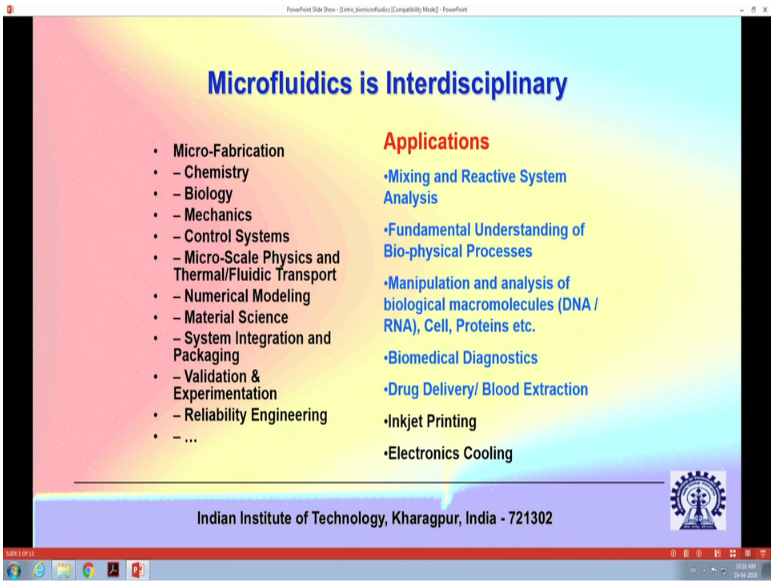
So, in that sense microfluidics plays a big role here, microfluidics plays a big role in cost or performance advantages situations; that means, in situations where microfluidics saves the cost or microfluidics gives better performance and not only that using microfluidics sometimes we are trying to achieve improved reproducibility accuracy and reliability. But it is a question you know we always claying that with microfluidic devices we are trying to come up with applications which are more accurate which are more reliable, but it all depends on the design. If the design is faulty it will not work in that way, so that is one of the important considerations.

There are many situations when by using microfluidics we try to mimic a biological system, for example I will show you later on that how by mimicking a mosquito's blood sampling mechanism that is how a mosquito sucks blood you can design and fabricate microfluidic needles. So, this kind of paradigm I think is quite important where you try to understand that microfluidics is not just about a buzz word, it should be applied in a context when it is needed when the science and the application demands micro the use of microfluidics.

Now, coming to biological applications biomicrofluidics is essentially biological applications of microfluidics. So, biomicrofluidics we have to understand very carefully that again it is a buzz word, so it is better to talk about biological applications of fluid flow through small passages that is what is essentially biomicrofluidics. Now, why we talk so much about biomicrofluidics these days, now biological world is such a world where there is a lot of application of microfluidics. Why? So, because there are several reasons, one is within a human body there are certain components which are like quote unquote god made micro channels and also there are many artificial devices or in vitro devices so called in vitro devices which are not devices within the human body or implanted within the human body but they are devices outside the human body.

But many biological activities like medical diagnostics testing of drugs and all those things can be performed on these devices. So, keeping this wide range of applications of biological applications of microfluidics into account, often we say that if these question is ask that what are the applications of microfluidics we first clearly say that there are 2 broad applications one is biological another is non biological. It shows that the biological applications are very strong and very heavy in the domain of microfluidics.

(Refer Slide Time: 16:42)



Now, next before getting into some of the applications of biomicrofluidics, which is the agenda of a couple of our introductory lectures we would like to first appreciate that microfluidics is interdisciplinary. This is very very important microfluidics is such a subject where it is very difficult to you know it is very difficult to establish one as an expert on everything in microfluidics.

As a researcher in microfluidics I have been working in this subject for about a decade or more than a decade and we where the first microfluidics lab to establish in the country, but at the same time I cannot claim myself to be an expert in microfluidics. The reason is that it demands such a versatile expertise that as an individual it is very difficult to have these expertise, so what are the expertise is that are needed let us go through this.

So first micro fabrication, micro fabrication is essentially about making microfluidic devices micro channels and all these, so this is basically a subject of advanced manufacturing. So, here there are several you know methodologies like ranging from classical lithography technique which is used by the semiconductor industry to soft lithography technique to making low cost microfluidic devices by mechanical micro manufacturing and in fact these days by either routine printing or 3D printing.

So, micro fabrication has come a long way from the traditional semiconductor chip fabrication base technologies to the modern technologies which are available in a low cost paradigm. Next is chemistry, often micro channel flows are dictated by the chemistry at the interface chemistry in a sense that chemistry may be combined with electrostatics or electrochemistry and that can dictate the flow in a very significant manner. Biology again as I told that biology is an important area and of course it is not just biology is an important area as a whole, we have to keep in mind that in the context of microfluidics biology is a very essential topic.

Then you know there are issues of mechanics I will come to the issue of biology later on, but let us cover the other aspects the issue of mechanics governs every mechanic every device in the mechanical world. So, without the knowledge of mechanics it is very difficult to design microfluidic devices typically mechanics over micro and nano scales that kind of mechanics has to be clearly understood.

Control systems are sometimes necessary to you know design control of microfluidic devices, micro scale physics and thermal fluidic transport this is an area of expertise of people who come people like us who come from background of fluid mechanics, numerical modeling like computational modeling of microfluidic processes simulation material science without material science you actually cannot do any engineering.

So, to make devices we need to understand the materials aspects, for example like what kind of material treatment can render a device with a particular weight ability hydrophobic hydrophilic, what kind of materials will lead to these what kind of surface treatment will lead to this so all these are very important. Then to make a device useful for commercial purpose we need system integration and packaging validation and experimentation reliability engineering all these and what and what not much more.

So, from here you can well understand that one particular for one particular researcher or one particular technologist it is very very difficult to get a full grasp all these. So, what is expected out of you so you might be very you know disturbed by looking into all these specializations and you might find yourself fit almost nowhere. But you have to understand that the perspective in which all these expertise's are talked about is an interdisciplinary outlook.

So, in microfluidics we often work as a team, so in the team there are people who are experts in certain subjects like experts maybe in fluid mechanics, somebody may be expert in biology but not an expert in fluid mechanics somebody may be expert in manufacturing micro manufacturing, somebody may be expert in electrical systems or electronic circuitry making devices. So, I mean you can have somebody maybe just a chemist trying to understand the chemical reactions between various fluids in a microfluidic device.

So, it is possible that people come from various backgrounds and when people come from various backgrounds it is not absolutely necessary that you know or you have to know the teeth bids of one particular background of all particular backgrounds in great details. That means, like I can give my own example I am by training a mechanical engineer and my specialization in is in fluid mechanics, I work of course in the domain of biomicrofluidics and it is one of my areas of research.

But my area of core strength is not biology I interface with biologists like my colleague Professor TK Mohithi who will be teaching part of this course he is an expert in biology. And, we often collaborate to solve outstanding research problems in the domain of biomicrofluidics, our students interact with each other they learn from each other and that is how an interdisciplinary environment develops.

So, for a non biologists like me what is necessary, for a non biologist like me it is not absolutely necessary that I become an expert in biology. but I need to interface with biologists I need to interface with medical doctors and for that a certain level of outlook needs to be developed. And, in this level of outlook is developed people can work at interfaces of medicine biology and engineering and this little bit of outlook can be a oriented or can be developed through certain basic orientation through certain basic exposure of biology to engineers.

So, Professor TK Mohithi in some of the subsequent lectures, in fact after these couple of introductory lectures will start with the topic biology for engineers. So, the whole idea will be to you know let engineers know what are the important facets of biology which need to be highlighted when you work in the interface of biology and fluid mechanics.

Coming to the applications microfluidics has many applications I will as biological applications are quite heavy.

So, I have highlighted the biological applications of microfluidics with a particular color and some non biological applications with some other color, like mixing and reactive system analysis fundamental understanding of biophysical processes, manipulation of biological macromolecules like DNA RNA cells proteins, biomedical diagnostics drug delivery blood extraction all these are you can see all these are microfluidic processes ink jet printing electronics cooling.

So, you can well imagine that there are applications of microfluidics all around, but biological applications are significantly dominating. So, with this little bit of perspective we will stop this particular lecture and in the next lecture we will go through certain practical examples. Examples based on research work done by our own lab and these examples will stimulate your mind on what could be the potential applications of microfluidics.

Thank you very much.