PolCoPUS
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Lecture No -53
Testing for applications

Hello welcome to the course on polymers in which we are looking at applications of polymers. At the same time we are looking at concepts and properties of the materials and uses. In the last couple of weeks we have paid a lot of emphasis on the properties of the materials and while we discussed electrical response viscoelasticity in polymers we are continuing some of the discussion related to the complex behavior that these macromolecular systems show.

So as we continue our discussion related to the viscoelasticity in polymers in this lecture, I wanted to highlight some of the trade tests which are used and trade tests are called this way because they are specific to a trade and by trade we mean a given application. So for example if let us say a fluid is being used as a shampoo then there will be a very specific test related to you know how does it feel when you spread it in hair kind of a thing, how does it feel to the hands.

So these are related to the trade of shampoos while a fluid behavior which is viscosity can be same for all of them, but necessarily viscosity need not correlate to how it feels in our hands and how it feels in our hair. So that is why there are trade tests which will then try to assess when you develop a shampoo material how good or bad does it feel to a customer.

So trade test therefore are always closely related to the application itself and so we will do a short review of why and how some of these tests are used in case of polymeric materials.

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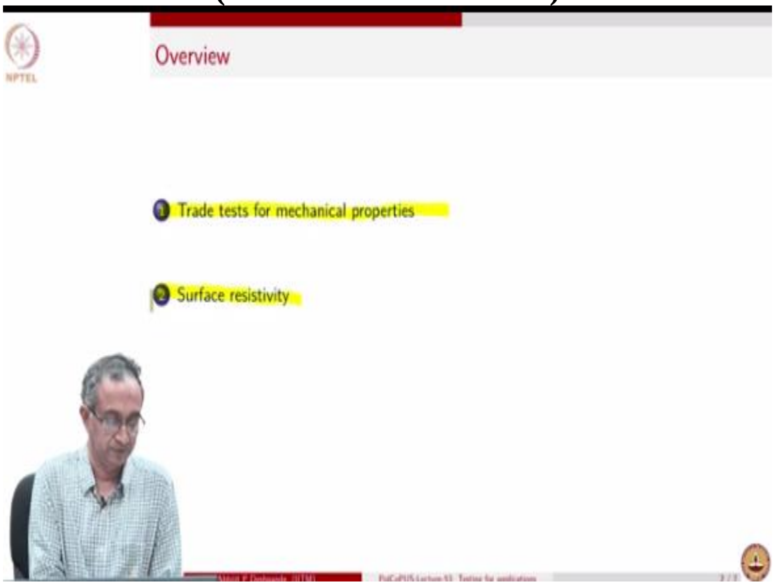

So our emphasis will remain on applications and uses of these polymers, so we will look at a survey of some of the trade tests which are used and we will also look at the electrical side of the trade test where surface conductivity or surface resistivity is measured, which is more applicable for certain uses of these polymeric systems.

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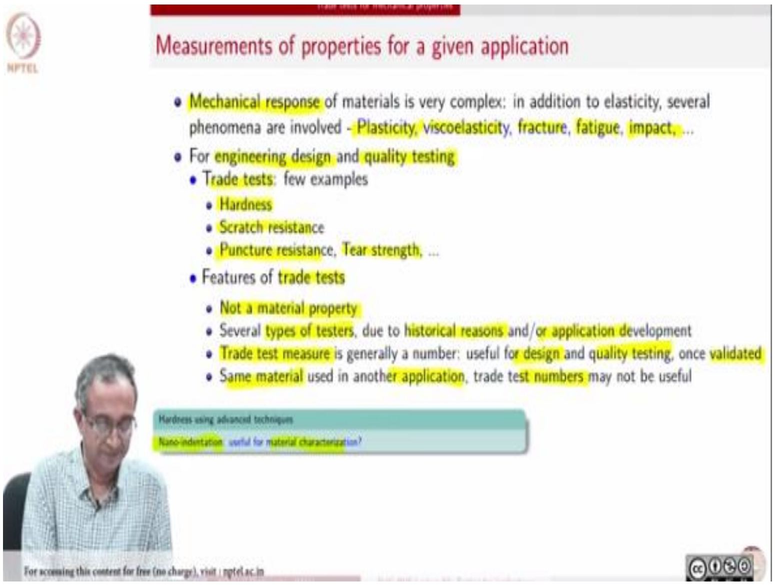

So measurement for mechanical properties for a given application sometimes can be very complex because the mechanical response itself is very complex. We know that there could be plastic deformation, there could be viscoelasticity, there could be damage in the material in the form of crack propagation, there could be damage in the form of fatigue which is accumulation of some of the damage with much less amount of loading, there could be a very high rate of loading in the material which leads to defects and the cracks propagating in a very different way.

So given that there are these multiple phenomena involved it may not be always feasible for us to correlate, some of the mechanical properties that we measure in the lab with the eventual application. So when I say this we should be cognizant of the overall process which takes place. So given that there is an engineering application in the end we have to design a part we have to put a material out for that application.

And sometimes if the understanding is not there we will need the empiricism associated with it so that we can design with confidence. Some other time we have a very good scientific information available so we can get quantitative information. So there is always back and forth between scientific understanding very careful examination, very brute force, lot of data collection and empiricism, a collection of all of these drives our overall set of applications for any material.

So this is true in case of polymeric materials also. So many times for engineering design and quality testing it is helpful to have these trade tests and some examples are for example is hardness or scratch resistance. So clearly how a material scratches is related to the mechanical properties because in the end scratch is a crack in the material but only a surface phenomenon. So how does let us say secondary or primary interactions or the microstructure of polymer how does it influence the scratch resistance so that is a fundamental question.

But in terms of evaluating whether a material may be suitable or not we can develop a trade test and then measure the scratch resistance and similarly for films or for sheets we can look at tearing strength or puncture, when we pressurize something how does it puncture and so on. So these are all ways where there are mechanical properties involved but it is unlike a simple rod which we extend and then try to test mechanical properties under very controlled conditions.

So the generally features of these trade tests are that it is not really a material property what do I mean by that it depends on what geometry is being used what condition is being used. So generally trade tests are like a protocol is given where very specific geometry and conditions are given only then whatever number comes is useful and this is again based on the empiricism, this is again based on our engineering judgment, years of experience of using a set of polymers for a given application.

So therefore there are several types of testers due to historical reason depending on application in one area or another area we will have the testers in all different kinds and trade test measure is generally a number, there may be units on it but given that it is not a material property. Generally we tend to think in terms of this being a number which is useful in terms of quality gradation and not really in terms of quantifying the material behavior.

So for example a 10 mega Pascal strength or a 15 mega Pascal tensile strength in a uniaxial tension or let us say a modulus of 2 giga Pascals as opposed to 2.5 giga Pascals these are all material properties and regardless of the geometry being used these properties tell us something about the material. In this case if let us say we have hardness of 60 or hardness of 70 it depends on what hardness tester was used.

Whether 60 is good for an application maybe but for another application even though we have same material being used the 60 as a measure may not give us a good idea. So therefore we have to change the test so many of these tests are specific given a validation for a application they are
useful for design and quality testing. And so same material in another application these numbers may not be very useful and just the way given that we have several ways to test.

Given that we know now material microstructure at microscopic scales as well as nanometer length scales, now can we do a hardness test at very low length scale. So for example nano indentation which tries to indent a material at very fine length scale of nanometer size and then depending on the load and displacement that happens due to this indentation can we get a material characterization.

So such a trade test does not exist right now it is not yet clear for any given application that this nanoscopic measurement is precise and therefore this gives a number which will be very immediately useful. But what I am trying to inform is that this is the process by which we actually get the trade test we have to get a set of numbers which are very useful for a given application for their design and quality testing.

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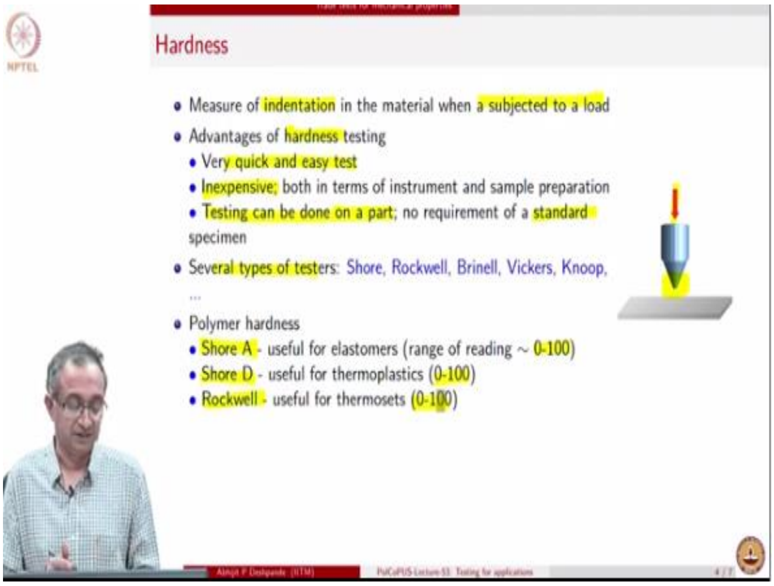

So hardness on the other hand what is practiced is a hardness tester of this kind where there you have a tip and this through a load this tip is indented on the material and then you measure how much is the displacement, how much does this tip indenting the material go inside the material, how much is the deformation in the material and its actually very complex from the point of view of what happens in terms of strain in the material.

So these days of course because of simulations capabilities that we have and the modeling capabilities, we have we can try to say that for a given material with a given material properties in terms of stress strain curve how will the hardness be there and such rationalizations are quite common these days. But practitioners go ahead and use the test and get the numbers and based on the numbers deductions are made.

So measurement of indentation as load is impinged on a material and the advantage of this hardness testing is a very quick and easy test very inexpensive, because of the instrument and the sample preparation requirement and other big advantage is you can do the testing on a part itself. You do not need a rectangular specimen, you do not need some other specimen whatever is the part you can measure the hardness at a point and get the idea.

So several types of testers are there is shore hardness, there is Rockwell hardness you can see that depending on the history, depending on the application various different types of instruments have been developed. For polymers generally shore A, shore D and Rockwell are used and you can see that the range of reading is 0 to 100 in all cases. But it is not that they are always a 60 shore D hardness may not be same as shore A hardness.

Because they are basically different load the instrument configuration is different but at the end if shore D hardness is useful for an application the technical data sheet of the polymer will give you that data. So that you can make judgments and then when you go from one grade of the polymer to the other because of cost considerations or because of processing considerations, you can try to search and keep your search limited to shore D hardness which is useful for your application.

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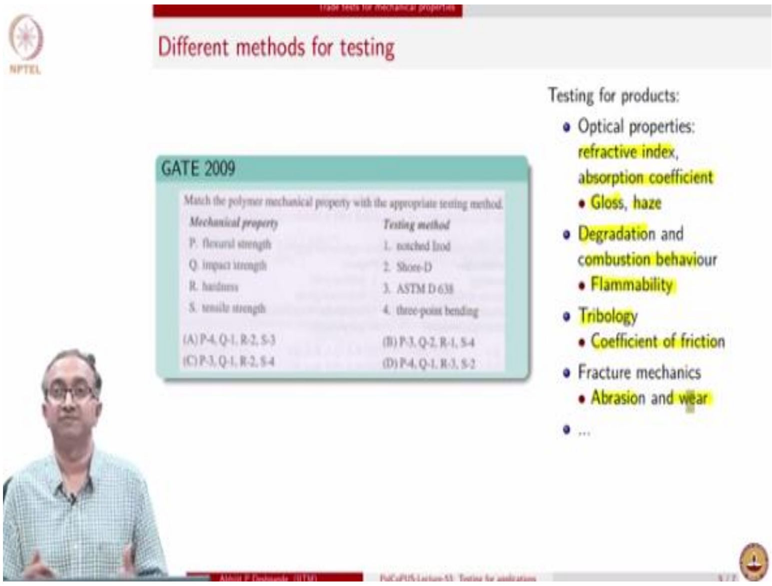

So that is why these are very good guidelines for practical applications. Just to highlight we can look at this exam question where different types of tests are used, so we have some tests which characterize the material properties. For example in this case the flexural strength or tensile strength are material properties and then there are trade tests which for example is shore D and notched Izod.

So in fact the way I have described itself gives you part of the answer, so if you look at the set of mechanical properties and set of testing methods you should be able to figure out which test is useful for which mechanical property. And generally not just in the mechanical domain such trade tests are prevalent for all different kinds of measurements also, for example many of the plastics where we want them to be glossy or hazy depending on the application.

So we have a refractive index which is a material property which could be used but absorption coefficient is something used from trade tests. Similarly degradation and combustion behaviour can be assessed by looking at rate of reactions which are happening during a combustion process. But we could do a test which is called flammability test, it gives you an quick look at what may be the combustion behaviour of a polymeric system.

Tribology which is a surface friction phenomena we could measure and similarly there is a breakdown of the material on surfaces. Whenever two materials slide past each other there is abrasion and wear, and again there are trade tests associated with how to measure the abrasion and wear of material. But fundamentally speaking it is a fracture phenomena confined to the surface, so the fracture energy the stress intensity factor and impact resistance or the overall stress strain curve all of these should give us indicators about abrasion and wear also.

But abrasion and wear trade test to give you a quick assessment semi quantitative or quantitative way of grading different materials.

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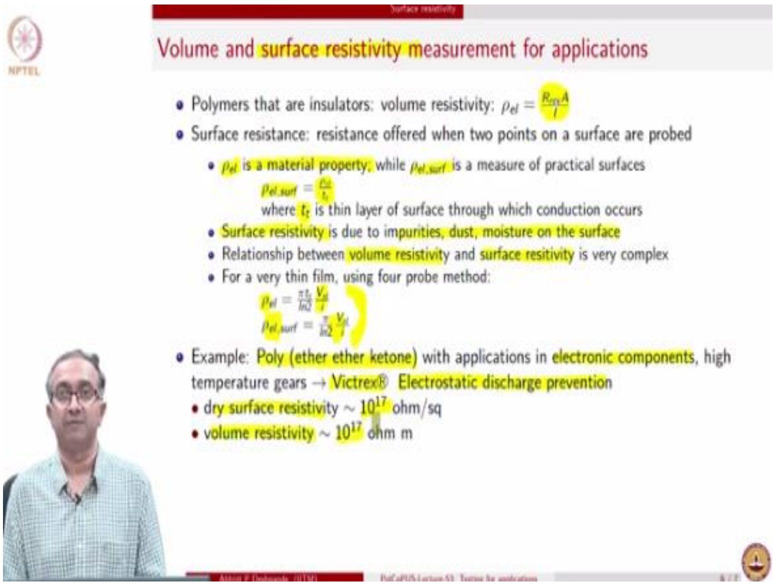

So continuing along these lines another important property which is measured for practical applications point of view is surface resistivity. So volume resistivity is what is material property that is what we define as resistivity or conductivity. So therefore ρ_{el} as is defined here is a material property and it can be measured by basically taking the material between two electrodes whose area is A and the distance between electrode is l.

So based on that we can measure the volume resistivity or the conductivity of the material which is a material property. On the other hand we can also measure surface resistivity or surface conductivity and this test is again completely from the point of view of applications, because the bulk resistivity or volume resistivity may not be important. Because the material is anywhere insulating so it is not really per serving any purpose of conducting in the application.

However depending on the quality of surface it may have accumulation of static charges it may have some discharge on the surface. So therefore surface conductivity may be a good measure of what its performance is in a given application. And so this surface conductivity is related to electronic conductivity if there is a very thin layer through which conduction happens, but problem with surface conductivity or resistivity is that it depends on whole lot of other factors.

So there is a difference between the bulk conductivity and surface conductivity due to dust and impurities on the surface some other solvent or moisture which is absorbed on the surface. So therefore surface properties are very different due to volume properties. So now you can see why application orientation, application of a given kind is, so important in terms of these trade tests or why trade tests are used for these practical considerations.

Because by measuring volume resistivity or conductivity of the material you may not know what is the surface resistivity useful for a given application. Because that depends on what is the nature of the surface and nature of the surface will depend on application. So if it is let us say an application where lot of oil and petrol and other such substances come in contact, surface resistivity would be different but let us say it is an application which is used in marine applications.

Where it is mostly salt water system which it gets exposed to then that is a very different environment and surface conductivity may be very different. So therefore surface conductivity depends a lot on what surface is in relation to the environment and so relation between volume resistivity and surface resistivity therefore is very complex. If you use a four probe method then you can correlate these based on the thickness the thin thickness that we talked about in terms of voltage and current measurement.

But generally this is not really well established, but what we do is we use these formula to calculate the surface resistivity given this theory. This theory is actually for a very specific case where volume and surface resistivity are related where the conductivity is through a very thin layer t_t and we are using a four probe method. But what we do for a practical purposes is just use the four probe method use this formula and get a number and then this number can be used for gradation.

Fully realizing that this is no longer a material property but it is a number which gives us a semi quantitative, qualitative idea of what the material response could be as a part in an application. For example poly ether ether ketone which is a material it is used in aerospace but it can be used in electronic components also. Their electrostatic discharge prevention is a very important property.

And so for that technical data sheets would try to report for example Victrex is a brand name for this material and they report the surface and volume resistivity. So that these can be used for deciding about the practical application.

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So with this we will close in terms of the tests you would have spotted that impact Izod is the technique for hardness it is sure and similarly for flexural we have to use three point bend. So three point bend is where two points are kept on a rigid plate and then we actually press it with the single point so that the material bends, so three point bend tensile. So these are all different ways in which we characterize the materials. So with this we will close this lecture related to trade tests, thank you.