Fuels Refractory and Furnaces

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Lecture No. # 14

Refractory in Furnaces

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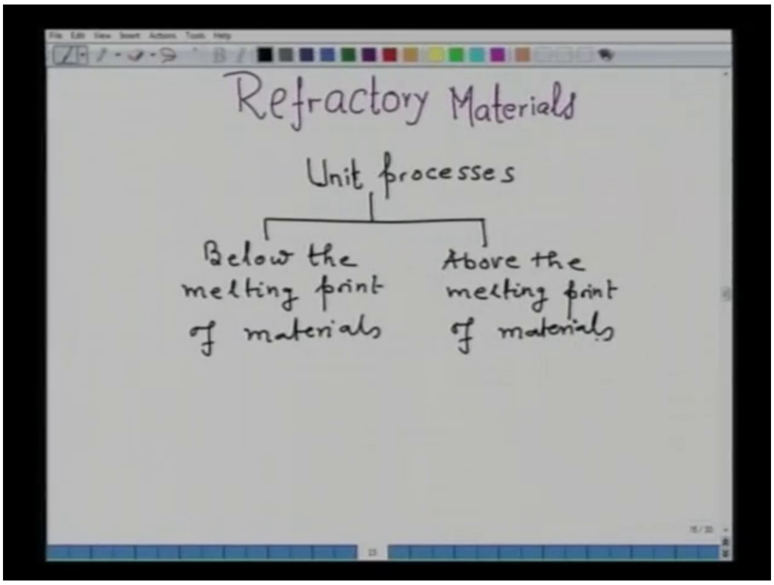

Today, we will be talking on the refractive materials. Refractive materials are very crucial for all process which employ heat, the material below or above the melting point; in most of the industries in particular iron and steel industry, cement industry, glass industry, ceramic processing, and I can name some more the various unit operate processes are in fact thermally driven. A very high temperature is required in order to convert the raw material into product. So, let us see some of the unit processes, I will not go into the detail of the unit processes, because that is not the subject matter of the lecture, but only to appreciate you the fact that the unit processes which are reused, for example, in metal extraction industry with which we are concerned, what is the environment under which the reactants are converted into products, so that you can appreciate the requirement of the refractory materials.

So, let me classify now unit processes; there are two classes of unit processes, one - which operate below the melting point of material and other class of processes they operate above the melting point of materials. Now, let us further classify both of them, first I will take below the melting point of materials.

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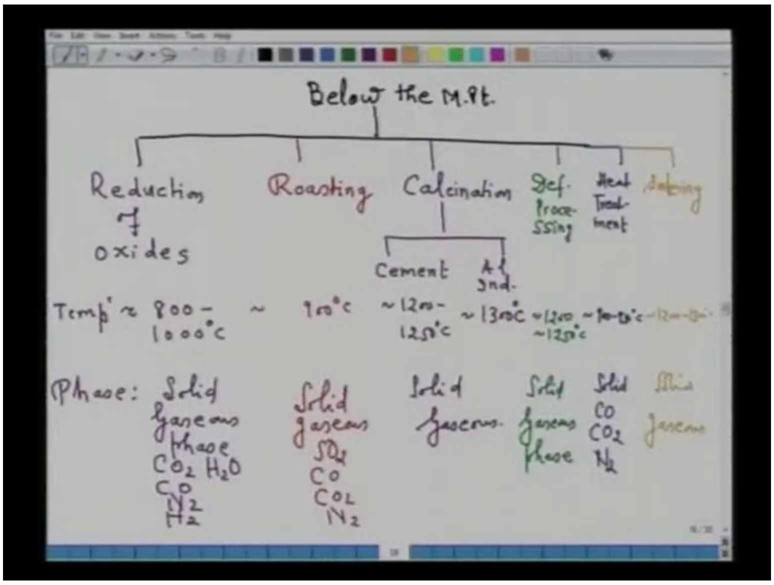

So, below the melting point, I am writing short form of melting point below the melting point the processes are that means below the melting point you do not heat the material above the melting point. The processes one of the processes all of you know is the reduction of oxides, these processes all of you are aware for the production of sponge iron. Now, in these processes temperature is approximately in the range 800 to 1000 degree Celsius. That is important for us to know the environment in which the reactants are converted into products. And then you have to search the material which can sustain the environmental effect of the various phases which are fall during conversion of raw material into products.

So, the temperature is one and the phases which are present phases which are formed also at that temperature of course, one is the solid phase. Then you have gaseous phase and among the gaseous phase you have C O 2, C O, nitrogen and if H 2 O is used then Hydrogen and H 2 O these are the gases which are present. Now, if I take another example or if we take roasting is another unit process which is carried out below the melting point of each component of the reactants. That means, we do not heat the material or the reactants above the melting point.

So, here again the temperature is of the order of let me say 900 degree Celsius, the phases which are present solid 8 900.

Then you have gaseous phase and here gaseous phase could be S O 2 in addition to C O or C O 2 or Nitrogen. Roasting is a very typical unit process which is employed for the extraction of metal from Sulphides. Another unit process is Calcinations now in Calcination for example, Calcium carbonate which is used in the cement industry. Where Calcium carbonate is decomposed into Calcium oxide and C O 2 and again the temperature requirement is very excessive. So, I can (( )) example one is the cement industry where temperature is of the order of 1200 to 1250 sorry 1300 degree celsius for the decomposition of Calcium carbonate.

Then in say Aluminum industry where the alumina which is produced by the Bayer process is subjected to very high temperature or drying because the requirement is anhydrous alumina or electrolysis. So, here also the temperature of the requirement of the 1300 degree Celsius. That means, very high temperature is required for the calcinations for example, in cement industry or in aluminum industry. Now, here again the phases of solid and gaseous phase then you have further deformation processing now in all finished product operation. For example, in the steel industry the bloom slab or blade they are heated to 1200 to 1250 degree celsius in order to perform the deformation, by rolling, by extrusion, by heat metal working, by forging or whatever.

So, here again these plumes blades or spades are heated to a high temperature of course, below the melting point for deformation processing. So, here again the temperature requirement is of the order of 1200 and in some cases 1250 degree Celsius. The phases which are there again solid phase and you have gaseous phase at high temperature. Still another operation say all of you know is the heat treatment. Now, here again the high temperature is used of course, below the melting point of the steel in order to perform the various heat treatment operation like annealing, painting, normalizing and so, on. So, here again the material is heated up to 900 to 1000 degree celsius depending on the composition.

So, here again the temperature requirement let us put it around 900 to 950 degree Celsius. In some of the annealing treatment if carried out at high temperature the treatment is done under gaseous atmosphere. So, we have the phases which are there in some heat treating operation solid phase is one, when we have gaseous phase like C O. If there is a reducing atmosphere is required C O 2, if you have oxidizing of atmosphere is required then Nitrogen if you require a inert atmosphere. Still another processing operation is sensing, in sensing also the material is heated below the melting point, but at a very high temperature depending on the material.

For example, if you are doing sensing of ceramic then you go to a temperature 1340 or even higher temperature than that. So, here the temperature could be around 1200 or even to 1300 degree celsius the phases again solid and gaseous phase. So, from this classification of various unit processes which are used below the melting point what message I have to give you is very simple. When you perform these high temperature operation then the phases which are present first of all they are very important in order to find out a suitable material so that these reactants can be processed. Now, this is these are the processes for below the melting point now let us look at some of the processes above the melting point.

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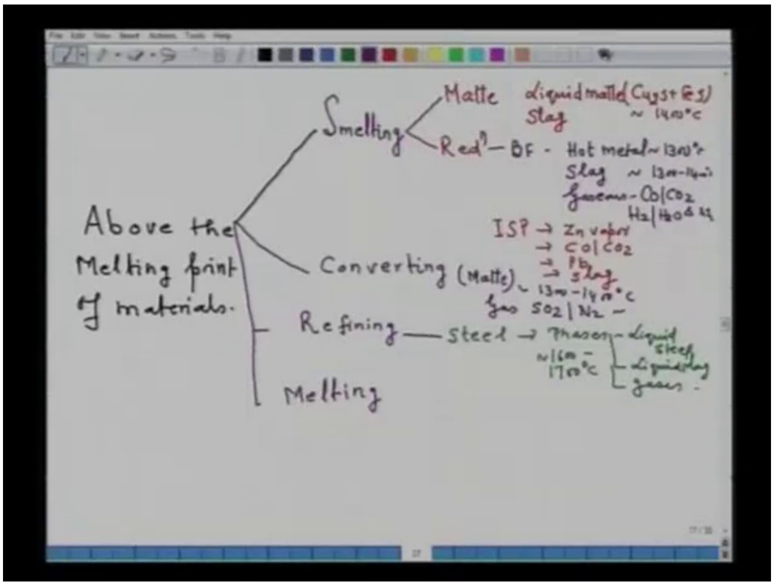

Above the melting point of materials one process is smelting, you heat above the melting point to carry out separation between the phases for example, (( )) and metal. So, there are two types of smelting, one you have the matte smelting and another you have reduction smelting. Now, in both these matte smelting or reduction smelting operations the temperature is very high. For example, in matte smelting if you take which you use for production of copper the phases which are in contact with the reactor or what you are going to design the phases are liquid matte. Which is a composition of Cu 2 S plus F e S and the temperature is of the order of 1400 degree celsius and mind you this is liquid matte.

And liquid molten salts are very reactive and you require all together different choice of materials. In case of reduction smelting the typical example is that of blast furnace and imperial smelting furnace is production of zinc. They are the typical metal extractions processes employing the concept of reduction smelting. So, if you go for say blast furnace for example, reduction smelting, blast furnace the phase which is there is hot metal, the temperature is of the order of 1300 degree celsius or I am giving just approximate temperature. Then the phase which is formed is also slag is a phase is also a temperature 1300 to 1400 degree Celsius.

Then you have gaseous phase which is C O C O 2 H 2 S 2 O and Nitrogen these are the phases which are in contact with the walls of the reactant chamber which you are going to design. In case of matte smelting the phase is liquid matte also the phase is slag, slag is a mixture of Oxides, Sulphides. Mainly the mixture of Oxides, that is also at the same temperature a little higher than the matte temperature. Now, in case of say imperial smelting process which all of you know, imperial smelting process which is used to extract Zinc. The phases which are in contact with the walls of the reaction chamber Zinc vapor mind you Zinc vapors are very reactive so, you have to search accordingly the material.

Then the phase which is in contact with the gaseous phase C O C O 2 then you have lead and you have slag, what I wanted you to appreciate is to see that. These are the type of phases with which metal extraction industries have to deal with in order to find a suitable material for the reaction chamber. Another say unit process for these into these class is converting. Now, in converting the phase which is in contact is simply matte 1300 degree celsius or even to 1400 degree Celsius. Then the gases will form gas will be S O 2 N 2 so, on also at the same temperature speed of the gas is important velocity of the gas is important turbulent flow of the gas is important so, these are the important issue say. For example, in a unit process it is used for converting and this converting is typically used in case of extraction of copper.

Third example of this one is the refining in steel making refining is done to produce steel from hot metal. And for example, refining say in case of steel the phases which are in contact phases are say liquid steel,(No audio from: 16:12 to 16:19) liquid slag and gases. They are at around a temperature of the order of 1600 to 1700 degree celsius under very very diversified conditions in which these phases are there during production of the steel from hot metal. All of you know the process like ld convertor or electric furnace is existing Then there are certain unit operation processes of operation which are used for simple melting.

Example Aluminum we just want to melt and cast it so, here you heat the material above the melting point of the material if it is a Aluminum and you go around 750 degree celsius or Copper you go around 1100 or 1200 degree Celsius. So, you go above the melting point so that you can cast this material so, to get a particular shape. So, what we can learn from here when we want to infuse this idea into the refractory material then the following fact emerge.

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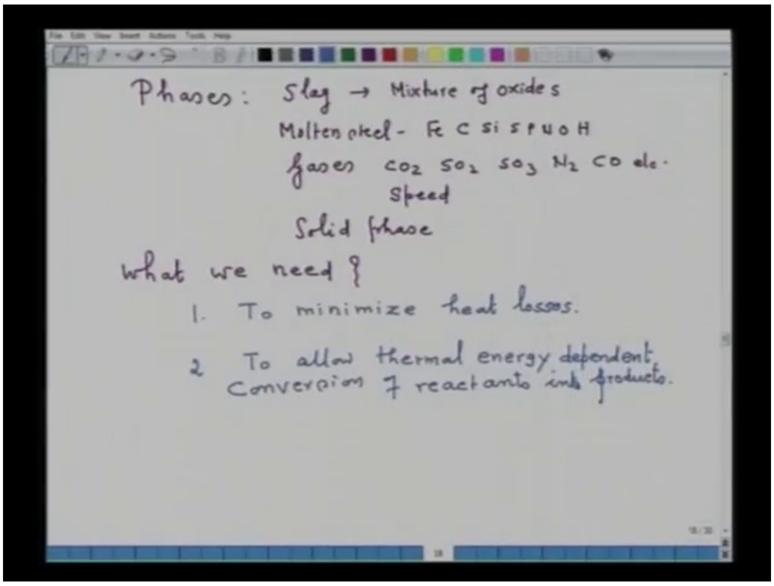

You have to see what phases are in contact so, the phases which are in contact in all unit processes that I have discussed could be many more in other industries also; for example, in glass making industry or glass contact with the walls of the refractory could be another industry, where high temperature phases are involved, temperature is involved, you can make the list complete. So, the phases which are in contact one is the slag and slag is a mixture of oxides; you have molten metal or say molten steel which has Iron, Carbon, Silicon, Sulfur, Phosphorous, Nitrogen, Oxygen, Hydrogen these are the phases which are present in molten steel.

So, gases and these gases could be C O 2 S O 2 S O 3 Nitrogen, Carbon monoxide and etcetera. The important thing in case of gases they are moving the speed of movement is also a important issue, gases will be in contact with the reaction chamber that is also important issue the speed of movement is highly turbulent. Also molten steel there is a continuous motion in case of slag and steel while producing steel from hot metal, the turbulent motion the reactivity and all these are the important issues in case of the phases which are present.

Of course solid phase is also a phase, but solid phase may not be that reactive in the sense as compared to liquid and gases. So, given this scenario before us there are different phases at different temperatures, there is state of movement is also different in some processes. The phases are laminar flow some phases are turbulent flow also it is important the phases are in contact for different time intervals. For example, in roasting typically it may take one and half to four hours converting may say take from matte to copper it may take around 2 hours or 3 hours. Steel making while converting hot metal to steel typically ld steel making takes an hour electric car furnaces it may take from one and half to over two hours.

So, what I wanted to say is that besides the temperature and the phases also important issue is the time during which the phases will be in contact with reaction chamber. So, these are the important issues which we have to think while searching the refractive material. Now, what we in fact need (No audio from: 21:15 to 21:22) what we need if I want to summarize we need in my mind it comes we need two things; some of the processes are autogenous you do not supply any heat from outside. For example, in steel making ld steel making is autogenous, roasting is autogenous also in case of processes where you supply heat from outside they are heating your reaction chamber by the use of fossil fuel, so you want to conserve the heat.

In case of autogenous processes, you want to utilize the heat which is produced during the reaction such that you do not need to supply any heat from the outside and still you can get the output in terms of temperature, quality, quantity as per you have desired. So, one important thing that you are looking is to minimize heat losses. We minimize heat losses typically this is important higher is the heat losses more calorie you are losing it. And if the process is autogenous you may end up in a problem so, it may be required to supply from outside. In case you are using externally fuel you have to supply more amount of fuel so, in fact the direction leads to conservation of energy.

Second important thing is that to allow thermal energy dependant to allow thermal energy dependant conversion of reactants into products. Now, what this thing means given to us these are the phases we can look the periodic table and we can find out that particular metal which is sustained at very high temperature. Can we use it no definitely not because if metallic material if it is used it will not meet the two requirements which I have just now listed. The phases will be highly reactive and we cannot do anything out of the metallic material though they are available sustained at high temperature now the question comes what are available to us.

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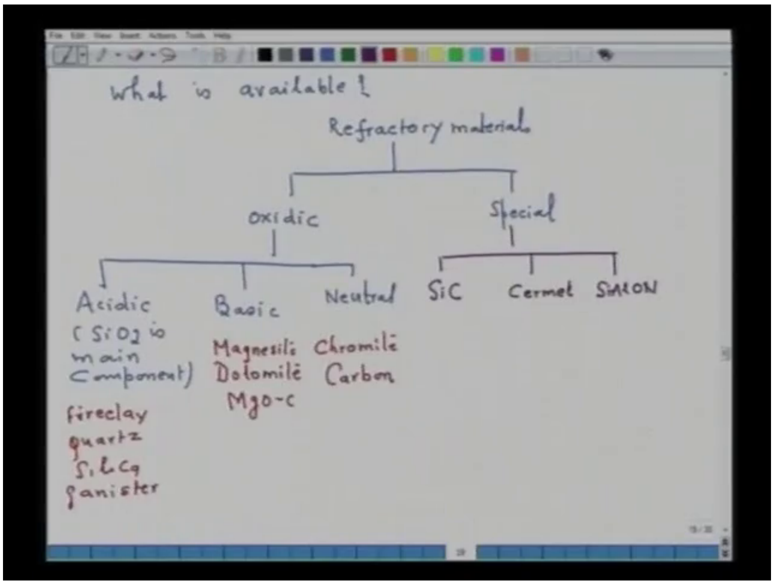

What is available to us that is where we call them refractory material. Now, the term refractory means, anything which can sustain a high temperature normally here in terms of metal extraction means that material should not fuse at the temperature of operation. All those materials whether it is metallic material or non metallic material they will be classed as retractable, but considering the application of those materials or the purpose which I have listed or in order to handle the phases, which I have just now listed. Metallic material because of the cost, because of the higher thermal conductivity, they are out of question, they cannot be used at all to construct a reaction chamber. So, what we are left with the refractory material, which are two kinds; one oxidic and another is a special material.

Now, among oxidic they are oxides what I am talking about the refractory materials they are oxides. So, then you have acidic and in the acidic refractory materials S i O 2 is the main component it is melting point is around 1720 or 1730 degree Celsius. So, very high melting point the typical examples say Fireclay is one, Quartz, Silica, Ganister, Fireclay is a mixture of Alumina and fired coal where in the fireclay the alumina content is around thirty to forty percent. Of course, this acidic refractive materials which have main component S i O 2 they cannot be used in an environment where you have basic oxides.

Now, here it is important to understand when I hope slag as an important phase then slag is also a mixture of oxides of S i O 2 M g O C O A l 2 O 3 C a 2 and so, on. The refractive materials which are acidic in nature they are also giving the composition S i O 2 and so, on.

So, the acidic refractive material in which S i O 2 is the principal component they cannot be used under basic environment that is C a O M g O F e O. They are basic oxides what will happen they will react material will fall collapse and the whole thing is lost. So, the acidic material they can be used only under acidic environment.

Another class of this oxidic is the basic into the basic the typically examples are the Magnesite, Dolomite, M g O C and also there are other basic refractive are available. Now, here M g O it has a very high melting point they of the order of 2600 degree celsius Calcium oxide is also has a very high melting point. So, these are the typically basic refractories. Now, as you know also the basic oxidic refractive material can be used only under basic environment if they are used under acidic environment reaction will be there and the reaction chamber will collapse.

Now, the third refractive class of the oxidic refractory is the neutral refractory and the neutral you have chromite, you have Carbon and could be many more they can be used under acidic or basic environment so that is the important point in case of oxidic refractory. Now, another class is the special refractory and in this special refractory they are used for special purposes. For example, one we have silicon carbide refractories then we have cermet the mixture of ceramics and metal another important is the sialon also a very important refractory.

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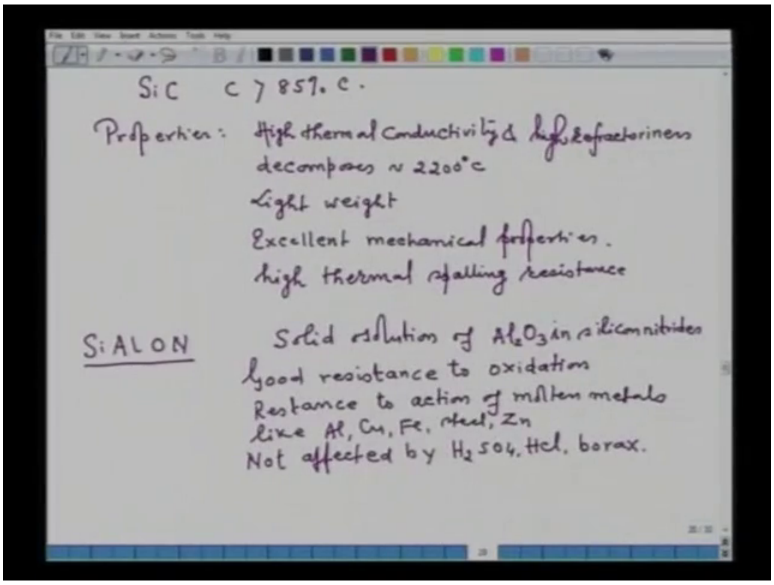

Now, if you look say silicon carbide refractory now these silicon carbide refractory their carbon content is greater than 85 percent their properties high thermal conductivity and high refractoriness. That means that can be used at a very high temperature it decomposes at around 2200 degree celsius and does not melt. They also have they are light weight then your construction will not be that heavy they have excellent mechanical property. Then high thermal spalling resistance very good refractory high thermal spalling resistance that they are very very expensive refractory in order to manufacture.

Another important refractory in this class is say sialon this is a solid solution of solid solution of alumina in silicon nitride how they are made a mixture of A l 2 O 3 and S i 3 n 2. That is silicon nitride is hot pressed at 18 to 30 mega Pascal pressure and sintered at around 1700 to 1760 degree celsius in graphite mold in order to obtain a low porosity dense product. These refractories have good resistance to oxidation also resistance to action of molten metals like Aluminum, Copper, Iron, Steel and Zinc. What I mean you know the molten metal they are very reactive if you are required handle and there the sialon refractory are very good.

But mind you they are very expensive refractories and their production method is also very, very complicated as you are required to produce under very closed environment. First of all you require a hot basin of the mixture and then you require very pure Alumina and very pure S i C N. So, the cost is very high of course, due to the economic consideration sialon refractories cannot be use for large applications. Also another important property is sialon refractories are not affected. They are not affected by H 2 S O 4 H C l Borax or all other these things they do not attack they are having good resistance against these particular acids.

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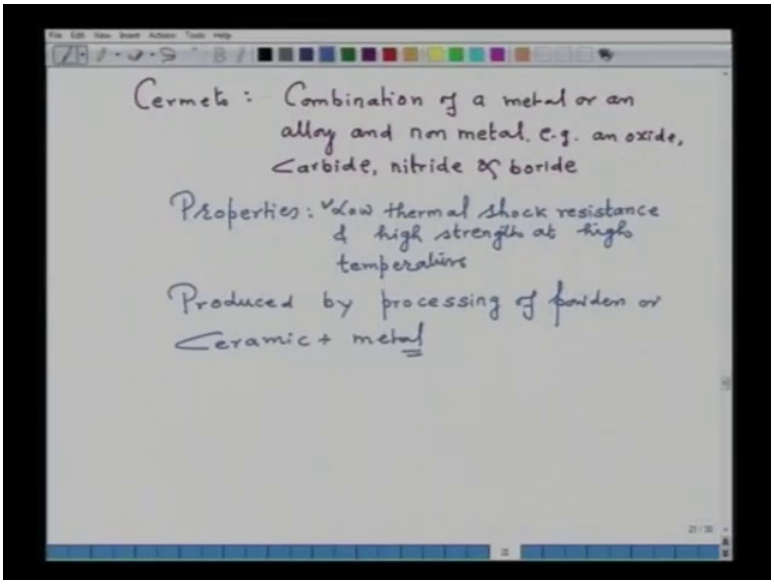

Another say the cermet it is a combination of a metal or an alloy and non metal. For example, an Oxide Carbide Nitride and Boride that is to mix metal and these Oxides and the material which you get cermet is again for a very important application. Because all of you know Carbide, Nitride and Oxide they are non conducting so, wherever though the application of conductivity is important there cermet can be used otherwise they can also be used. So, properties some of the properties of cermets they have low thermal shock resistance and high strength at high temperature and high strength at high temperature. This is one particular property they are produced they are produced by processing of powders by processing of powders of ceramic plus metal.

So, again the production method is processing of powder that is the one of the important method and this cermet refractories they are again very hard and strong refractories .Now, let us see some the important class of oxide refractories.

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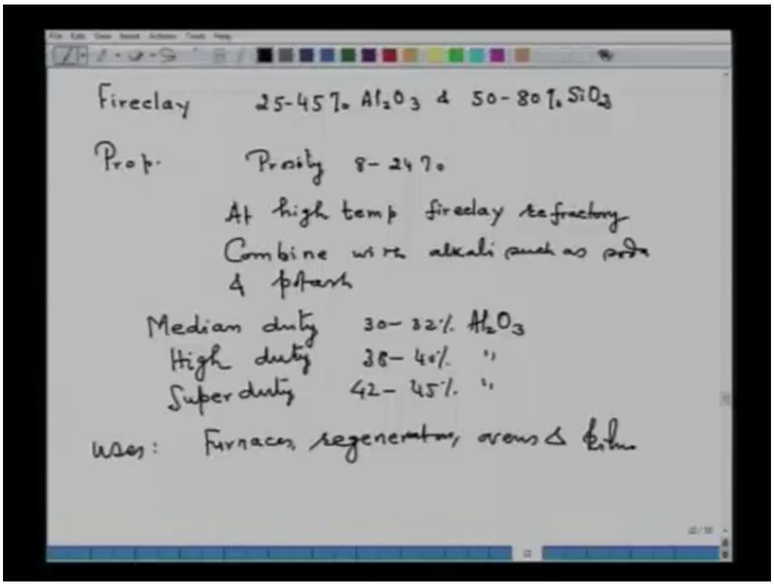

One let us take it first of all fireclay they contain first of all fireclay is a mixture of S I O 2 and A l 2 O 3 contains a 25 to 45 percent A l 2 O 3 and 50 to 80 percent S I O 2. A l 2 O 3 has a very high melting point S I O 2 lower melting point resistance of Alumina it increases the melting point of the product that you are making by a mixture of S I O 2 and S I O 2. Some of the properties is porosity it varies from eight to 24 our percent depending on firing temperature. Because one of the important thing that I must tell you is that these refractory material whether oxidic or special they are not naturally occurring products.

They are being made practically by taking the respective components for example, if you want to produce fireclay do not think that fireclay is occurring in the nature. You just dig from the mine and use it no it is not there you have to make S i O 2 you have to produce A l 2 O 3 you have to mix them, you have to fire them at very high temperature. It is in this process the porosity gets eliminated or it remains that depends on the firing temperature and time. That is what the wide range of porosity is there eight to 24 percent. Now, at high temperature fireclay refractories combine with alkali such as soda and potash what does it mean that means in the environment where alkali oxides are there you should not use fireclay refractories.

Because they will react and the material will collapse here itself you have three different classes depending upon the alumina content. You have say median duty, refractory median duty, fireclay which has 30 32 percent Alumina. Then you have high duty which has 38 to 40percent Alumina and you have super duty which has 42 to 45 percent Alumina. And among these fireclay refractories super duty refractories they are again used for very special applications they are very refractive. Their typically uses are furnace,s regenerators, ovens and kilns in most of these processes which handle the material below the melting point depending on their requirement fireclay is very widely used refractory among these class.

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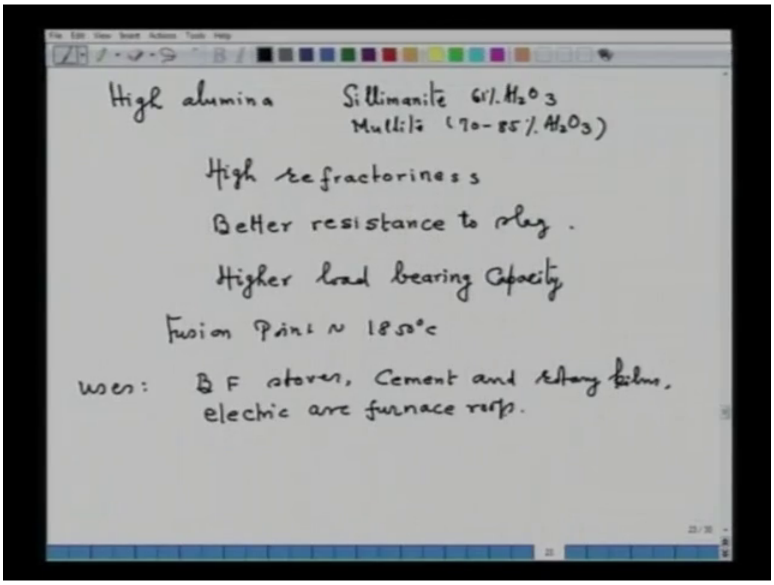

Another important class in this high Alumina refractory typically sillimanite, sillimanite which has around 61 percent Alumina. Then you have mullite which has 70 to 80 percent

Alumina. Then of course, you have pure Alumina which is again a very special type of refractory can sustain very high temperature. Some of the properties they have high refractoriness, better resistance to slag and higher load bearing capacity. You should also know that Alumina it takes as an acid refractory in a basic environment and a basic refractory in a acidic environment so that s one another typical property of Alumina.

The fusion point the fusion point is around 1850 degree celsius of course, you can see in the phase diagram of the different phases correspond into mullite or sillimanite of melting point. The typically uses of these refractories glass furnace, stoves cement and rotary kilns cement and rotary kilns, electric arc furnace roof, glass making furnaces also metals also they are being used.

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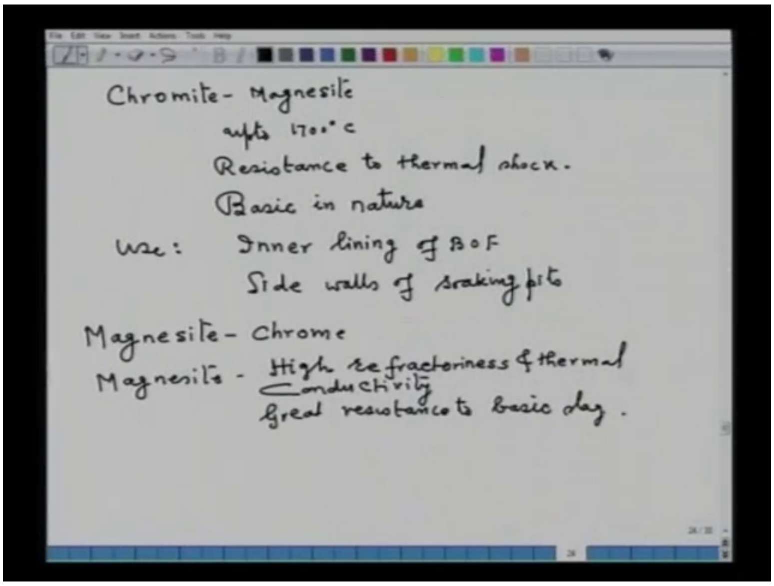

Another important class is Chromite magnesite refractories. Cromite magnesite refractories now here the amount of chromo is greater than magnesite they can be used up to 1700 degree Celsius. They are resistant to thermal shocks and they are basic in nature. What does it mean, if it is basic in nature you cannot be used under acidic environment? And typically they are used inner lining of B O F and side walls side walls of soaking pits. Soaking pits are typically furnaces which are used for heating the materials below the melting point

Then another class is Magnesite chrome refractories. Magnesite chrome refractories now here you have angiomagnet greater and this magnesite, dolomite magnesite chrome they are all basic refractories. And among magnesite refractories the magnesite refractory it has a high refractoriness and thermal conductivity, great resistance to basic slag. And they are in fact cannot be used in the acidic environment. They are many other products which are there for very special applications I have given you some so that you can appreciate what is available to us in order to meet the requirement of the various phases. Which are produced during conversion of the reactants into the product to various new processes?

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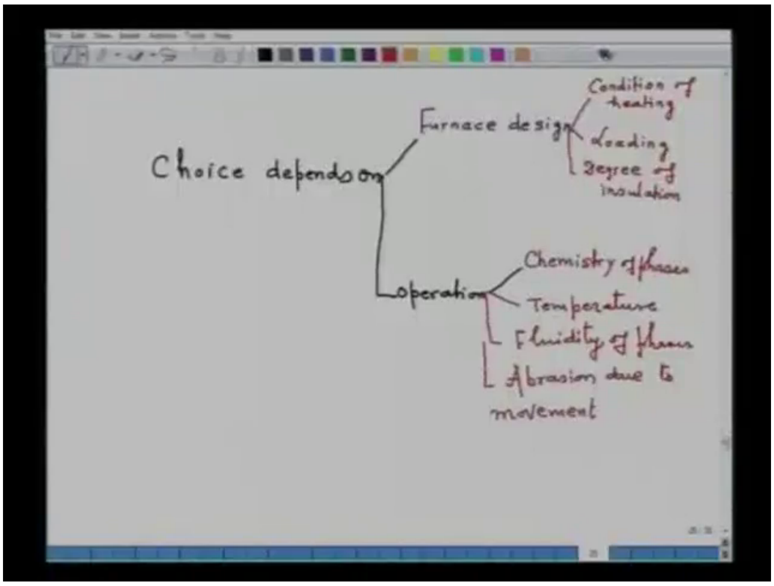

Now, the choice of refractory depends on what? Choice of refractory depends on what choice in fact depends on several factors you have seen various types of refractories are available. Various can be produced by the combination of S I Om 2 A l 2 O 3 C l 2 O 3 Carbon and so, on. The choice depends on one of the important factors is the furnace design, furnace design is one of the important factors and among furnace design what is meant over here what is the condition of heating? Under condition of heating whether once you are heated does it remains for once together if you go on when it is heated once and brought to a temperature 1200 and then the refractory requirement or equi polar which is everyday it is retake.

So, these are the thing as which are important in case of furnace design that is what is the requirement of the treatment of reactant. And how long a furnace should be kept under the hot condition and accordingly the selection of refractory has to be made. Another important criteria of a furnace design is the loading say how are you going to load and how much is the load that the refractory has to accept. It third important thing is the degree of insulation degree of insulation. Could be one or two factors more that mean you have to decide what type of furnace you are going to design, for what particular operation accordingly you have to select the material. Another important choice that depends upon your so, called operation.

Now, under the operation what you should know chemistry of phases. What phases are present? Solid, liquid, gas, metal, vapor and so, on. What is the temperature and you have to go for the maximum temperature, what is the fluidity of phases fluidity of phases and also it is important to know abrasion during movement, abrasion due to movement. So, these combination of furnace design and operation will tell you what type of refractive material you should use in you may go for a very high quality it cannot be required though it is good. But from economic consideration may not be required what I mean to say the selection of refractory is a very complicated and one is to understand the unit process very well in order to optimally design, with a refractory material.

And to create a reaction chamber which can sustain the diversified requirement of the phases and to give a longer life. Because ultimately it is life of the refractory that is more important life of the reaction chamber that you design is the more important. On that account there are certain properties which you have to look and you will see the activities.