Basics of Mechanical Engineering-2

Prof. J. Ramkumar

Prof. Amandeep Singh Oberoi

Department of Mechanical Engineering

Indian Institute of Technology, Kanpur

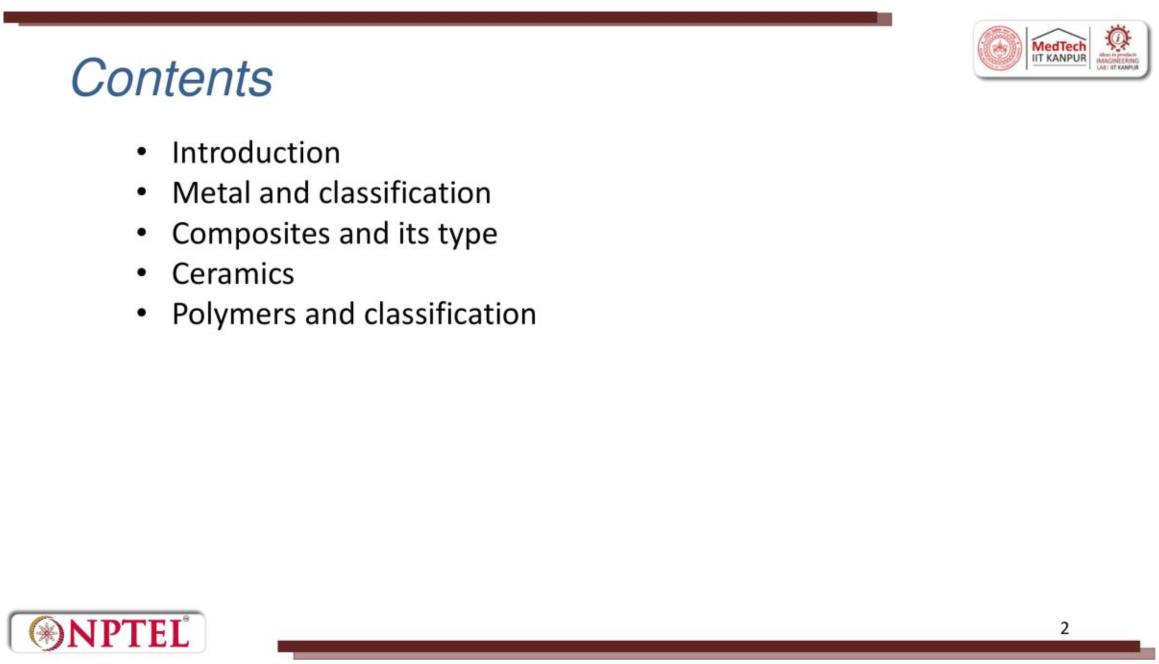
Week 01

Lecture 02

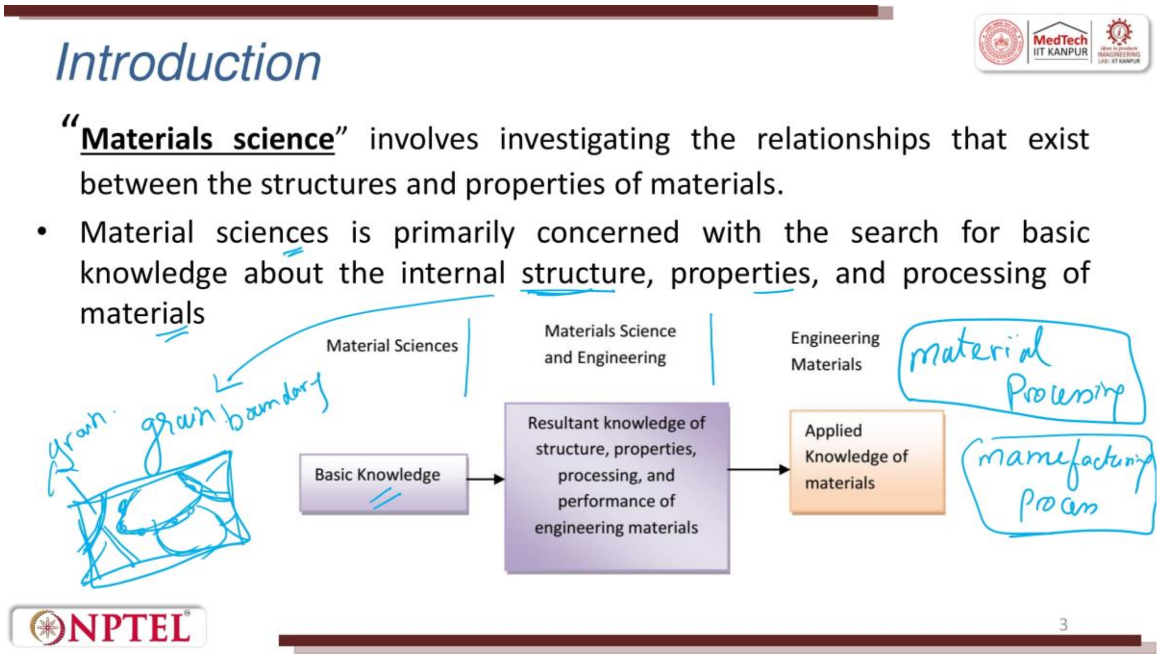
Engineering Materials (Part 1 of 3)

Welcome to the lecture on Engineering Materials. I have classified this Materials lecture into three parts. For manufacturing, understanding Materials is very important. Moment I understand the Material, its performance. In terms of mechanical properties and service condition exposure, I can do better manufacturing.

When we do a proper efficient manufacturing, it always leads to customer satisfaction, reliability and repeatability of the product.



So, in this lecture, we will try to have a Introduction. followed by it will be Metal and classification, Composite and its type, Ceramics and Polymer and classification.



Understanding Materials always leads to "Material Science". Material Science involves investigating the relationship that exists between structure and properties.

When we talk about any metal, we always try to talk about the properties in a macro scale. But moment you wanted to talk in terms of micro scale, today we talk about a new area called Grain Engineering. I know this is what is output required for the customer or in the product. So, now how do I design or tailor make my grains? You can make the grain larger, smaller.

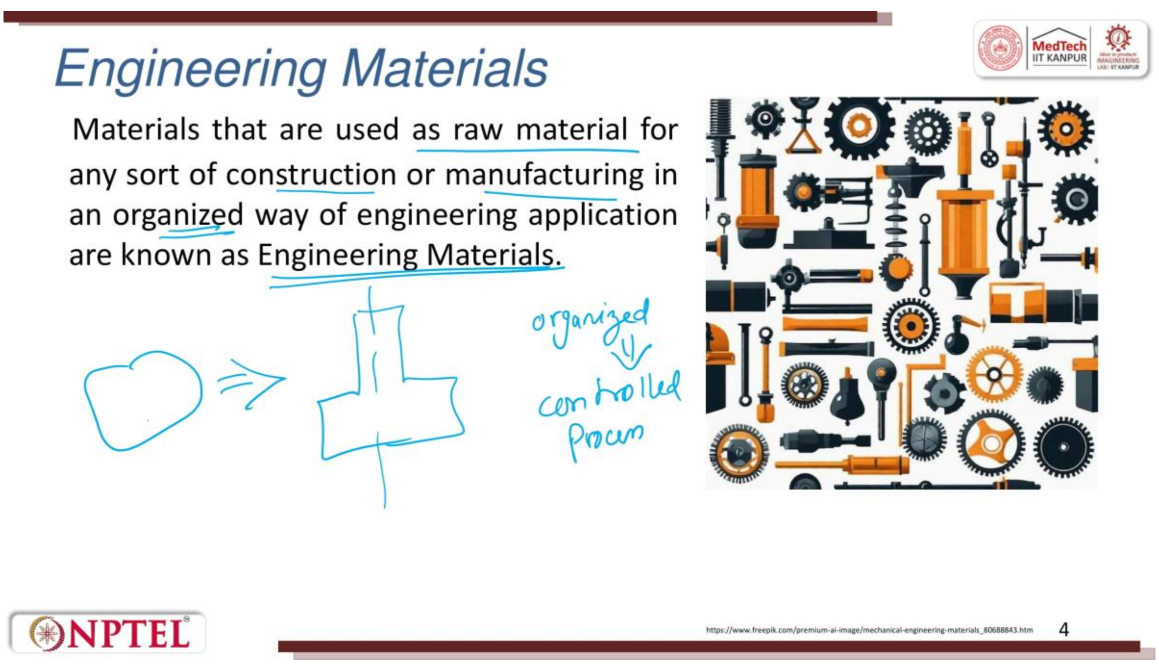
You can try to have some precipitation around the grain. All these things are possible. So, if I have to do this, I have to understand Material Science. This involves a relationship between the structure and the properties. Material Science is primarily concerned with the search for basic knowledge about the internal structure, properties, and the processing of materials.

How do I process the material? There are two things we are talking about. Material processing and manufacturing process. When I talked about grain engineering, it all revolves around material processing. So, Material Science is primarily concerned with the search for basic knowledge about the internal structure.

The internal structure is nothing but the grain. Every material is made out of grains. So, this is a grain, and this is the material. I am taking a typical material, and I am trying to segment it into small parts. When I look into a microscope, I try to see these grains. So, a material is made out of grains.

So, internal structures are nothing but the grains and along the grains, what we call it as grain boundaries. This is very important. The size of the grain plays a very important role. So, you can enlarge the grain, shrink the grain, stop the grain movement, or play with it. All these things are Material Science.

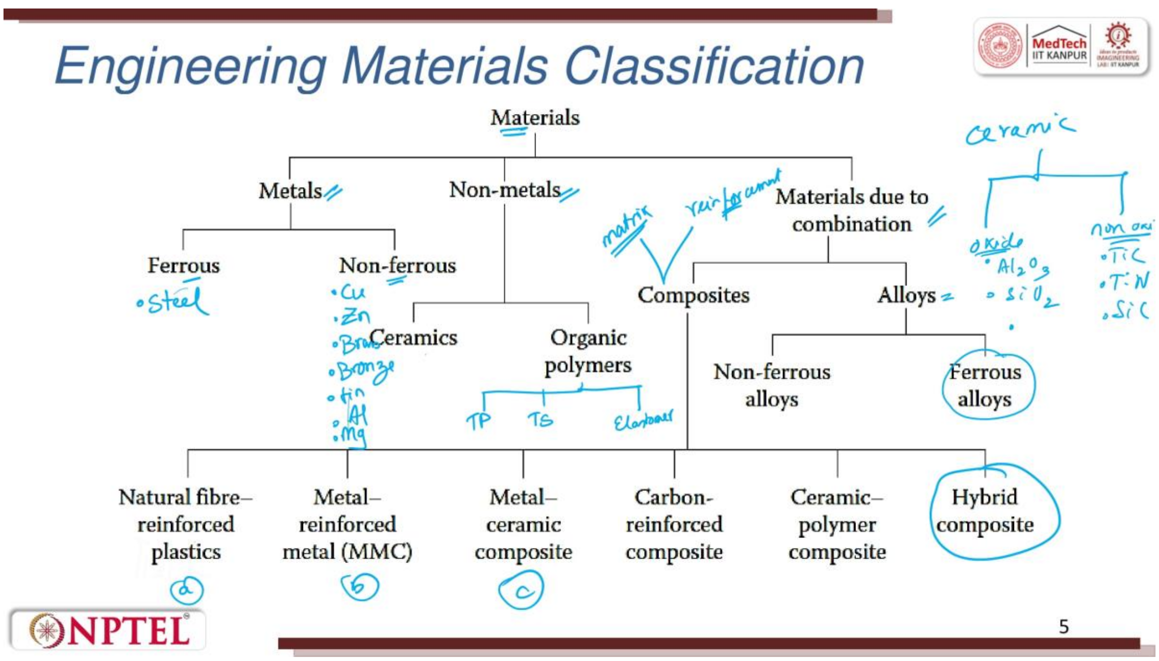
Internal structure, properties, and the processing of the material are Material Science. So, Material Science gives you the basic knowledge. Material Science and Engineering result is nothing but the resultant knowledge of structure, property, processing, and performance of Engineering Material, which is Material Science and Engineering. The Engineering Material we use is nothing but the applied knowledge of Materials. So, you can now clearly distinguish Material Science, Material Science and Engineering, and Engineering Materials. So, this understanding is very important because, based on this understanding, we will try to choose a process.



When we look into Engineering Materials, Materials that are used as raw material for any sort of construction or manufacturing in an organized way of engineering application are known as Engineering Materials.

So, we know there is a material available. We have to convert this into a part. We know there is a material converted into a part. So, that is what we call it as Materials that are used as raw material for any sort of construction or manufacturing in an organized way. See, why are we talking about an organized way?

Because an organized way means you are trying to have a controlled process. Why a controlled process? Because every time you try to make, you should get the same output. So, the organized way of engineering applications is known as Engineering Materials.



Materials can be classified in many ways. The most basic and fundamental way is that they are classified into three parts. One is Metals, Non-Metals, and Materials due to combination. You are trying to combine materials. Materials here may be between A and B of Metal and Non-metal to get an output. So, they are classified into three basic steps: Metals, Non-Metals, and Materials due to combination. It might look a little surprising.

Today, if you try to look at a domestic application, Non-Metals play a very, very significant role, a very significant role. More polymer products are available today. Let it be automobiles, let it be your ordinary kitchen utensils, let it be now heavy-strength materials, Non-Metals are coming in a big way. Under Metals, you have two basic classifications, which are nothing but Ferrous and Non-Ferrous. When we talk about Ferrous, we try to talk about steel.

Again, in steel, you have classifications. So, ferrous means steel. Stainless steel utensils, what you use at your home, high carbon steel, high-strength steel, low weight, high-strength steel. So, steel is part of ferrous. When we talk about non-ferrous; copper, zinc, or a combination of copper, zinc, brass, bronze, tin, these are multiple things, aluminum, then you have magnesium. These are all different types of non-ferrous materials.

All these non-ferrous materials are exhaustively tried today because of their lightweight. For example, 40 years, 50 years before, we were using as white body material. We were using steel. Now, we try to use aluminum. The folding chairs were made out of steel.

Today, we are trying to make this out of frame structure where aluminum is exhaustively used. So, aluminum is light in weight. It has better environmental-resistant conditions. So, they are exhaustively used. When we want to make engineering materials, we try to have all these non-ferrous materials getting mixed into the iron material to give better performance. That is what we are coming under the alloy classification.

When we talk about ceramics, there are again two classifications of ceramics: one is oxide ceramics, and the other is non-oxide ceramics. Oxide ceramics include alumina, silicon dioxide, etc., as part of oxide ceramics. Non-oxide ceramics include titanium carbide, titanium nitride, and silicon carbide. These are some of the non-oxide ceramic materials. As you know, ceramic materials have a high-temperature resistance property.

That means they can withstand very high temperatures for whatever application you want. Organic polymers can be classified into three parts. One is thermoplastic, thermoset, and elastomers. Elastomers are nothing but rubber. So, again, these can be further classified into thermoplastic, thermoset, and elastomers.

Now, let us move to the next classification, which is materials due to combination; you have composites and alloys. Composites are materials where you have two major components. One is called a matrix, and the other is called a reinforcement. The matrix can be made out of metal, ceramic, or polymer. The reinforcement can be made out of ceramic or metal to meet the engineering requirements.

We will see this in more detail. But when you try to take these composites, they are further classified into several parts. They are classified as natural fibers. When I mentioned reinforcement, you can have a natural fiber reinforcement. You can have a metal reinforcement, right?

You can have a ceramic reinforcement, which is glass as a ceramic material. So, that is called a ceramic polymer reinforced composite. You can have carbon fiber reinforced polymer. You can have inner metal ceramic getting dispersed or inner polymer metal getting dispersed. All these combinations are possible today.

And apart from all these, you can also try to have a hybrid, which is a combination of multiple things. Hybrid means you try to take A, B, and C to meet the engineering requirements. So, composites are classified into several types. Again, the basic thing in a composite is you will have a matrix and a reinforcement. The matrix is basically to hold the reinforcement so that you can get high-strength properties or hybrid properties.

When we talk about alloys, alloys are again classified into ferrous alloys and non-ferrous alloys. What I explained here is steel, when it is mixed with non-ferrous material, it forms a ferrous alloy. You can also have non-ferrous alloys like bronze and brass. These are all non-ferrous alloys. So fundamentally, if you see engineering materials classified,

basically into three types: metals, non-metals, and materials due to combination. This is a very important understanding. Suppose you wanted to have very high strength, very light in weight, then get back to this table and find out, should I use ferrous, should I use ferrous alloys, should I use non-ferrous alloys, or should I go for composites. We will see the properties a little later in the discussion. So, when we talk about metals, there are so many metals; it is a huge menu. In the menu card, you will have a huge list of metals.

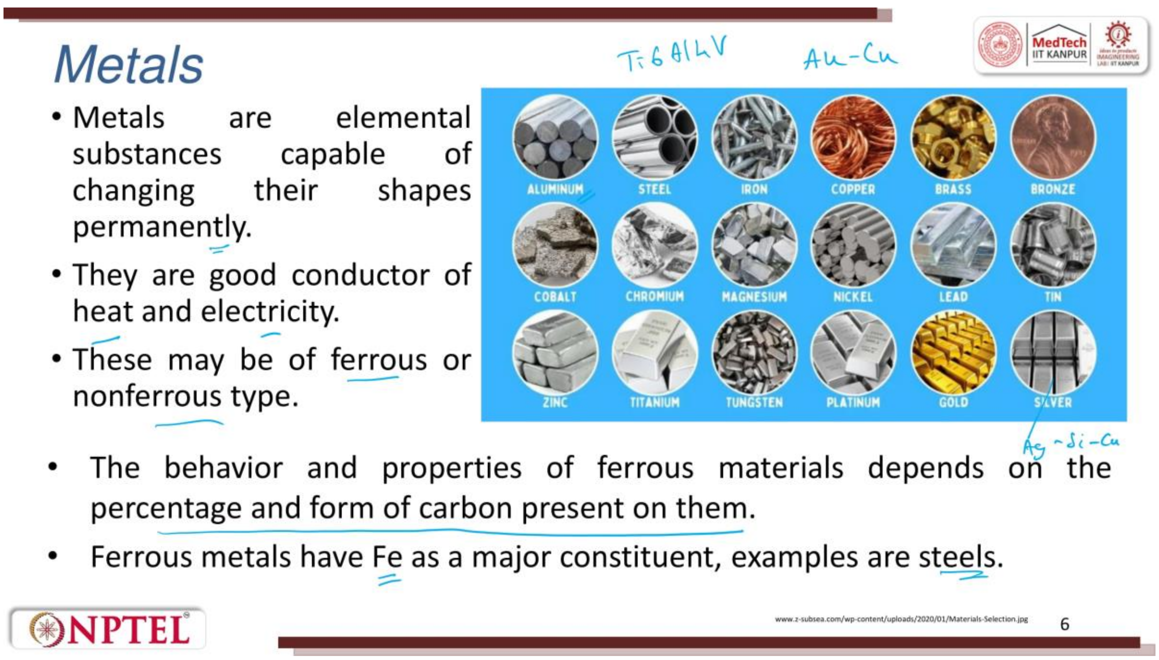
So, aluminum, which is commonly used; steel; iron; copper—today, copper is exhaustively used for high-conducting applications—copper; brass, which can be used for fittings, which can be used for artifact making; then bronze. These two, brass and bronze, are used for artifacts. Artifacts mean some display items. Bronze is also used. Then you will have cobalt, chromium, magnesium.

Aluminium, magnesium, and titanium are extensively used in automobile applications today. They are not used as pure materials. They always have a combination. So we always talk about aluminium alloys, magnesium alloys, and titanium alloys for various applications today. In biomaterial applications, titanium alloys are extensively used.

You have nickel-based alloys. Nickel-based alloys are used for exotic applications. For example, today you have high strength, high temperature, and non-corrosive materials. We go for nickel-based alloys. Then lead, which is very heavy.

Lead is used, as well as tin and zinc, right? Then you also have tungsten. Tungsten is a heavy material. Today we are trying to make many aerospace applications tungsten-based. Platinum and gold, pure gold has no value.

Gold, when it is mixed with an alloy of copper, helps in making ornamental items. Then you also have silver. So, you see, there is a huge spectrum. You can have one metal. You can have a two-metal combination, or a three-metal combination. Today, they are trying to have a six-metal combination to meet the requirements.

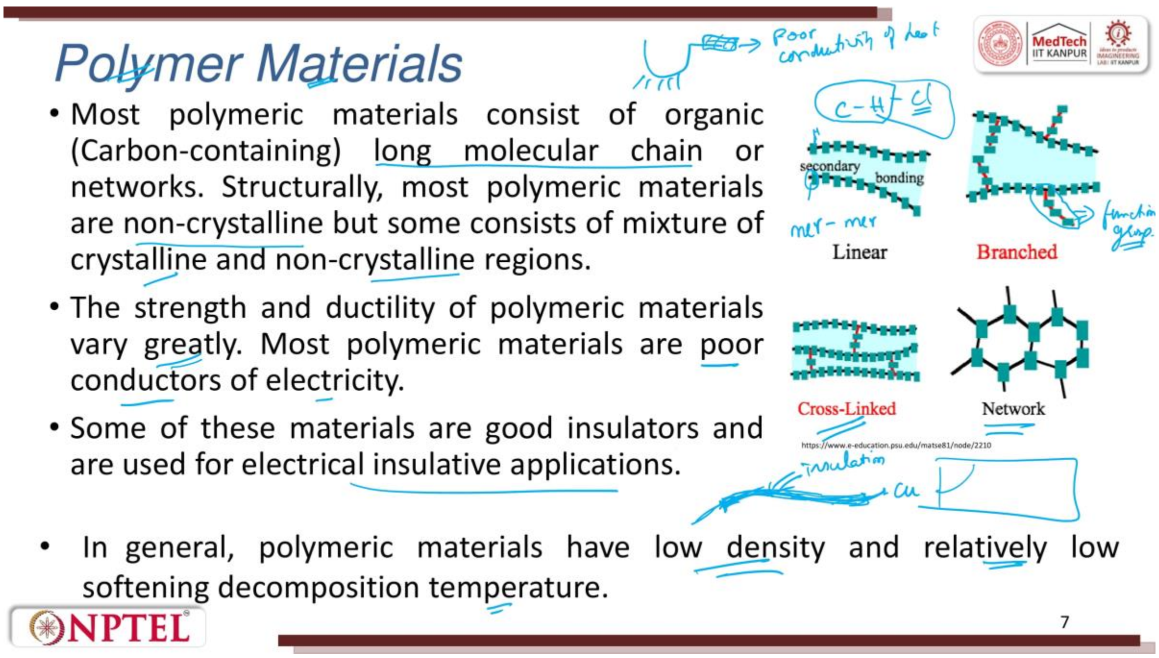


Metals are elemental substances capable of permanently changing their shapes when a force is applied. They are generally good conductors of heat and electricity. For example, if you want a vessel for boiling water, a good conductor is required. If you are looking to transmit electrical power from one place to another, we use copper cables.

So, electricity is very important. There can be ferrous and non-ferrous types as well. So, when it is steel, it is ferrous; non-ferrous types are also there. The behavior and properties of ferrous materials depend on the percentage and combination of carbon in them. So, the moment you add carbon to steel, the performance of the material changes.

The Ferrous Metals have Fe as a major constituent. As an example, you can try to look at steel. Say for example, titanium, you can have Ti6Al4V. You can have this combination, right? When we talk about gold also, we try to have AU, and then copper combination you can try to have.

Silver is again AG and SI combination you can try to have or you can try to have copper combination into that, depending upon your requirements. So now it is clear. Depending upon the addition, you can try to have various strength properties. you can try to have heat conducting and electrical properties.



When we look into polymers, polymers are made out of C and H, carbon atom, hydrogen atom and then you can try to have some other atom to bring to the or add value such that you get a good engineering application. Most of the polymer material consists of organic carbon content. These carbon content are all formed into a chain.

There in Metals I was trying to tell you they are made out of grain. So here, this carbon gets fixed in a chain. This chain is called as molecular chain. They are always long. There is a long molecular chain and all the carbon and hydrogen sticks here.

And when you have carbon and hydrogen sticking here or this combination sticking here, the individual block is called a mer. Several of these mers join to form a polymer. Most polymeric materials consist of organic long molecular chains or networks. If you have a long molecular chain, you will have different applications or different properties. If you have a network, you will have different properties.

So if you have a long chain, a free chain, and if these free chains are not attached anywhere, what happens? The free chain keeps on moving. So you will have a greater amount of mobility. So the ductility will be very high. The moment you start pinning the chain,

That is called cross-linking. When you cross-link, the chains do not have the freedom to move left or right. So they are all held rigid. So now when we try to create such polymers, you will aim to have high strength. So you can also have branches on the polymer.

In the polymer molecular chain, you can also have branches. These branches are attached by some functional group. So when the functional group is added, these small chains get attached to a long molecular chain. So, by looking at the structure, you can try to have multiple or varying properties. Structurally, most polymer materials are non-crystalline in nature.

But some polymers have a combination of crystalline and non-crystalline regions. So you can have a polymer that is partially crystalline and partially non-crystalline. So non-crystallinity gives you different properties compared to that of a crystalline polymer. The strength and ductility of the polymer material vary greatly. The big difference between metals and non-metals, for example, with respect to polymers is that polymers have poor conductivity of electricity and heat.

So when we try to look at a vessel in your kitchen, we always try to make a handle out of it. This handle will have poor conductivity of heat. When you have a kettle, it will have poor conductivity of electricity because in a kettle, you heat it by electricity. So, poor conductivity of heat and electricity is observed in a polymer. So, the handle that you see in a vessel is made out of polymer.

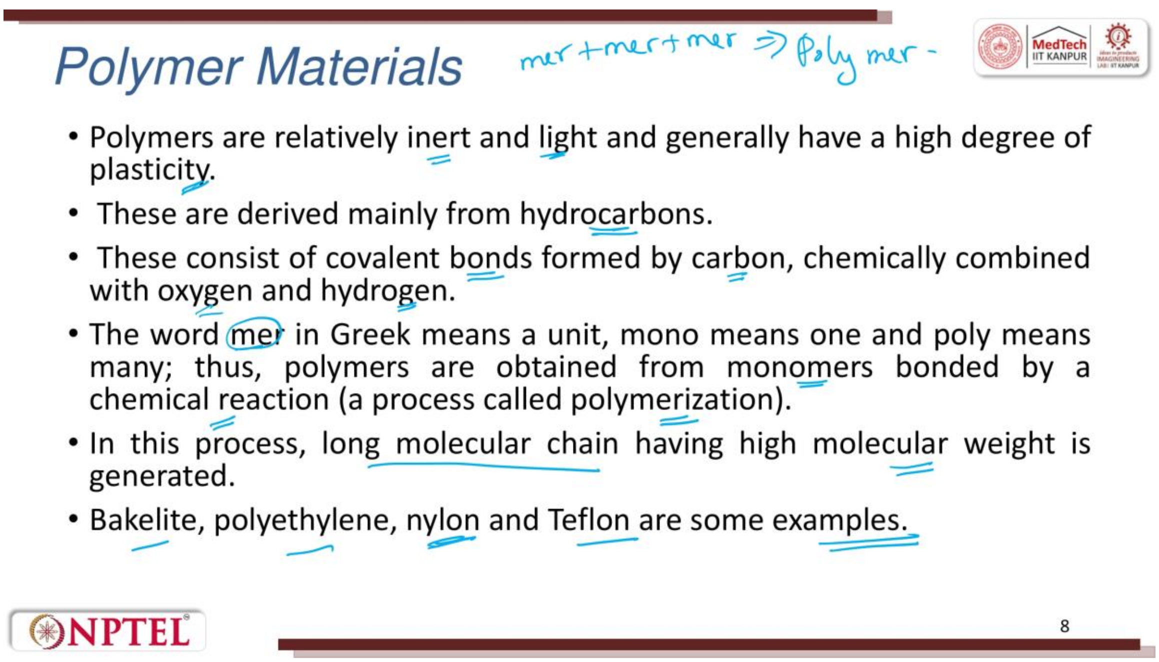
You can try to add a greater amount of branching, cross-linking, and all, and you can try to make it out of polymer. You can try to have a bake light that is used for holding. Some of these materials are good insulators and are used for electrical insulation applications. For example, you have a wire. The wire is covered by a polymer material. This can be a rubber-based material or elastomer.

So, this makes it a poor conductor. So, it is called insulation. The wire is a copper wire or aluminium wire. In general, polymer materials have low density and relatively low softening or decomposition temperature. So, this low density means the weight is low.

So, when we make the cables, the cables are hung on top of a ceiling. So, if it is heavy, then you will have to make proper fixtures to hold it. So, since it is light in weight, you just strip it or stick it on top of a ceiling. So, low density means low weight. So, when we take a kettle, again, the low density gives you a bigger advantage.

The handle becomes very light. You can always have a wooden handle, but a wooden handle is heavy. A wooden handle absorbs water. So, polymer does not absorb water. So that is what it is.

And then, it is relatively low decompression temperature. So, what does it mean? When we apply a very small temperature, you can try to deform it. This property is not there in metals. So basically, when you try to work with metals, you should always try to use a higher temperature. So you spend more energy to deform and get the final output.

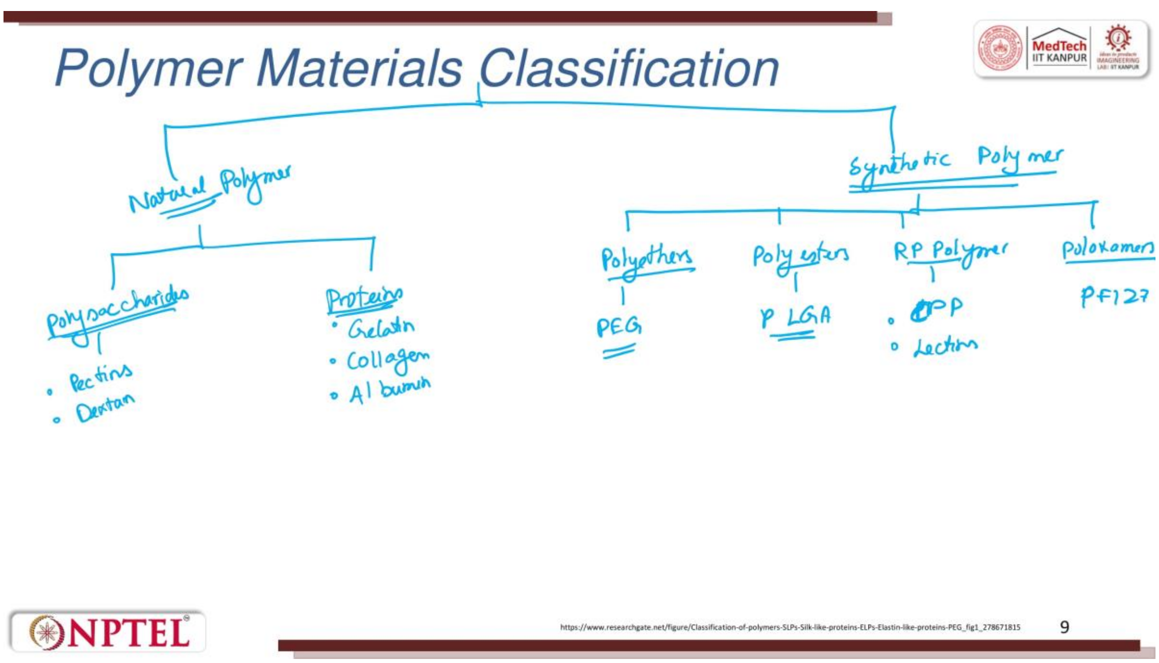


The polymer materials are relatively inert and light, generally having a higher degree of plasticity and ductility. They are derived mainly from hydrocarbons. They consist of covalent bonds formed by carbon, chemically combined with oxygen and hydrogen. The word 'mer,' see this is what 'mer' plus 'mer' plus 'mer' leads to polymer.

The word 'mer' in Greek means a unit, 'mono' means one, and 'poly' means many. Thus, polymers are obtained from monomers bonded by a chemical reaction called polymerization. In this process, you get a long chain having a higher molecular weight. When we try to compare metals and polymers, the molecular weight of polymers is generally in several thousands, whereas here it will be very low. Why? Because the molecular weight is calculated by the number of mers put together.

Bakelite, polyethylene, nylon, and Teflon are some examples. Teflon, where do we use it? Wherever we want to have a fitting and where in the fitting we want it to be leak-proof. We always try to use Teflon tape. So, this is what I said.

It will have a high degree of plasticity. You can try to wind it. Nylon is extensively used again for fittings. You can have nylon fittings in taps. So they have toughness and can be easily made.



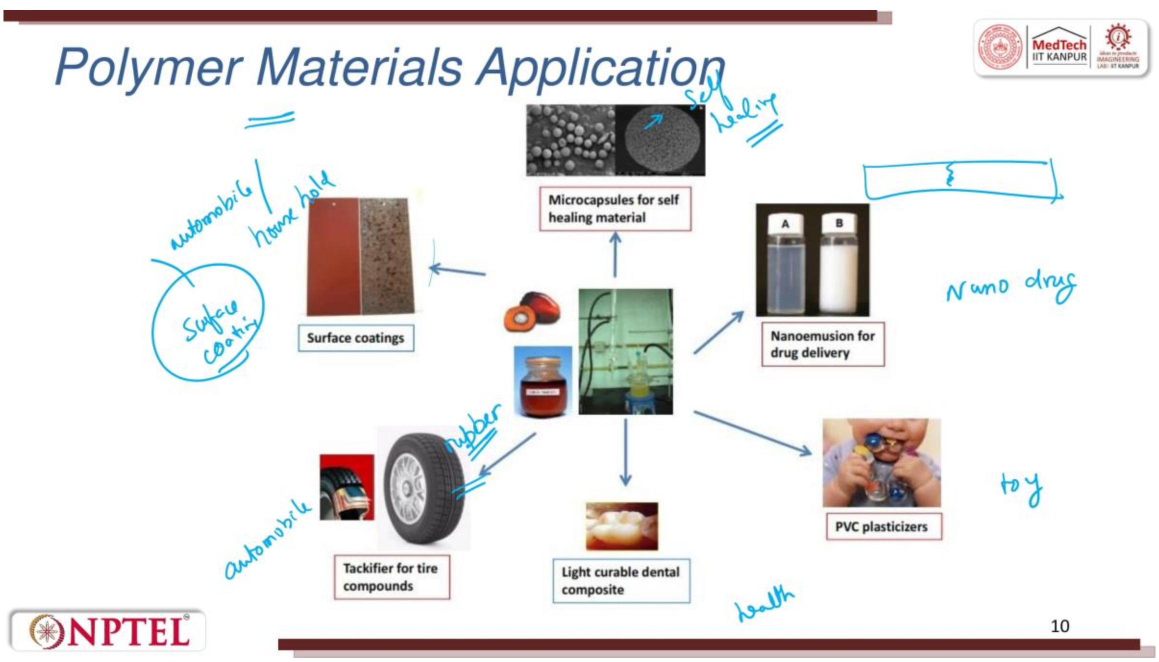
So, Polymer Material Classification. So here, polymer is again classified into two types. One is natural polymer. The other one is synthetic polymer. Synthetic polymer means it is artificially made.

Natural polymer means you extract it from a tree or something. For example, rubber is extracted from a tree. A syrup comes out. So, that is a natural polymer. So, again in natural polymer, you have two types.

Proteins are natural polymers. Then, polysaccharides. They are also a part of natural fibers. So, some examples, if you see here, these are some of the examples: dextane. These are some of the examples of polysaccharides.

So, when we talk about proteins, we include gelatin, collagen, albumin, which is found in eggs; these are all part of proteins. They are all natural fibers. Now, when we talk about synthetic fibers, we have polyethers, then we have RP polymers, and we also have poloxamers. So, under polyethers, we have PEGs, and then we have PLGA.

These are all classifications, and you would have used or seen these when looking at the specifications of a product. Then there is CPP, or you can have lactides, okay. So, when you look at poloxamers, you will have PF127. Now, it is very clear that polymers can be produced synthetically. Synthetically means using a polymerization process, and through this process, I can functionalize, add a branch, form a network, or create rigid structures.



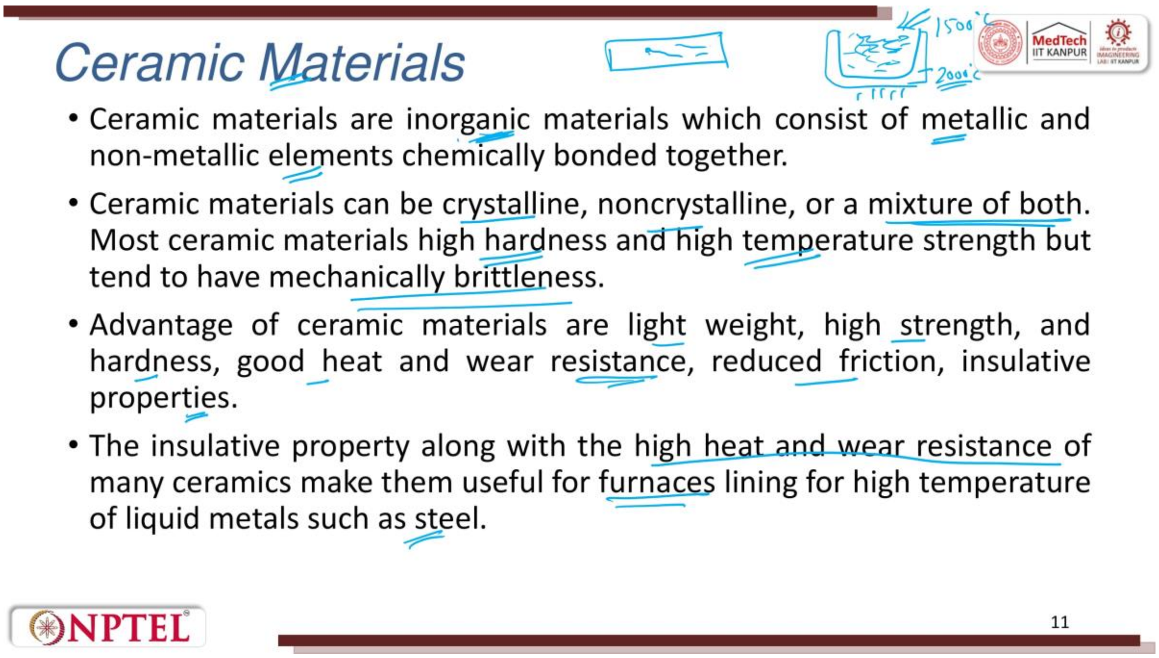
Here are some of the major applications of polymer materials. They can be used for making microcapsules for self-healing materials. Self-healing materials mean you take a material, puncture it, or crack it. When these self-healing capsules are applied, these cracks are arrested and closed. These are microcapsules made out of polymers that have self-healing properties. You can also create surface coatings out of polymers.

So, the surface coating, when we try to have an internet cable, when you try to cut it, you see optical fiber covered with a rubber material, or you can try to take a copper wire insulated with a rubber-like structured material. So, surface coating, you can also try to do a flat coating, polymer coating on top of a metal surface which will prevent chemical reactions and rusting. You can also have polymer materials for tackifiers for the tire compounds. So, there are rubber materials which also fall under polymers and are extensively used. So, these rubbers are vulcanized. You can see the several wires around it; you can also try to have some shapes which are given on top of a tire such that it can increase its performance.

Then you can have light-curable dental composites. So, today what we do is, when you go to a dentist for filling your teeth, for a tooth which is decayed, he makes a paste, keeps the paste on the cavity, and then he exposes it to a UV light or some light such that it accelerates its curing. So, you can use it for dental cavities, light-curable dental composites. You can have PVC plasticizers. PVC bottles are there, PVC lids are there, and kids' toys are made out of PVC.

So, they are used, and nano emulsions for drug delivery are also used. So, polymers find their applications in nano drugs, in automobiles, in healthcare, in toys, in self-healing. These are new materials, self-healing, and then you can also use them for surface coatings. Again, where is surface coating used? It is extensively used in automobiles or households.

So now you see polymer is spread in every part, every segment Polymer Materials are available. And each and every process for making the output is different.



Moving to Ceramics. Ceramics are inorganic materials. Polymers are organic and under organic we had a classification: thermoplast, thermoset, and elastomers.

Then when we try to take Polymer, we had synthetic and natural. But when you come to Ceramics, it is plainly inorganic material which consists of metallic and non-metallic elements bonded together. Ceramic Materials can be crystalline, non-crystalline, or a mixture of both like what you had in Polymer. Most Ceramic Materials have very high hardness and very high temperature strength, which is not possible either in polymer or in metal. Why is very high hardness required?

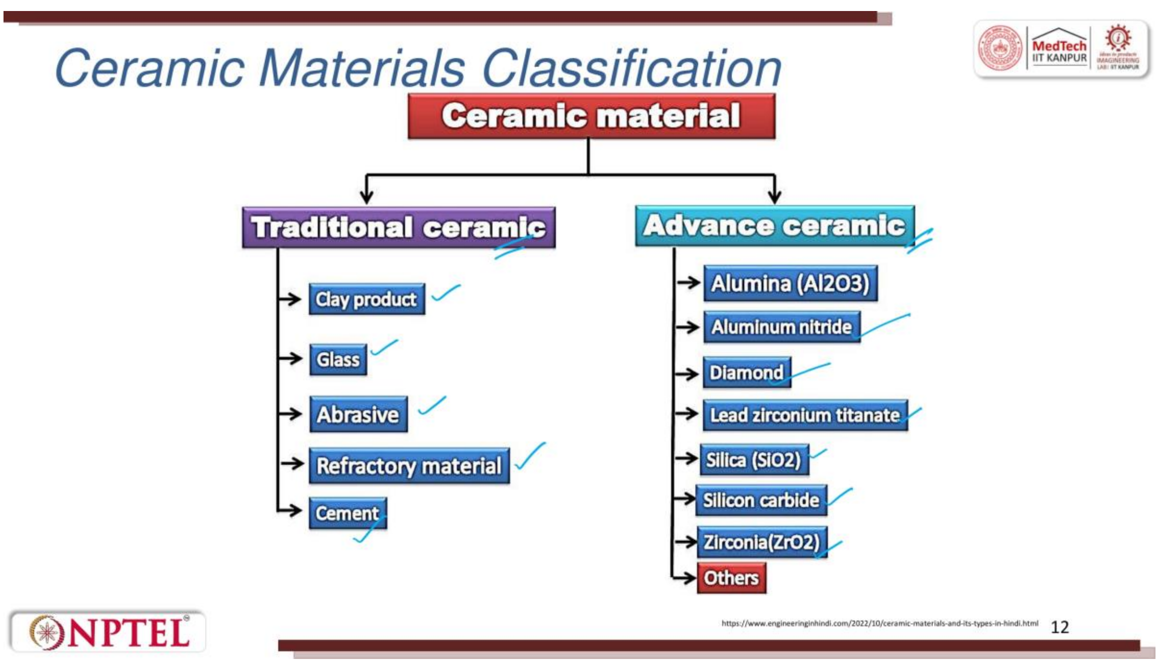
Because this tries to give you scratch resistance. High hardness means when you have a material, if you want to indent the material, it is not possible. If there is a scratch, it will not so easily happen if you have high hardness. Of course, scratch can also talk about toughness. So, high hardness and high temperature strength, but it has very poor mechanical properties. That means to say, it is very brittle.

Glass has very high hardness. In glass, if you try to scratch it with your nail or a spoon, it is not possible. But when you drop it, it shatters. That is what we mean by high hardness, high temperature strength, and brittleness. The microwave bowl you use has very high hardness.

The bowl can withstand very high temperatures and has very poor mechanical properties. It is brittle. The advantages of ceramic materials are light weight, high strength, high hardness, good heat and wear resistance, reduced friction, and insulative properties. These are all the advantages. That is why ceramics are extensively used. For example, in a chemical plant, we use hoses that are made of polymer coated inside with ceramic material.

The ceramic material provides more corrosion resistance and wear resistance, right? The insulative property, along with the high heat and wear resistance of many ceramics, makes them suitable for furnace linings for high-temperature liquid metals in steel. See, when you need to boil something. So, this is a material that needs to boil or heat at 1500 degrees Celsius. Naturally, the container must be made to withstand 2000 degrees Celsius or 1800 degrees Celsius because you are trying to heat it.

So, if that is the case, we always try to use insulating material. So, insulative material, which is why if you take a furnace, the lining or the holding will be made out of ceramic material.



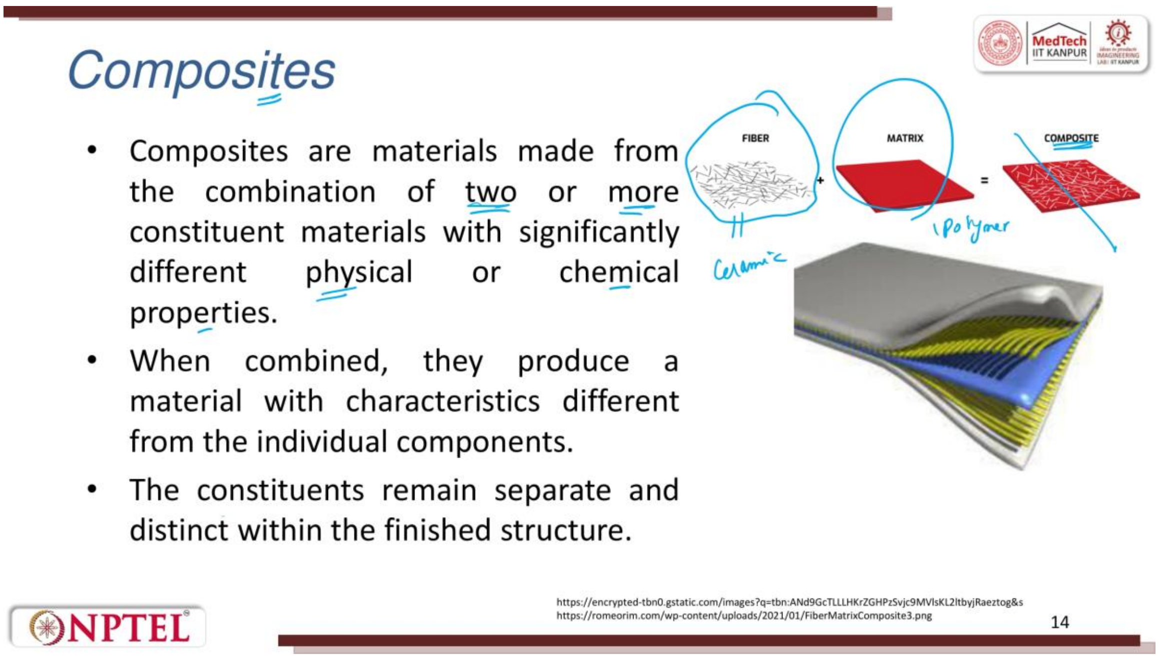
Ceramics are also classified into two types, which are called traditional ceramic and advanced ceramic. Earlier, I classified them into oxide and non-oxide, but here we are classifying them in a different fashion, which is called traditional ceramic and advanced ceramic. Advanced ceramic means they have been used for some engineering applications.

So, in traditional ceramic, we have clay products, glass, abrasives which are used in grinding wheels, refractory materials, and cement. When we look into advanced ceramics, we have alumina, aluminium nitride, diamond, which is lead zirconium titanate, silica, which is SiO2, silicon carbide, SiC, zirconium oxide, and many more things. So, these things are called advanced ceramics because they have been manufactured to meet certain requirements. This lead zirconium titanate has a very interesting property: when the material is stressed, it expands and contracts, a very interesting property. So, ceramics can be classified as traditional ceramic and advanced ceramic.

So, here are some of the examples where you see a lot of applications. If you see an IC chip, a silicon wafer, it is all ceramic material. You can see, these are all alumina, Al2O3. These are some of the things which are used for engineering applications. In ball milling operations for grinding powders, we use zirconium oxide balls. When you want to hammer and break, we try to have these balls.

So, you can see this. When we talk about traditional, you can see glass, clay, pottery which is used, and you can see all these ceramic utensils like cups and other things. So, these are all traditional ceramics. So, advanced ceramics are playing a very important role. In polymer composites, we are trying to have ceramic material also integrated.

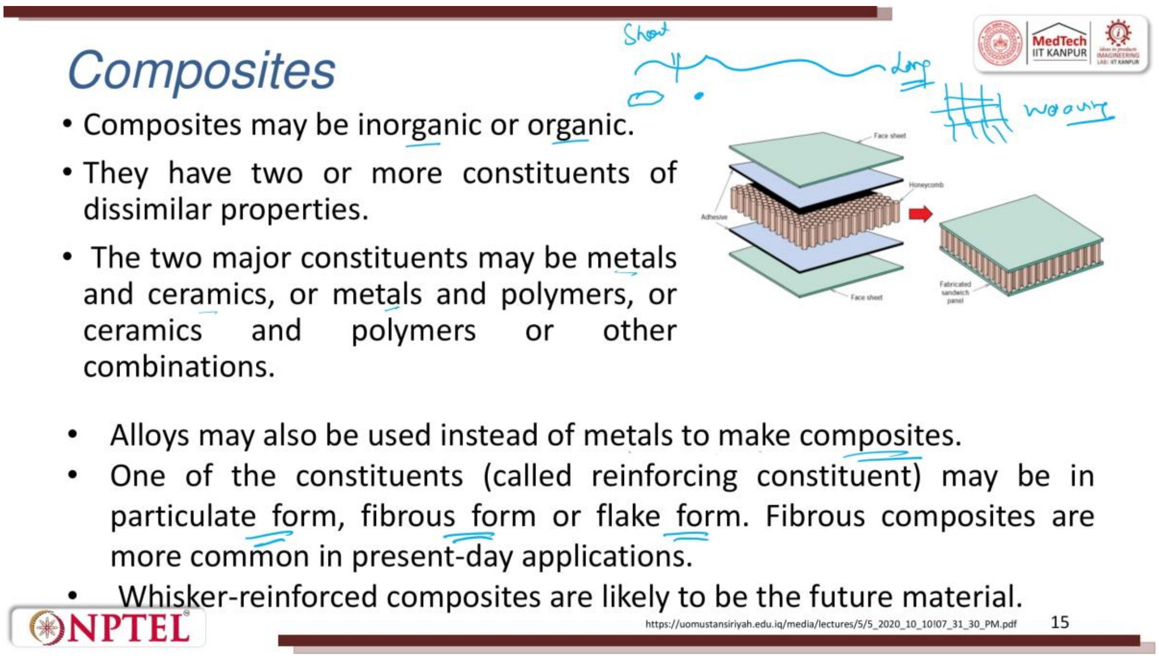
So, now let us look into a new classification. Until now, what we saw was, we saw metal and classification of metal, polymer, classification of polymer, ceramic, and classification of ceramic. These three are very important. The moment you understand this, then you can quickly go ahead and generalize some of the properties which we will see. And why do you have to know this? Because we have to choose a proper manufacturing process to meet the product requirements.



Now, let us get into a new material which is called Composites. Composites are materials made from a combination of two or more constituent materials with significantly different physical and chemical properties. If you look at it, you will have a fiber which is a ceramic material. A matrix which is a polymer material, completely different properties, insulating, you can have conducting, non-conducting, whatever it is, lightweight, heavy, you can have all these things playing. So, having different physical and chemical properties wherein fiber and matrix are infused, or they are merged, or they are bonded together to form a composite material.

When combined, they produce a material with characteristics different from the individual components. When you try to mix these two, the fiber loses its properties, the matrix loses its properties, and you get a hybrid property. However, when you cut the material, you can clearly distinguish where the fiber is and where the matrix is. The constituents remain separate and distinct within the finished surface. In alloys, when you try to mix them, it is very difficult to distinguish where the X metal is and where the Y metal is.

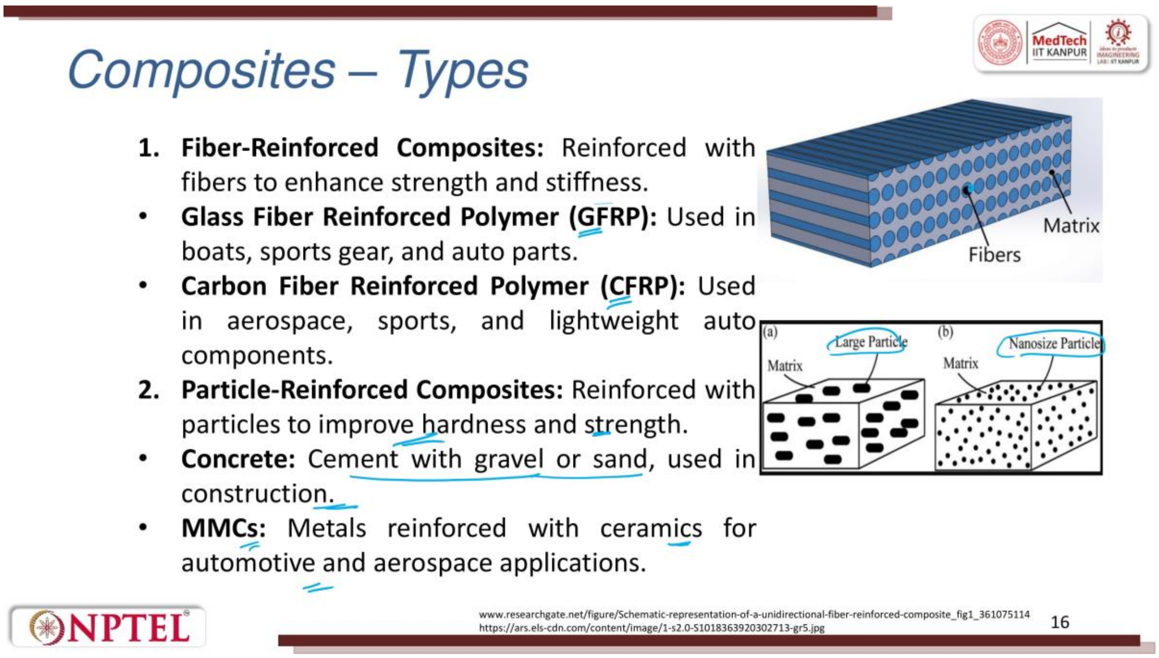
But in composites, when you cut a section, you can try to identify individual components like fiber and polymer, and you can see them clearly. So, here they both combine to give a synergistic property, which is nothing but composites.



The composites may be inorganic or organic. Why? Because polymers can be organic. So, it can be ceramic-based, metal-based, or polymer-based. They have two or more constituents with dissimilar properties.

The two major constituents can be metal and ceramic, metal and polymer, ceramic and polymer, or other combinations. When we try to compare with alloys, alloys may also be used instead of metals to make composites. So, one of the constituents, called the reinforcing constituent, may be in particulate form, fibrous form, or flake form. So, the reinforcement, whatever we are referring to, can be in long fiber form, flake form, particulate form, or fibrous form. The fibers can be short or long.

It can be woven, it can be individual fiber. So, whisker-reinforced composites are also gaining a lot of importance today.

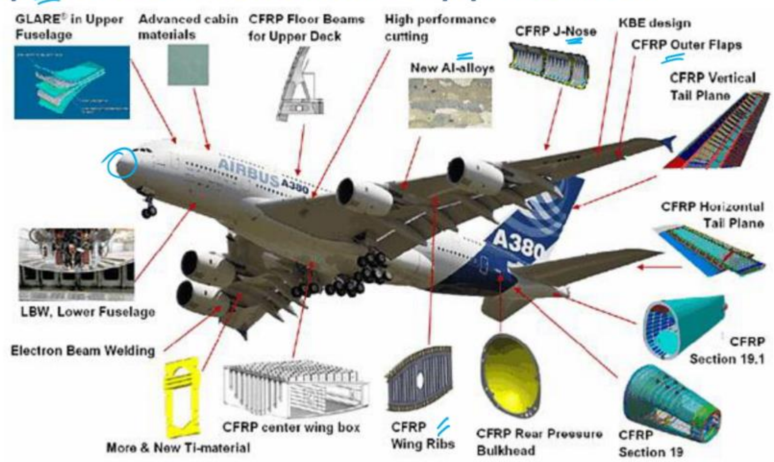


So these are the fibers. When you try to cut a cross-section, you can see fibers and you can see the matrix. The function of the matrix is only to hold the fiber, right? The fiber gives you the strength.

So here you can clearly see the matrix, large particles, you can see the matrix and nanosize particles. Flakes are also in between, or they can be larger than the large particles, okay? So, the types of composites can be: Fiber-Reinforced Composites, where the reinforcement with fiber enhances the strength and stiffness. So, you have glass fiber-reinforced, carbon fiber-reinforced, wherever you are trying to have very high toughness. For example, bulletproof jackets. You have a nose cone made for helicopters or fighter jets; they are all made out of carbon fiber-reinforced polymers.

They are lightweight, have higher toughness, and can withstand higher temperatures as compared to that of glass fiber. They are used in boats, sports gear, and auto parts. The Particle-Reinforced Composites are used to improve the hardness and strength. For example, concrete. Cement with gravel or sand used in construction is a particulate reinforcement.

Composites Materials Application



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When we try to talk about brake shoes, brake pads, they are all metal-reinforced with ceramic in automotive and aerospace applications.

So, if you try to take a typical example, A380 Airbus plane, you see where are all the parts which are all used to be made from composites. You can see ceramic fiber reinforced, new aluminum alloys which are there. You can try to see in the wings where CFRP is used. Then, inside they are using glass fiber reinforced.

They also have carbon fiber reinforced web ribs. Then this nose part also today they are trying to make out of composites. Glare is used in the upper few slots so that the material is light which has lot of engineering properties like high stiffness, all these things, such that it can withstand very high temperature. See you should understand the flight typically travels or moves from 45 degree Celsius to minus 30 degree Celsius or minus 20 degree Celsius. That's the temperature range it varies.

The speed varies from start is 0 kilometer per hour to 800 kilometer per hour look at the speed, right and here it undergoes tremendous shock when it goes up or down it undergoes a tremendous shock. So, all these properties are obtained by Composite Materials.

Non-Ferrous Matels

- Non-ferrous metals do not contain Fe and C as their constituents.
- Aluminium,copper, silver, nickel, zinc, tin, chromium, etc. are some examples.
- Al, Cu, Ag and Au are good conductors of electricity
- Ag is the most malleable, Au is the most ductile, and chromium is corrosion resistant.
- Zinc is used in metal plating, tin is used to make bushes.

https://hitopindustrial.com/wp-content/uploads/Exploring-the-World-of-Non-Ferrous-Metals-and-Their-Uses.webp

When we try to talk about Non-Ferrous, Non-Ferrous do not contain Fe or C as the constituent. So you have aluminium, copper, silver, nickel, zinc, tin, chromium are some of the examples. Aluminium, copper, silver, gold are good conductors of electricity. They are also having good heat conducting properties.

Silver is malleable, gold is the most ductile, and chromium is a corrosion-resistant material. So today, we take nickel and chromium and add them to get an exotic material property response. Zinc is used for metal painting, and tin is used for making bushes. So, you see non-ferrous materials having a lot of applications. Metals are generally classified on the basis of their iron content as ferrous and non-ferrous materials.

Ferrous Metals

Metals are generally classified on basis of their Iron content, as Ferrous and Non-Ferrous metals.

Ferrous Metals:

Metals that contain iron as a primary component. e.g.

- Steel: An alloy of iron and carbon, known for its high strength and versatility.
- Cast Iron: Iron alloyed with carbon and silicon, known for its excellent castability and wear resistance.

Characteristics: Typically magnetic, prone to rust and corrosion without protective treatments and generally possess high tensile strength.

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https://o.quizlet.com/dqP9Az5XECPZU8E1m7pzUA.jpg
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Ferrous materials are again classified as steel and cast iron. An alloy of iron and carbon, known for its high strength and versatility, is called steel. The moment you say steel, you should understand it is not iron; it is iron plus carbon. You will have other ingredients, but these two are dominant. When we talk about cast iron, it is iron alloyed with carbon and silicon.

So, here the carbon percentage will be higher in cast iron as compared to that of steel. So, it is known for its excellent castability and wear resistance. Typically, iron will have magnetic properties, be prone to rust and corrosion without protective treatment, and generally possess high tensile strength. So, these are the characteristics of steel. That is why we call it stainless steel.

We add certain elements, and the rusting will not happen. Whereas, in mild steel, you will generally see rusting happen. So, the ferrous metals are classified into ferrous and non-ferrous. In ferrous, we classify it under steel and cast iron.

Alloys

- An alloy is a combination of two or more metals.
- They possess properties quite different from those of their constituent metals.
- An alloy is prepared for a specific purpose to meet the particular requirement of an application.
- Alloys may be ferrous alloy or non-ferrous depending on the base metal used.

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https://www.wieland-diversified.com/blog/a-comparison-of-copper-nickel-alloys-and-stainless-steel/ 20

When we talk about alloy, it is a combination of two or more metals. They possess properties quite different from those of their constituent materials. Alloy is prepared for a specific purpose to meet a particular requirement or application. The alloy may be a ferrous alloy or a non-ferrous alloy. When we look into the properties, these are the very important properties that you should always consider. You can choose any material, but look into all these properties so that you can get what you want.

Metals/Non-Metals Properties

1. **Mechanical**: creep, fatigue, toughness, hardness, impact, ductility, malleability, resilience and brittleness.
2. **Physical:** density, melting point, colour, shape size, finish and porosity.
3. **Thermal:** expansion, conductivity, specific heat, thermal fatigue, thermal stress, thermal shock and latent heat of fusion.
4. **Magnetic**:hysteresis,retentivity,permeability, susceptibility, coercive force and reluctivity.
5. **Electrical:** resistivity, conductivity, dielectric constant, dielectric strength, relaxation time, loss angle and power factor.
6. **Chemical:** corrosion resistance, passivity, atomic number, molecular weight, acidity, alkalinity and oxidation.
7. **Nuclear:** half-life period, decay constant and radiation absorptivity.
8. **Optical:** reflection, refraction, transmission, fluorescence, lustre and luminescence.
9. **Acoustical:** sound reflection, absorption, damping and transmission.
10. **Metallurgical:** phase rule, solid solution, crystallization rate and diffusion.
11. **Cryogenic:** ductile–brittle behaviour, low-temperature impact behaviour and very-low-temperature phase changes.
12. **Structural:** strength, stiffness, elasticity and plasticity.
13. **Technological:** weldability, machinability, formability, castability, fabrication ability and hardenability.
14. **Surface:** friction, abrasion, wear and erosion.
15. **Aesthetic:** feel, texture, appearance and lustre.

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When we talk about the properties, mechanical properties include creep, fatigue, toughness, hardness, impact, ductility, malleability, resilience, and brittleness. Creep is when a constant load is applied to a material, and you observe its response. Fatigue is when you repetitively perform an operation, such as opening and closing a door, and a spring takes that load; that is fatigue. Toughness is when you try to jump on it, or if a spoon falls from a certain height, it will not break or shatter; that is toughness. Then you have hardness, right?

You have impact, toughness, and they get along. Ductility and malleability. Ductility is the way you can draw, the way you can bend. Physical properties are density, melting point, color, shape, size, finish, and porosity. So these are all the physical properties.

When we talk about thermal properties, it is expansion, conductivity, specific heat. Specific heat is very important because when you try to apply heat and when you try to deform, you should know what happens. Specific heat, thermal fatigue, thermal stresses, thermal shock, and latent heat of fusion. Specific heat is very important because when you try to apply heat and when you try to deform, you should know what happens. Specific heat, thermal fatigue, thermal stresses, thermal shock, and latent heat of fusion. Thermal shock is when the plane goes from 20 degrees Celsius to minus 30 degrees Celsius. Magnetic properties such as hysteresis, retentivity, permeability, susceptibility, and reluctivity.

So, all these things are magnetic properties. When we talk about electrical properties, resistivity, conductivity, dielectric constant, and dielectric strength are some of them. Chemical properties are corrosion resistance, passivity, acidity, alkalinity, and oxidation. So, chemical properties are very important, which is why we use stainless steel tanks or polymer tanks for holding chemicals. Nuclear properties are half-life period, decay constant, and radiation absorptivity.

When we talk about optics, reflectance, refractance, transmission, fluorescence, luster, and luminescence. So, all these things are optical properties. Aesthetics is also very important when you try to make a product for aesthetic applications. So, we like to see sound reflection, absorption, and damping. When we talk about metallurgical phase rules, solid solution, crystallization rate, and diffusion are important.

Cryogenics is also an important property, where you see ductile to brittle behavior, low-temperature impact behavior, and very low-temperature phase change. Then structurally, we have strength, stiffness, elasticity, and plasticity. So, the next one is friction, adhesion, wear, and erosion. Aesthetics involves feel, texture, appearance, and luster. On top of all these things, you have various technologies, whether it is weldability, machinability, formability, castability, fabrication ability, and hardening ability.

All these properties are very important when we try to choose a material. So you have to put this table and see what properties you want and which material to choose. So these are some of the standard references which we have used for preparing this slide. I hope you would have understood the classification of ferrous, non-ferrous, composites, and alloys in detail.

Thank you very much.