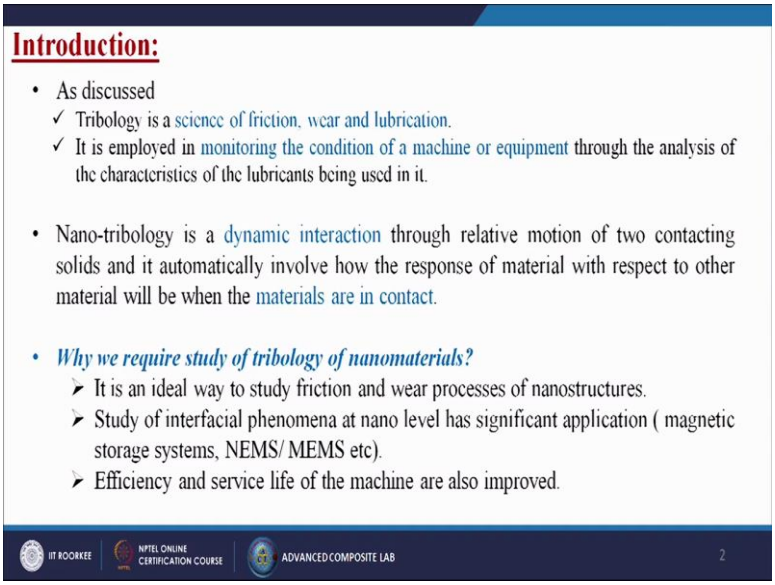
Surface Engineering of Nanomaterials
Dr. Kaushik Pal
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture - 05
Effect of Tribology on Surface of Nanomaterials

Hello. In this chapter we are going to start the effect of Tribology on surface of Nanomaterials. So, first as introduction we can say or may be last subsequent chapter we have gone through that different types of parameters like frictions wear lubrications. So, in a single word we can say that all together is coming or may be giving a definition is called the Tribology. So, Tribology is a science of frictions wear and lubrication.

(Refer Slide Time: 00:56)



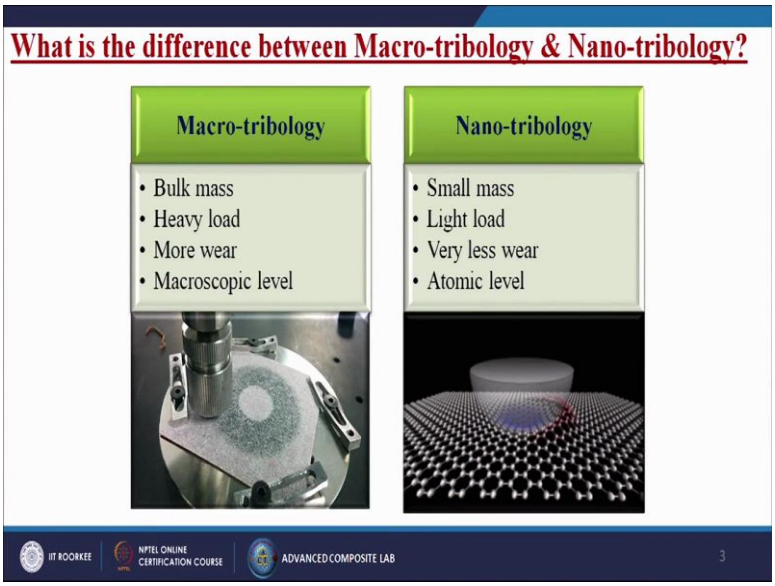
So, altogether is known as the Tribology. It is employed in monitoring the condition of a machines or equipment through the analysis of the characteristics of the lubricants being used in it. So, it is a process, it is a combinations of process by which we can see that when the machine is coming and then it is installing then after that when it is starting. So, from starting to the ending the whole life is there any problem or fault inside the machine or not, is there any wear or maybe tear maybe the noise problem inside the machines or not, whether the proper lubrications is there or not or maybe is there any fault. So, the whole thing is known as the Tribology.

Nano Tribology is a dynamic interaction through relative motions of two contacting solids and it automatically involve how the response of material with respect to other material. So, in our first slide we have discussed about the Tribology for the macro level, now we are discussing the Tribology for the Nano level. So, Nano level means nowadays we are talking about the Nano, each and every time we can hear the term Nano. Nano is nothing, but the materials which is having the (Refer Time: 02:10) power of minus 9 meter in sight. So, when we are dealing this small particles, when these small particles also coming into the contact there is having some kind of Tribology or maybe some kind of frictions or maybe some kind of wear. So, the Tribology which is dealing that part is basically called the Nano Tribology.

Where we require study of Tribology of Nanomaterials; it is an ideal way to study friction and wear process of nanostructures, study of interfacial phenomena at Nano level has significant application like magnetic storage systems, NEMS or MEMS here I have given only 3, but there are n number of examples are there, nowadays we are using mobiles, nowadays we are using some kind of I pads, laptops, where the size is getting smaller and smaller.

So, whole the storage systems and the operating systems is going into in higher magnitude, previously we are using 10 megabyte storage systems, nowadays we are using 1 terabyte storage systems and it is going more and more, but relative to it is dimensions and width it is going into the decreasing manner, so the materials is giving more properties, but it is dimensions and weight or maybe the size is getting into the smaller sections. So, when we are compacting these all materials; that means there is a direct contact in between the materials itself, which generates the friction. So, when you're talking about the memes or maybe any kind of semi conductors or maybe any kind of electronic device there are n number of chips, n number of diodes, n number of materials are using which is say IC is very very small, maybe some materials which we can't see by our naked eyes also, but still they are coming into the contact and some wear or may be friction is going on.

(Refer Slide Time: 04:15)

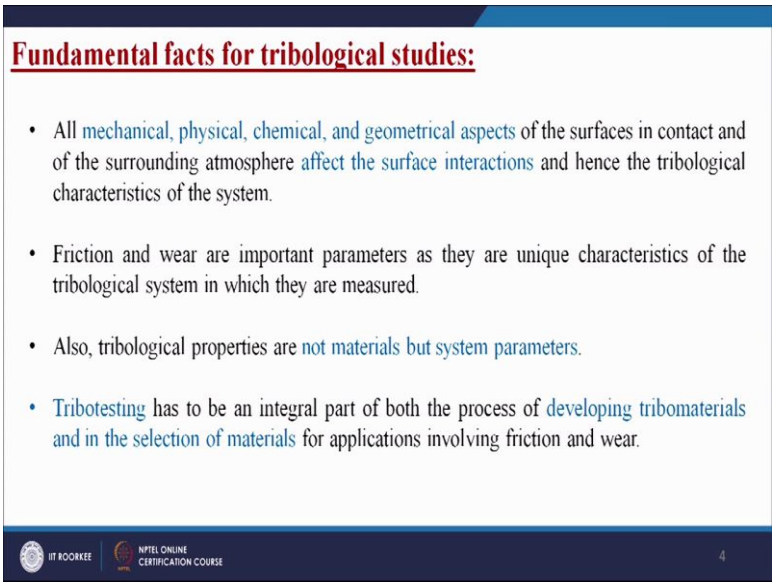


So, what is the difference between macro Tribology and Nano Tribology? In the macro Tribology it is the bulk mass, the size and weight of that particular equipment or may be the machines are bigger, heavy load generally you were applying heavy load on to those machines or maybe they are generating heavy power or maybe heavy energy or maybe heavy load. More wear maybe there are n number of materials is touching together.

So, if we accumulate all the wear, the volume of the wear may be more at that particular case and it can see into the macroscopic level or maybe sometimes we can see it in by our naked eyes also, but when we are talking about the Nano Tribology it is very very confined one, it is needs some precise equipment to observe the Tribology or maybe the wear or maybe the abrasions, it is sometimes very difficult to measure those functions and also maybe the wear can be robust or maybe the wear can be less also, we cannot use maximum load as like the macroscopic level because that material does size and shape of the particular material is less. So, sometimes maybe they are the sophisticated one so they cannot bear that high load, sometimes we are giving the low load also. So, there are several numbers of differences in between the macroscopic level and the microscopic level.

Fundamental facts of for tribological studies; from this slide will see that what is the why we are doing the Tribology? What we are getting from the Tribology itself or may be that rather what we are gaining from starting the Tribology?

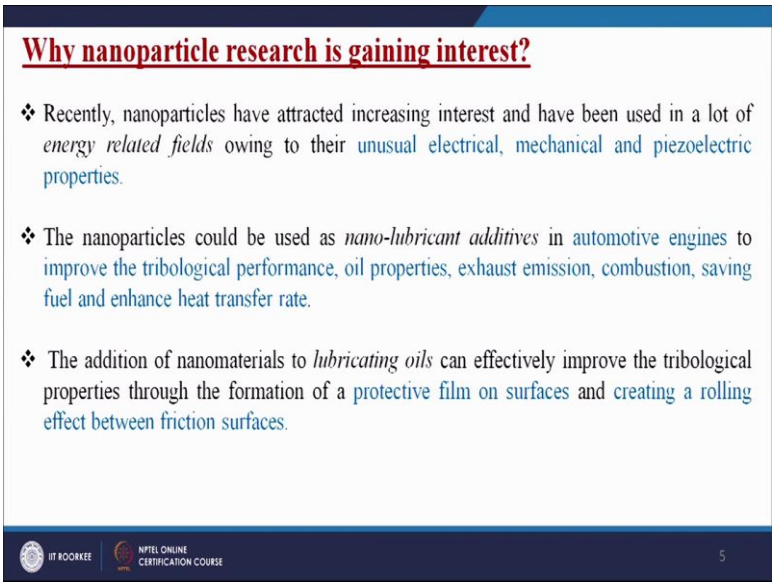
(Refer Slide Time: 06:09)



So, first is called the all mechanical, physical, chemical and geometrical aspects of the surface in contact of the surrounding atmosphere affect the surface interactions, and hence the tribological characteristics of the system. So, from morning to night we can see each and every time maximum materials is coming into the contact; rather when we are walking on to the surface also our feet or maybe our shoes is touching with the surface, without contact nothing is possible. So, that time it is generating certain kind of frictions, it is generating certain kind of heats by which material is getting degraded; the tribological parameter always coming into the picture.

Friction and wear are important parameters are they are unique characteristics of the tribological system, in which they are measured. Also tribological properties are not materials, but system parameters as I told already, that it is called the system response. It is not the any kind of phenomenon; we are doing some operations that is why that machines or equipment is giving that response to us. Tribotesting has to be an integral part of both the process of developing tribomaterials and in selection of materials for application involving friction and wear. Nowadays lots of scientist's lots of researchers are working on this particular topic; how to reduce the friction? How to reduce the wear and how to give the maximum properties or maybe the maximizing the life of any equipment or may be machines.

(Refer Slide Time: 07:38)



Now, we will discuss that why Nanoparticles research is gaining interest? So, till now we were discussing about the macro level, but why? As I already said that nowadays we are trying to do every research on into the Nano level because there are plenty of variety of things is available, not only that we can synthesize those materials, that materials is having very very fantastic properties than the virgin materials or maybe that composite materials, not only that that material chemical properties, physical properties are more than 100 times, 200 time, 300 times better than the normal materials.

So, that is why nowadays people are doing research on the Nano particles. So, recently Nanoparticles have attracted increasing interest and have been used in a lot of energy related fields, owing to their unusual electrical mechanical and piezoelectric properties. So, as I said already Nano particles is giving some extra ordinary properties regarding in terms of physical properties, in terms of mechanical properties, in terms of chemical properties, in terms of electrical properties and also simultaneously it is shape and size is also small and also it is less expensive and you can easily carry from one place to another.

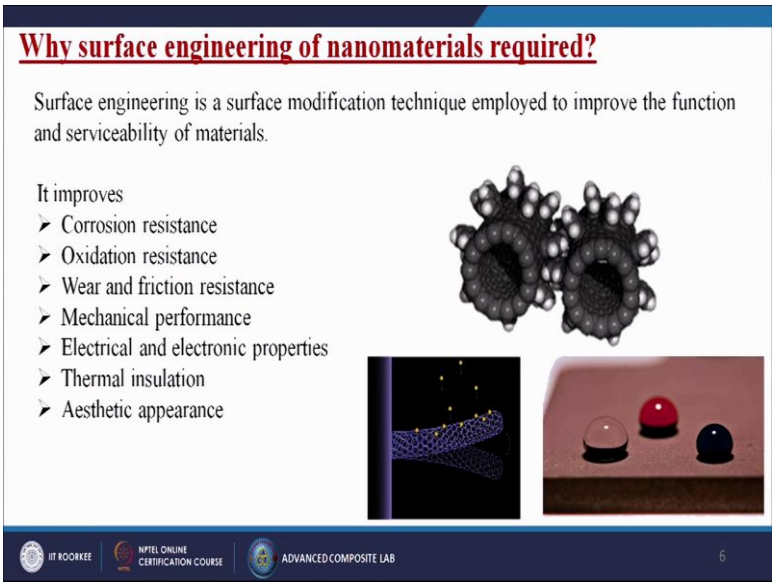
The Nanoparticles could be used as Nano lubricant additives in automotive engine to improve the tribological performance oil properties; nowadays we are using certain kind of Nanoparticles, some kind of coated Nanoparticles, which we are putting as a emulsions or may be mixing directly to the lubricating oil, so that when it is coming into

the contact in between the surface, it can absorb the more energy than the oil itself or may be it can exerts the energy at the dump side, so that that material can be used for a several times, it will not break, it will not lose it is properties.

The addition of Nanomaterials to lubricating oils can effectively improve the tribological properties through the formation of a protective film on surfaces, and creating a rolling effect between friction surfaces and not only that these Nanoparticles are sticking with the surface of 2 meting parts, so that if there is some pressures or may be frictions also they are not leaving those surfaces, that is why always there is a lubrication film is formed or may be there the surface is always lubricated.

Next is called the why surface engineering of the Nanomaterials required? So, from this particular slide, we can understand that when we are doing the surface engineering? Why it needs? The thing is that now we have made some materials, now we are using those materials, but that material is getting some problems in terms of wear, abrasions. So, now, we have to rectify these problems, but if we replace these materials it will be very very expensive, what we will do either will do some kind of coatings or maybe some kind of modifications, in terms of chemicals or physical, so that it is properties get increased that particular is coming on to the umbrella of surface engineering.

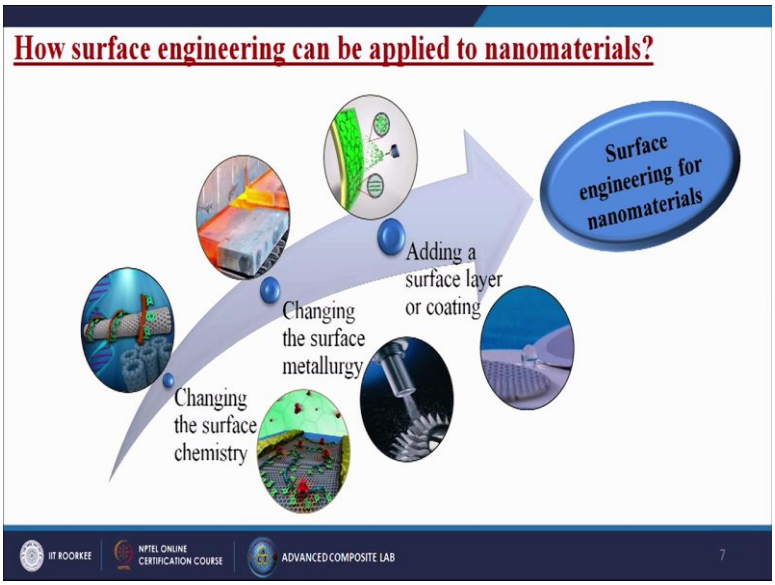
(Refer Slide Time: 11:00)



So, surface engineering is a surface modification techniques, employed to improve the function and serviceability of materials; it improves lots of applications, lots of

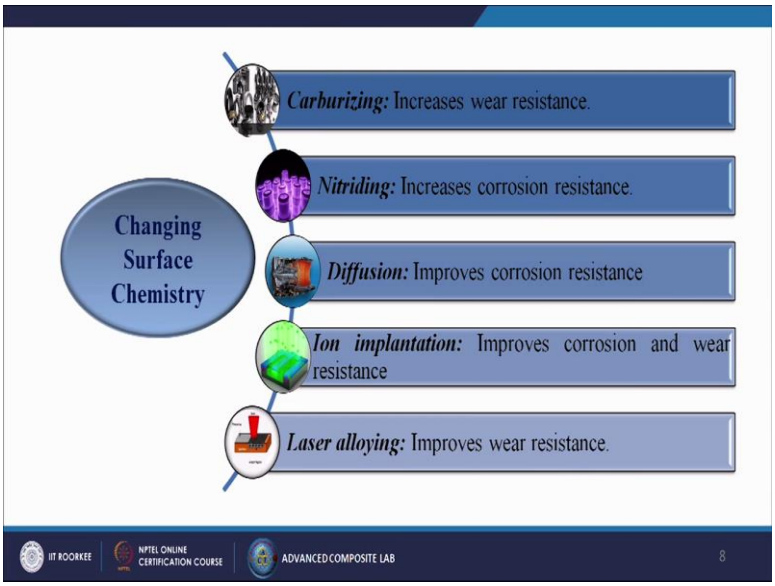
properties like corrosion resistance, oxidation resistance, wear and friction resistance, mechanical performance, electrical and electronic properties, thermal insulations, aesthetic appearance here I have mentioned few, but there are n number of applications n number of properties which can be modified by using the Nanomaterials.

(Refer Slide Time: 11:31)



How surface engineering can be applied to Nanomaterials? So, first initially that Nano particle can change the surface chemistry, it can react with the base materials or it can be made a coatings onto the base materials so that that surface will not directly come into the contact with the environment or maybe it will be lubricated. Second is called the changing the surface metallurgy. So, we are adding certain kind of Nanofillers into the base metals and doing the mixing or maybe making some kind of alloys or (Refer Time: 12:02) which is giving a tremendous property than the virgin material. Next adding a surface layer or coating; so on the top of the surface we are giving certain kind of coatings, so that it can made a film like structure or maybe sometimes the Nano particles is making a reactions with the base metals, so that it can form a self coating to it is outer surface, so that the material will not be eroded or maybe not be corroded.

(Refer Slide Time: 12:41)



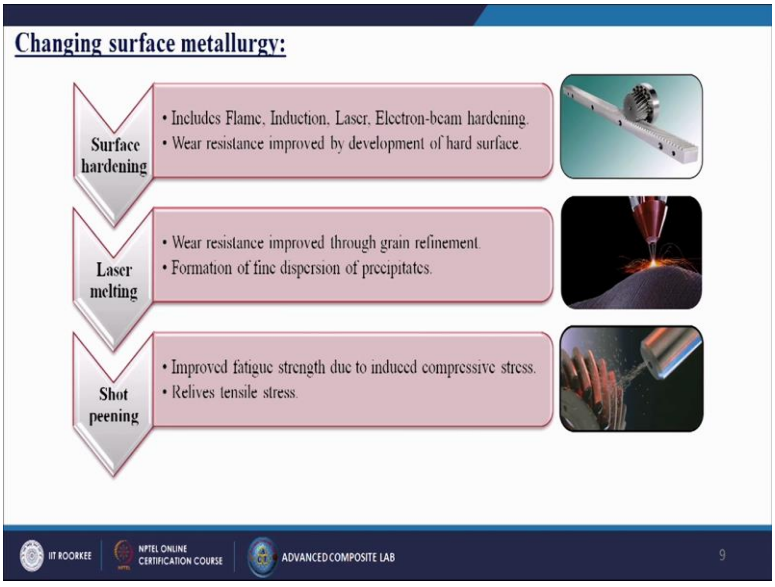
Next changing the surface chemistry; how we can do? We can do by the carburizing method, which will increase the wear resistance. Carburizing is nothing, but in the carbon environment either we can hit that material or maybe we can add the carbon content to the particular material, so that the material will be resistant in some particular environment; next is called the Nitriding. Nitriding means the same thing, now instead of carbon environment we are putting those materials into some ammonia environment or maybe some nitrogen environment, where that material can absorb the nitrogen in it or maybe nitrogen can create certain kind of film on to it is surface, so that the material will be corrosion less.

Next called the diffusion improves corrosion resistance, we can heat that material, so that material can defuse and it can generate some kind of verging properties or may be some kind of virgin surface, so that it will be non reactive to the environmental surface. Next called the ion implantations; so here we are having some kind of precursors, by which we are giving certain kind of energy to that particular precursor in terms of maybe heat, in terms of pressure, in terms of load, so that it can release some kind of ion, that ion directly coming and it is reacting with your base metals or may be coated on to your base metals or maybe it is going inside your base metals and doing the implantation, so that your base material properties is going to be changed. Last one is called the laser allowing improves the wear resistance, from that name itself you can understand that we are using certain kind of laser, you know what is the meaning of laser, it is the called the light

amplification of stimulating emissions of radiations, just we are creating the laser then we are putting the laser on to the metal surface due to that laser, either the material is getting heated up or may be the laser is penetrating inside the material, so that it can change it is properties of that particular base materials or may be some kind of laser pinning which will come into the next slide or maybe the subsequent slide.

So, due to that repeatedly we can depress the surface of that particular base materials, it can make a film or maybe the solid film, it cannot react with the environment itself.

(Refer Slide Time: 11:00)

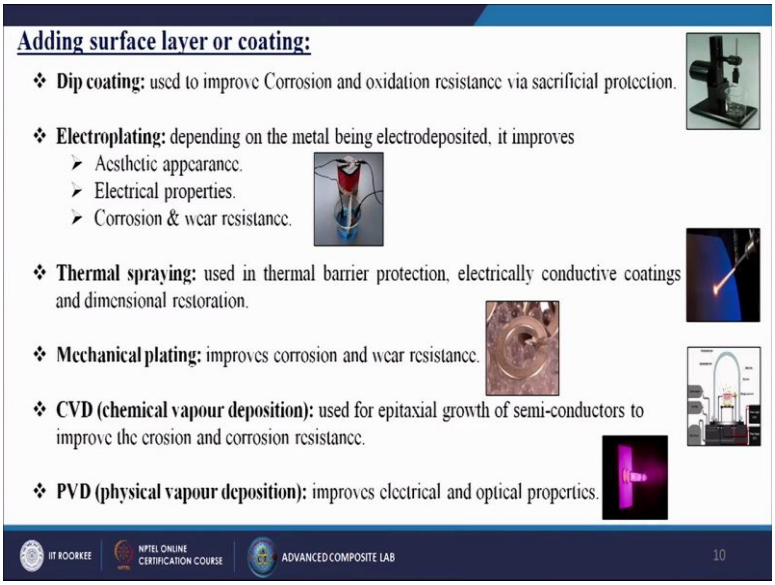


Changing the surface metallurgy; by doing the surface hardening; that means, we are applying certain kind of temperature or rather in our metallurgical term, we can say it as a hit treatment process. So, that we are hitting that material into certain temperature more than it is (Refer Time: 15:18) temperature, but below it is melting temperature. So, that the material properties can be changed, new crystal structure can be formed, by which the material will behave in a good manner or maybe it is rather it is physical properties or mechanical properties will be improved. second is called the laser melting already I have discussed by which we can increase the wear resistance and the formation of fine dispersion of the precipitates and last one is called the shot peening; shot peening is nothing but the, I can give you one example suppose you are having one surface and top of that surface you are having some balls, either these balls is made by the ceramics or maybe some kind of metals.

So, if you are having several balls and if you allow those balls to fall free fall from the certain height. So, it will gain certain kind of kinetic energy, that kinetic energy will come directly and that ball will hit that surface; due to that your surface will automatically depressed or maybe if there is any cracks and pours is there it will be compressed. So, a hard layer will be formed on top of the surface, this is known as the shot peening operations. So, by applying the laser or may be applying the some normal ceramic ball, we can do the compression of that particular surface, by which we can modify the surface properties or maybe the surface of that particular material.

Next adding surface layer or coating; so, there are several types of coatings which we can apply to that particular material.

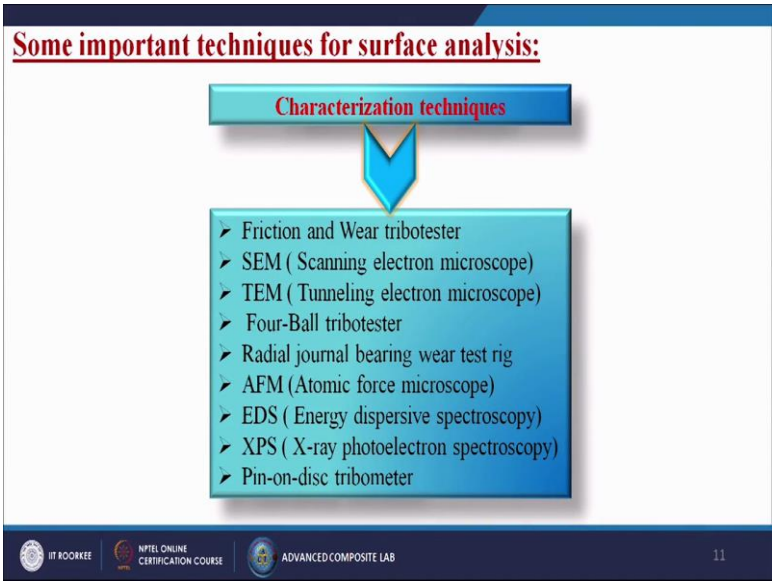
(Refer Slide Time: 17:00)



So, first one is called the dip coating used to improve corrosions and oxidations resistance via sacrificial protections. So, we are putting that material into some chemicals, by which the whole material can be covered by some other material, which is non reactive to the environment itself. Electroplating; so we are using some anode and cathode we can create certain kind of potential difference, so that one material will be eroded and that will make a coating on to the another material right. So, whatever the material you are using for coating, that material should be less corrosives or maybe less oxidative to the environment itself.

Next called the thermal spraying used in thermal barrier protections, electrically conductive coatings and dimensional restorations, mechanical plating improves corrosions and wear resistance, CVD is called the chemical vapor deposition process. So, in that particular case we are doing certain kind of reactions, some kind of vapor is forming then that vapor we are allowing to substitute or maybe the deposit on to your surface, so that your material surface will be getting some kind of cover. Last one is called the PVD, which is known as the physical vapor deposition process, by which we can improve the electrical and optical properties. So, last two methods we can create certain kind of vapor, which can directly come and make a layer on to your surface.

(Refer Slide Time: 18:32)

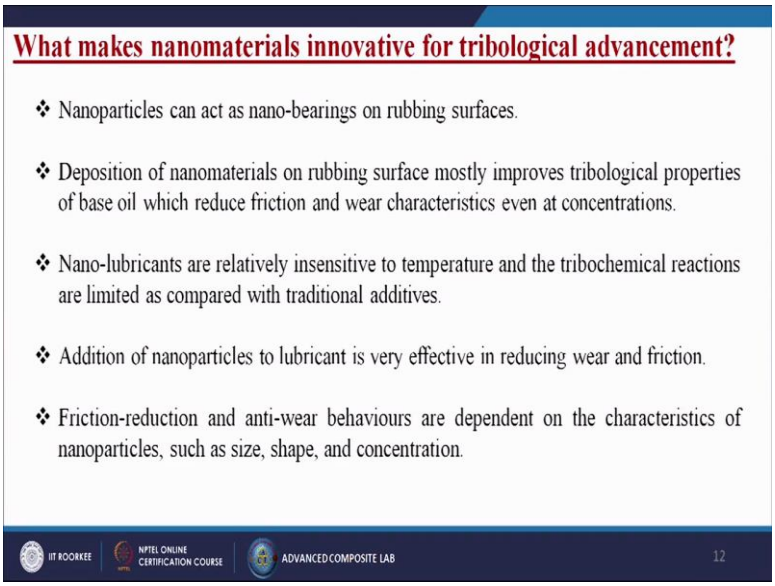


Now, we will discuss about the some important techniques for surface analysis. So, how we are going to measure that is there is any wear or maybe there is any abrasions or maybe when we are doing some kind of the coatings, how we can measure all those? So, first one is called the friction and wear tribotester. So, it will give you some kind of noise signals by which you can understand that whether your coating is proper or maybe it is worn out so that you can go for the second times. Next called the scanning electron microscopy; so by seeing it into the microscopic levels, you can zoom the figure, you can see that whether which there is any cracks or maybe any kind of ports are there or not which we cannot see from our naked eyes.

Next is called the transmission electron microscopy; next is called the Four-Ball tribotester; Radial journal bearing wear test rig; Atomic force microscopy; EDS is called the energy dispersive spectroscopy; XPS is x ray photoelectron spectroscopy pin on disc tribometer. So, these all will give you the different properties about the materials, not only that it will not give only the surface properties or also it will give you the atomic level properties of that particular material too.

Now, in the next slide we will discuss that what mixed Nanomaterials innovative for the tribological advancement? So, why we are using the Nanomaterials? What advantage actually we are going to get by doing this surface engineering?

(Refer Slide Time: 20:10)



So, now, Nanoparticles can act as a nonbearing on rubbing surface; deposition of Nanomaterials on rubbing surface mostly improves tribological properties already I have discussed, because in the macroscopic level if you see that if I am having a bigger particle it is very difficult to stick on to the surface, but if I am having a very fine powder, it is easier to them to easily stick with that surface itself. Next Nano lubricants are relatively insensitive to temperature and the tribochemical reactions are limited as compared with traditional additives, these are less expensive and it can be easily fabricated in the lab itself so that it is having some wide applications. Addition of Nanoparticles to lubricant is very effective in reducing the wear and frictions, friction

reduction and anti wear behaviors are dependent on the characteristics of Nanoparticles such a size, shape concentration.

So, depending on our requirement we can increase or decrease the size of that particular Nanoparticle, we can do certain kind of coatings of that particular Nanoparticle. So, by which we can use that lubricants for several applications.

Thank you.