Medical Biomaterials
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Lecture – 25
Metallic Biomaterials

Welcome to the course on medical biomaterials, we will continue on the topic of metallic biomaterials. Metals have a very unique property that is called the lattice structure ok.

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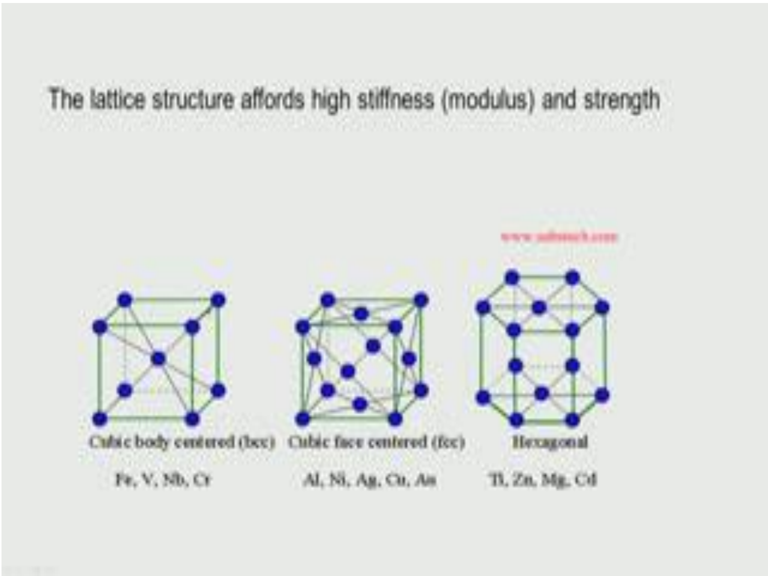

That means the metal the atoms in the metal are arranged in certain fashion in if you look at it in as of cube they are arranged in a certain fashion, which gives them high stiffness; that means, modulus and also the strength. There are different types of arrangements that are possible for example, ion vanadium, chromium (Refer Time: 00:52) all these form something called a body centered cubic; that means, if we take a this as a lattice cubical structure, then there will be atoms in all these a 8 corners as well as there will be one atom in the middle that is why it is called body centered cubic.

And this particular lattice is repeated and that is how this these elements will be seen as actually. So, if we keep breaking it to smaller and smaller and smaller finally, you will end up with these body centered cubic that will be repeated throughout that is called the crystal structure. Similarly if we look at alimonies, nickel, silver, gold copper they perform something called face centered cubic; that means, in addition to atoms being present at the corners that is 8 atoms, there will be 6faces in a cube. So, those faces are also have atoms that is why it is called face centered cubic. And if you look at titanium zinc, magnesium, cadmium they appear like a hexagonal as you can see this is hexagon; that means six faces. So, there will be atoms and all these six faces and then there will be one in the center that is the hexagonal.

So, the repeating unit of this crystal of titanium will appear like this. So, there will be stack together that is how the crystal is formed, and this type of crystalline arrangement gives them very good stiffness and strength as well. And very interestingly from when the temperature is changed some metals changed from say f c c that is face centered to b c c sometimes they changed from hexagonal to b c c and so on actually. So, those are all temperature changes which in change in temperature leading to change in their faces. So, this is the repeat unit and the crystal will made up of this type of a repeat units and that is the beauty of metals, and sometimes when you have alloys when; that means, you have 2 atoms who which may have similar atomic radius, then some of these spaces may be occupied by the other atom at a very low concentrations. So, if the radius of the second atom is much larger than the crystal structure may be disrupted.

So, all these things can happen with metals and we will look at it little bit in more detail in this class as well as in the next class.

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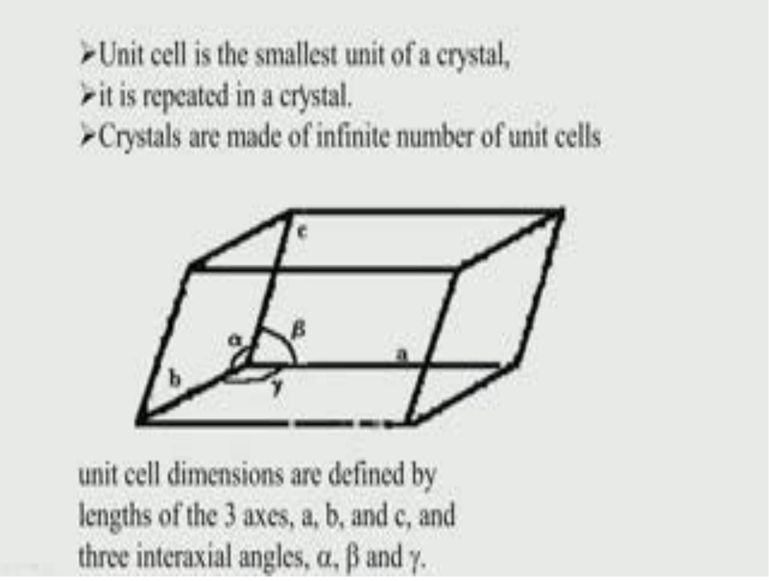

So, as I said unit cell this is the smallest unit of a crystal. So, if you take a crystal of ion and keep breaking it into smaller and smaller and smaller finally, you will end up with this type of cubical lattice and that will be a body centered cubic. So, you will atoms here here, here in the corners and there will be one in the center. So, this central atom is unique for this particular lattice whereas, these corner atoms are shared by 8 different cubes that may be placed. So, you need to remember this. So, this is unique only for this lattice whereas, these corners are shared by a 8 different cubes, and again here if you take the face centered cubic these atoms which are on the faces are shared by 2 lattices one on top of another ok.

Same thing here in hexagonal this particular atom is shared by another hexagon which may be coming in top of that actually. So, it is not unique, in b c c like you see here this particular atom is unique to this particular lattice structure. So, this say crystal is repeated the. So, in a crystal this particular lattice is repeated again and again to infinite number of unit cells. So, this is called a unit cell; now these unit cell has 6 important parameters a b c these are the 3 lines alpha, beta, gamma these are the 3 angles. So, 3 axis a b c and 3 angles alpha beta gamma.

Now, these a can be equal to b can be equal to c, or a can be equal to b, but c not equal to c similarly the angles can be 90 degrees and all equal and some cases angles need not be equal. So, you can have different permutation and combinations. So, we will have different types of unit cells. So, all crystals will fall under that category, it is true for metals and also for say salts which are crystalline salts like sodium chloride, they will all fall under this family there are only one set of family I mean there are many sets of families based on the way their axis dimensions are whether they are equal to each other not equal to and whether angles whether the angles are equal or not equal to and so on actually. So, the beauty of it. So, if a metal has a unit cell of certain dimensions, and it falls in one family then you can say that some of the physico chemical parameters or properties may be similar we will look at little bit more in detail ok.

So, this is called a unit cell. So, a crystal will contain infinite number of these unit cells, and unit cells can be defined based on the 3 access length a b c, and 3 angles alpha beta and gamma.

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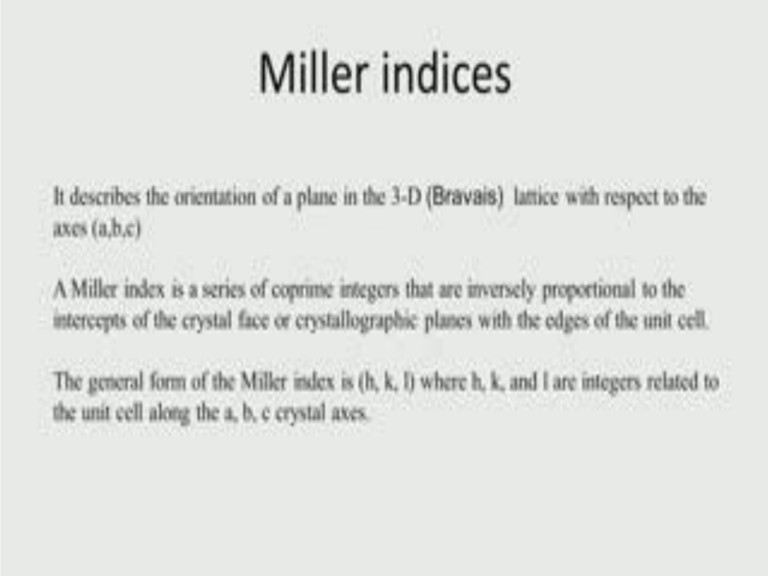

These can be described by a term that is called the miller indices; this miller index it describes the orientation of a plane in a 3 d lattice this is called bravais lattice with respect to the axis a b c. So, we have in a 3 dimension the axis a b c, and miller indices tells you what is the orientation. A miller index is a series of coprimer integer, so it is all whole number 121, 111 like that that are inversely proportional to the intercepts of the crystal face or crystallographic planes with the edge of the unit cell. So, these crystal planes where it cuts these axes that is what I am telling that is what is the miller indices. So, the general form of miller index is h comma k comma l where h k and l are integers related to the unit cells along the a b c crystal axis. So, we have the a b c crystal axis, and h k l are integers and we will know where they cut with each other ok.

We will spend more time on this. So, we do not have to worry I may it may appear very confusing we will spend some time.

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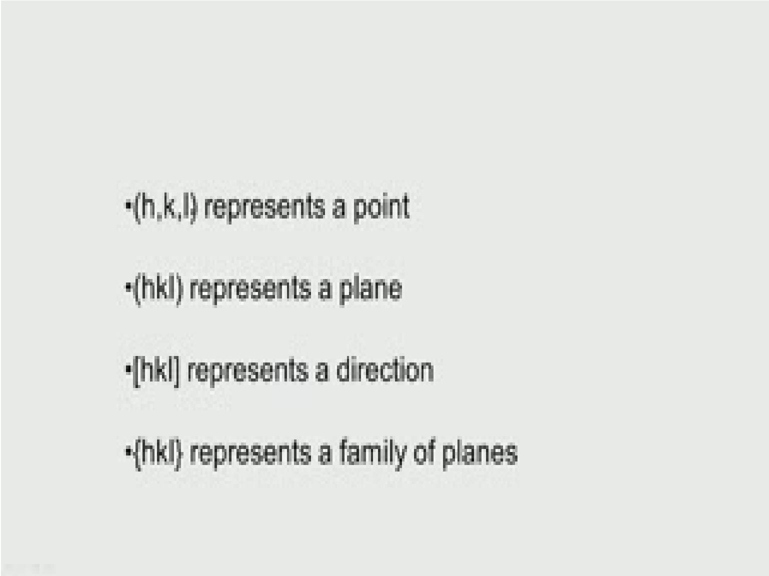

So, in a 3 dimension if you have a point in a 3 dimension of course, it can be represented by h k l. So, if a point is there in the x direction it is say one centimeter away, and y direction from the origin it is 2 centimeter away and z direction from the origin it is 3 centimeter away, then that point is called one 2 3 right this we have studied in our school; so, but if we represent like this then it represents a plane. So, if it is represented like this comma, comma then it represents a point. Then if you represent like this then we are talking about direction from the origin of the 3 dimension, and if you are representing like this type of bracket then it represent a family of planes, that is what it means actually family of planes we will look at it in more detail.

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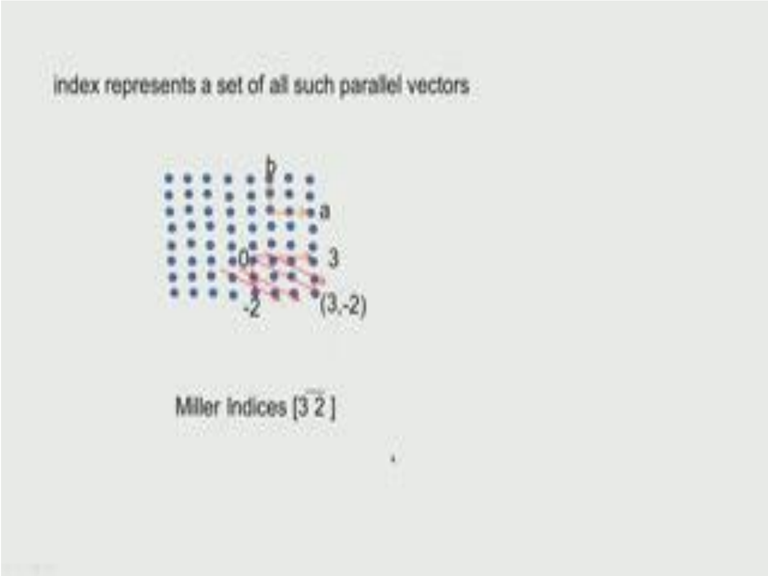

Now 2 dimension look at this. So, we have say a and b. So, you can have this is 2 dimensioned. So, we are having a axis like this b axis like this direction is like this. So, if it is 3 dimension of you can have a c axes which is perpendicular to the plane of this paper. Suppose this is a origin and the direction is like this you know 3 along and here along the b it is minus 2 because it is going in the negative direction because b is going like this a is going like this direction. So, for a it is positive, but b is minus. So, this point is 3 minus 2 you understand. So, because the representation is a going like this b going like this that is why we call this as minus 2. So, this point is called 3 comma minus 2 now the miller index for this like I said the representing a direction. So, we call it 3, 2 and there is a line on top and then we put a square bracket line on top means negative and then you need to put a square bracket.

So, it tells you direction of this vector, we call this a vector direction is represented by 3 2 with a dash on top, when you put this it means minus and when you put like this it means it is a direction miller index whereas, when you put 3 comma minus 2; that means, it represents this point and as I said we this point we call it minus 2, because the direction for b is like this. Direction for a is like this if the direction for b had been this way then of course, this could have been a plus 2 point. So, that could have been 3 comma plus 2 do you understand. So, because of the convention the direction you have put a and b like this we represent this point as minus 2.

Now we can have several parallel lines right. So, for all these we can have 3 comma minus 2 as the vector these are all set of vectors which have this type of 3 minus 2 because they are all parallel to each other they are all parallel vectors ok.

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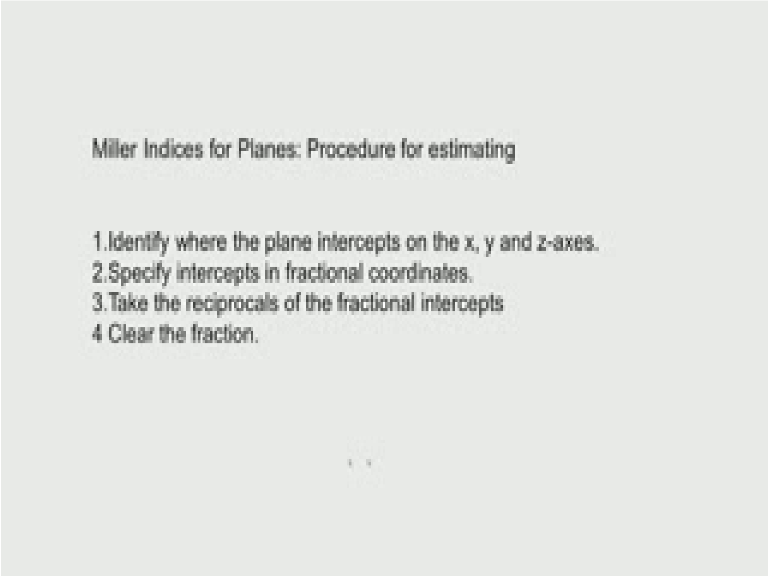

So, now let us go to plane because in a crystal structure in a lattice we are going to have planes. So, for these planes how do we determine the miller indices, once you call it plane it is going to be 3 dimensional a b c right. So, how do we find out now find out where the plane intercepts the 3 axes the x axis he y axis and where it cuts them ok.

So, specify them take the reciprocal; that means, you take reciprocal of each one of them, and then if still it is coming out as a fraction we make it as a whole number that will be the miller index for that particular plane understand. So, first see where the plane because the plane once we call it a plane it is a 3 dimensional it is an a b c type. So, we see where they cut a 3 axes, then we take a reciprocal of that if you get fractional then we clear the fraction. So, that they you get a whole number and that is called the miller index for that particular plane; we will look at some examples do not worry.

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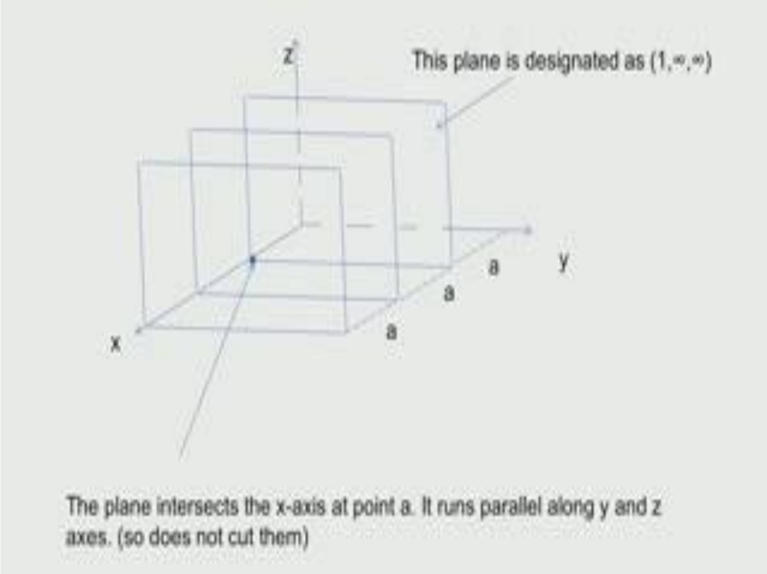

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Before that let us look at it see if this is x axis this is sorry this is sorry this is x axis say this is y axis, this is z axis. Now look at all these planes parallel planes imagine take this plane this plane is cutting the x axis at say 1 we will call a as 1, but it is not cutting the y and z axis understand. So, it is not cutting the y and z axes. So, 1 comma infinity comma infinity this is how this plane is designated, because it cuts the x axis say at a whereas, it is parallel to the y axis as well as a z axis it is not cutting that. So, we call this infinite. So, this plane is designated as one comma infinite comma infinite. So, once this plane we know so obviously, it is parallel to the y axis it is parallel to the z axis we understand this.

So, we can have several planes like this you know which are all parallel to each other like this. So, we can have like this like this like this like this, but they are all parallel to each other. So, they do not cut the y axis they do not cut the z axis. So, they will cut only the x axis at different places say a, a is one means one then a, may cut at 2 a, they may cut at 3 a and so on actually, but they are all parallel to each other, so their y and z directions are may represented as infinity ok.

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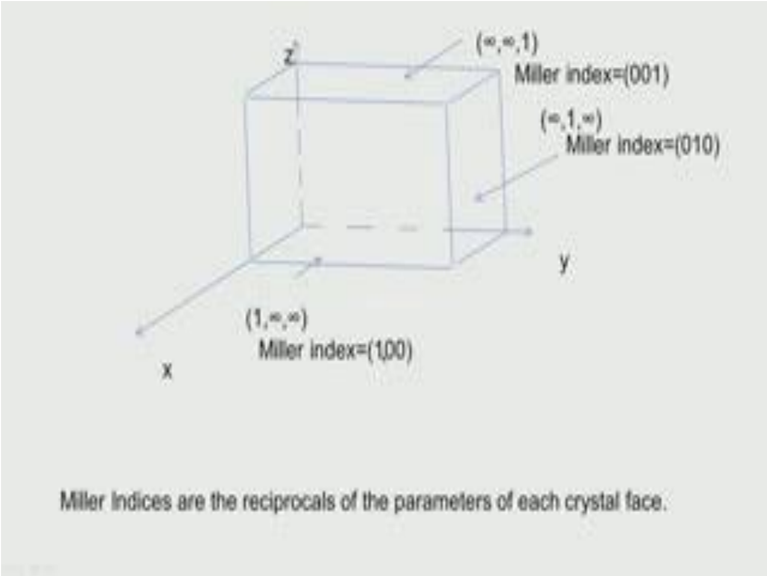

Now, we can have similarly planes like this which cuts the y axis, but it does not cut the x and the z axes. So, like infinity one infinity just like a previous class I said one infinity comma infinity, if you have a plane like this it is infinity one comma infinity. Similarly we can have a plane which cuts the z axes, but it does not cut the x and y axes. So, it is parallel to x and y. So, it can be infinity infinity one. So, this particular plane of this cube can be one infinity infinity, this particular plane of the this cube is infinity one comma infinity, because one this one is representing that it is cutting the y axis and this one here represents that it is cutting the z axis not the x and y axes.

Now how do we calculate the miller index for each of these we take the reciprocal. So, one is one infinity reciprocal is 0 infinity reciprocal. So, this miller index for this plane is 100 similarly say this is infinity 1 infinity. So, the miller index of this plane is 010 because reciprocal of infinity is 0 reciprocal of 1 is 1 a reciprocal of infinity is 0. So, we get 0 1 0 look at this plane infinity 1. So, the miller index of this will be 0 01; because miller index what do we do we take the reciprocal of the parameters of each crystal face understand.

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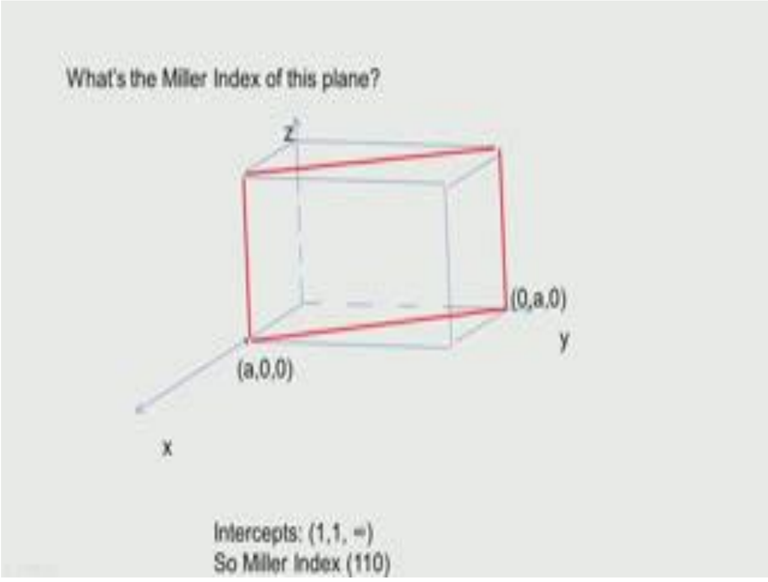

Now, let us go into a slightly difficult problem it is not so difficult, but you assume I want to know the miller index of this particular plane the one which is marked in red. So, it is cutting the x axis at a, it is cutting the y axis at a, it is not cutting the z axis. So, this a is 0 0 this point is 0 a is 0. So, 0 means no x it is not cutting the x axis a means it is cutting the y axis at a 0 means it is not cutting the z axis.

Now, I want to know what it is the miller index of this particular plane. So, it is cutting the x axis at 1, it is cutting the y axis at 1, then the z axis it is not cutting. So, we take reciprocal. So, the miller index of this will be 1 1 0 understand. So, it is cutting the x axis at a or and it is cutting the y axis also at a. So, they are equal. So, we can call it 1 1, it is not cutting the z axis so infinity. So, miller index will be 1 by 1, 1 by 1, 1 by infinity 0. So, this miller index for this plane is 1 1 0, this is the plane which represent the longer diagonal of a cube ok.

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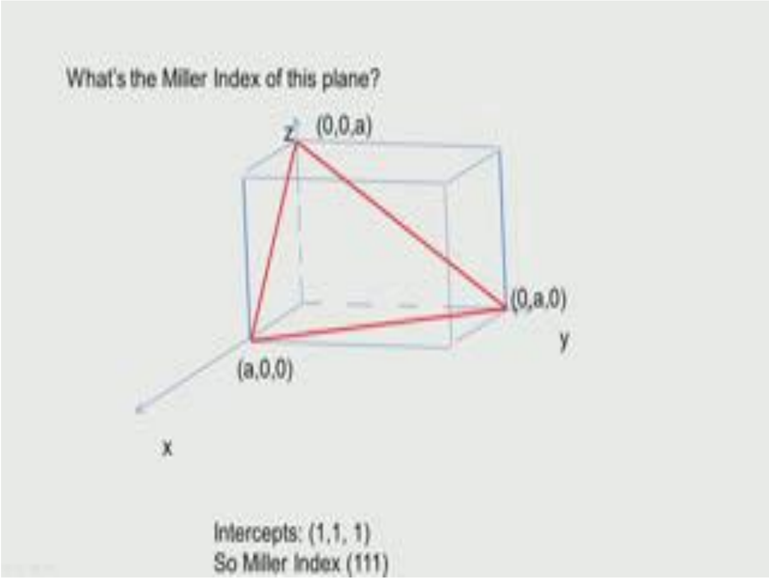

Now, let us look at this, this particular plane it is cutting the x axis at a. So, this point is a 0 0, this point is 0 a 0 this point is 0 0 a right 0 0 a means this point is x is 0, y is 0, z is a. So, what will be the miller index? So, we can say a a a comma a comma a. So, that will be when you take the reciprocal 1 1 1 understand. So, it is. So, the miller index of this particular plane will be 1 1 1. So, if you we can do the reverse also. So, we take the reverse of this miller index so; that means, this plane cuts the x by 1 that is 1 by 1 is 1 1 by 1 is 11 by 1 is 1. So, it is cutting the x y z at 1 1 1 points.

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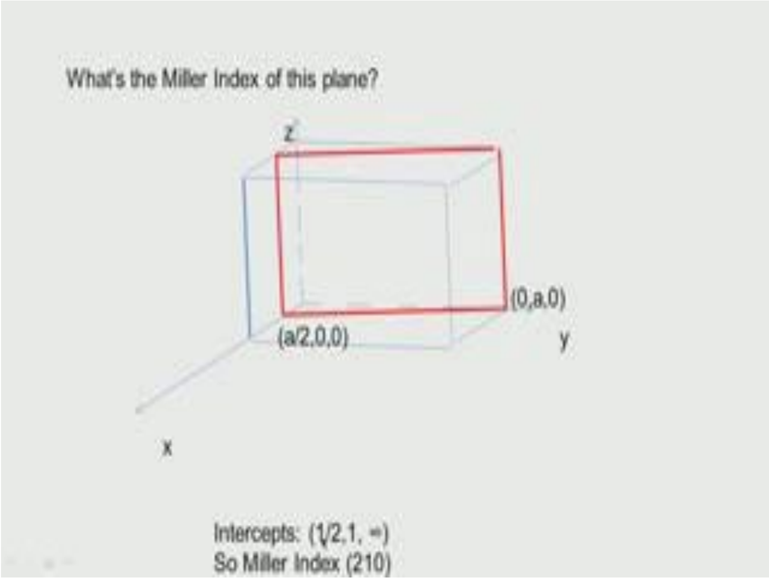

Let us look at this particular plane. So, look at this plane. So, this particular point is x is equal to 0, y equal to a, z is equal to 0 and this particular point is x is equal to a by 2, y is equal to 0, z is equal to 0. So, what do we do? For the intercept is a by 2, a and infinity or it is half one infinity. So, when we do the reciprocal this becomes 2, this becomes one and this becomes 0. So, do you understand this particular situation we have a the plane is cutting the x axis at a by 2, y axis at a, and z it is not cutting so we will call it infinity. So, it is a by 2 we will call it half, a we will call it 1 infinity. So, when we take the reciprocal this becomes 2 1 0. So, this plane the miller index of this plane is 2 1 0.

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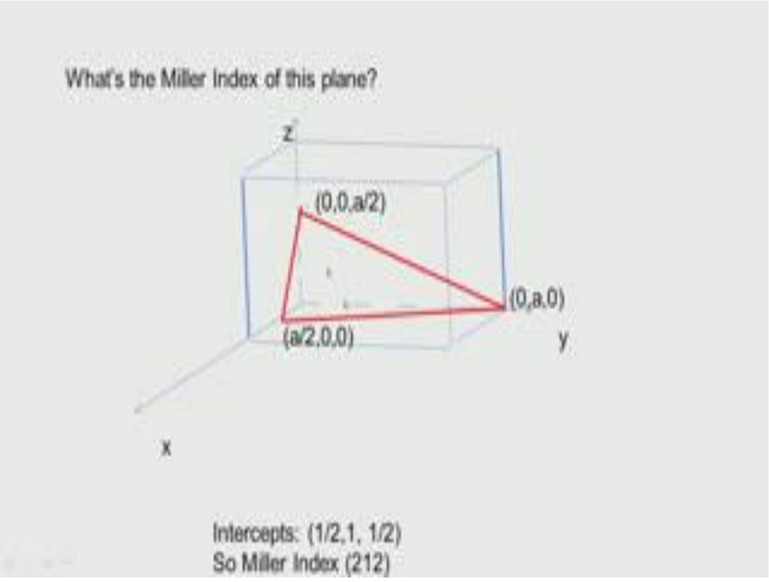

Let us look at another plane. So, look at this plane it is cutting the x axis at a by 2, it is cutting the y axis at a, and it is cutting the z axis at a by 2. So, the half 1 half. So, when we take the reciprocal it becomes 2 1 2. So, the miller index of this plane is 2 1 2 you understand. So, it is quite simple it is not very difficult, we need to see where the plane cuts in the x and y and z axes, and then we take the reciprocal and make it into whole number. So, it is not very difficult. So, we can have negative situation also, when the plane cuts x and the negative direction or it cuts the y in the negative direction or z also in negative direction. So, if we have negative and we take a reciprocal we may have to put a dash on top of it to indicate that it is a negative.

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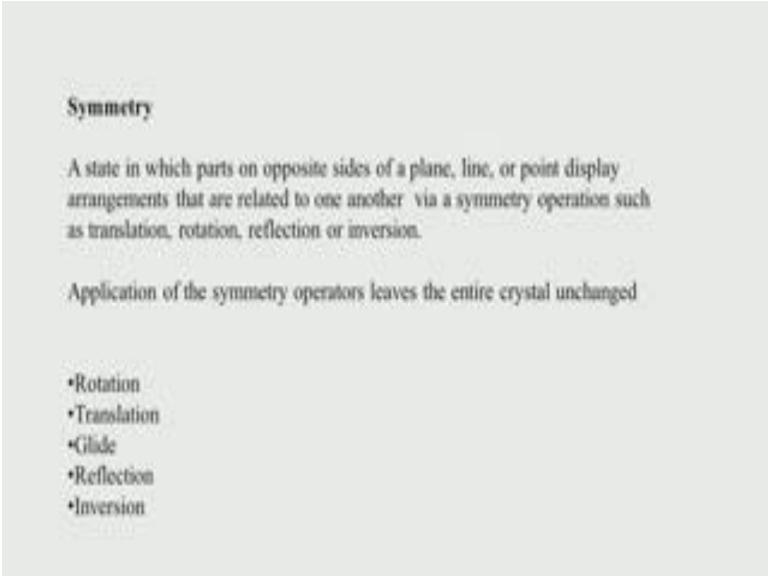

Now, all these unit cells have lot of symmetry, they have different types of symmetry; that is a symmetry is a state in which parts on opposite sides of a plane line or point display arrangements that are related to one another, that is called a symmetry via a symmetry operation such as translation, all these cells unit cells have symmetry. Symmetry there are different types of symmetry like when we look into a mirror there is called a reflection symmetry right. So, like that you know all these unit cells have symmetry. So, in it is very very important to know what is this symmetry means actually and symmetry plays a very important role in grouping various crystals with similar physico chemical properties.

So, what is this symmetry? This is symmetry is a state in which parts on opposite sides of a plane line or point display arrangements that are related to one another through a symmetry operation such as translation rotation reflection or inversion. So, basically symmetry is rotation. So, when I rotate it what I had the original has against the rotated form if they are same that is called the rotational symmetry. So, if I have translation symmetry; that means, when I move translate it or move it the original form has against the move moved form or similar is called translational. Then we have gliding symmetry; that means, if I glide it from one position to another and the original form and the glide that form after the gliding. Then it is called gliding then the reflection if there is a symmetry of the original form under reflected form then we call it reflection symmetry and similarly inversion. So, when you inverted the original form and the inverted form are similar then that is called inversion symmetry.

We will not go too much into it, but symmetry is also very important to know the various types of crystals will have different symmetry forms ok.

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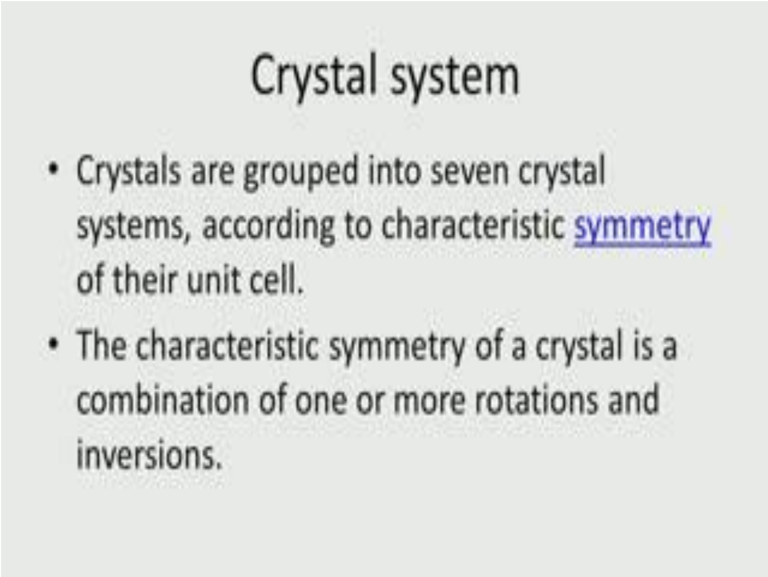

So, crystals are grouped into 7 crystal systems according to characteristic symmetry of their unit cell like I said here you know, they can have rotational symmetry, they can have translational, glide reflection inversion and you can also have combinations of that. So, the crystals are grouped based on this particular symmetry form, symmetry of their unit cells and you can have combination of one or more. So, you can have combinations not just one, you can have 3 of them some crystals may have 3 symmetries some of them have 2 symmetries and so on actually, that is what is called the crystal system.

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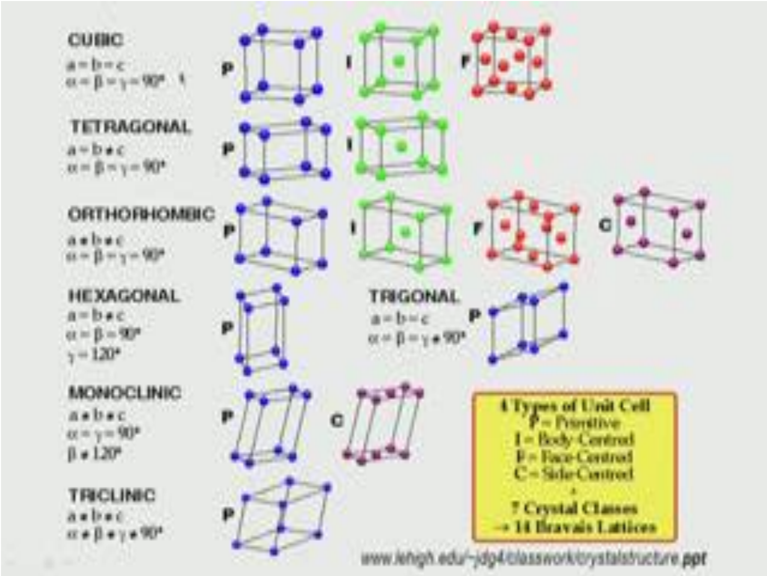

So there are 14 bravais lattices, and there are 7 crystal classes this data was obtained from this particular power point reference. So, there are 7 major crystal classes like cubic, tetragonal, orthorhombic, hexagonal, monoclinic, triclinic, trigonal. Cubic, tetragonal, orthorhombic, hexagonal, monoclinic, triclinic, trigonal these are the 7 crystal classes they are grouped based on these 6 parameters; the 3 lengths that is the a b c length and 3 angles the alpha beta gamma. Now each of these form can have the primitive structure; that means, atoms present only in their corner or they can have a body centered or they can have a face centered. So, when you do that we end up with 14 bravais lattices. So, there can be 7 crystal classes, and there are 14 bravais lattices.

for example, if you take cubic its symmetric in all respects complete a is equal to b equal to c; that means, all the 3 sides are equal, the 3 angles alpha beta gamma is equal to 90 degree. So, this particular class has all types of symmetries because all the lengths are equal all the angles are equal and they are equal to 90. Now in this cubic you can have a primitive structure, you can have this body centered cubic as well as you can have a face centered cubic has that. Similarly if we take tetragonal you can have here in tetragonal a equal to b like this, but c is not same as a and b. So, instead of being a cubic it can be like this you know extended form, and alpha beta gamma are equal to 90 degrees ok.

So, here you can have basic form or primitive form and you can have a bodies centered cubic. So, there are 2 types, 2 bravais lattices for the tetragonal class. If you take orthorhombic a is not equal to b not equal to c, but angles are equal to 90 degrees look at this. So, you can have a primitive form, we can have a body centered form, we can have a face centered form, we can also have a side centered; that means, the 8 corners are filled and only these 2 sides are filled unlike the face centered where all the 6 sides you have atoms. So, this particular orthorhombic crystal class as got 4 bravais lattices. So, that is why totally we have 14 bravais lattices and we have a 7 crystal classes.

So, look at triclinic this is the most unsymmetric system; a not equal to b not equal to c alpha not equal to beta, not equal to gamma, not equal to 90 degrees. So, there is only one form that is called the primitive form. So, all the metals will have crystals which will fall in one of this one of these crystal classes and one of these bravais lattices. So, that is the beauty of metals we can group them together and if you are preparing metal alloys if; that means, if you are adding another metal to one metal based on the dimensions, it may go and replace one of these hot atoms or they may destroy their crystal structure. So, we can sort of a priori design what type of impurity or second metal that can be added to the first metal maintain property or modified property and so on actually. So, study of this crystal structure and crystal classification is very very important in designing a novel metal always ok.

So, we will continue more on this crystal structures in the next class as well.

Thank you very much for your time.