Solid State Physics
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Lecture – 05
Crystal Structure

So, we will discuss about Bravais lattice in this class. So, we have mentioned about the space lattice or point lattice both are same.

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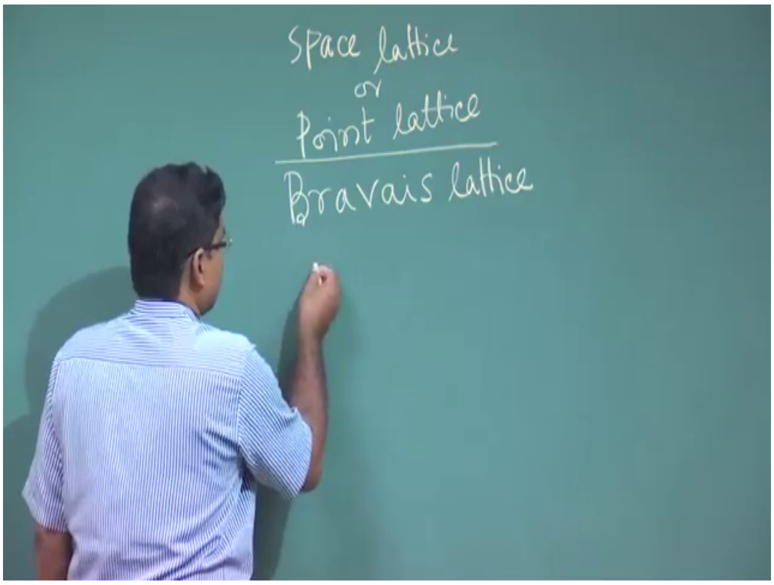

So, now, what is Bravais lattice? As I mentioned that this space lattice or point lattice these are completely based on mathematics; so, in space we arrange some points in such a way that each point has the similar surrounding identical surrounding basically.

So, how to get such type of arrangement of the of the points that I discussed that if you divided this space taking a 3 sets of parallel planes, then intersecting point basically corner points are the basically lattice point and as a whole it forms the lattice that is space lattice to point lattice.

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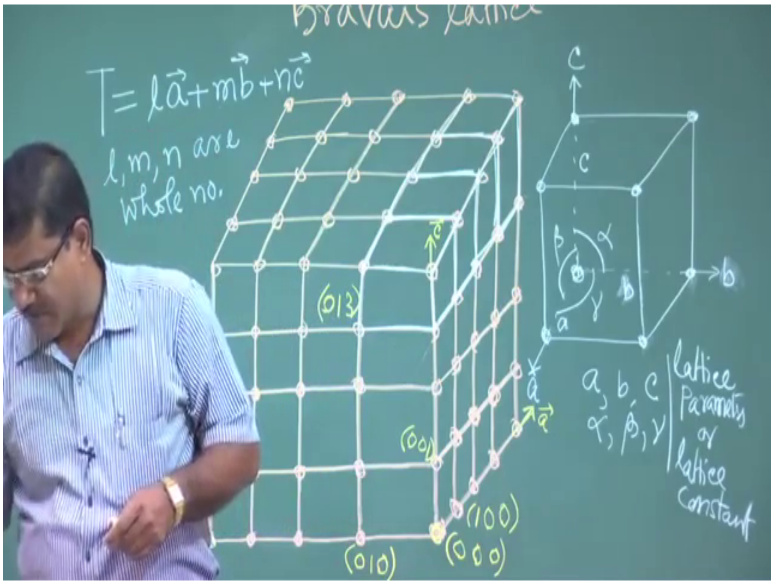

So, if you take a volume in space. So, this is a box say; it is a space in box form, now this space, if you divide with 3 sets of parallel planes, then what happens let us see. So, 3 sets of parallel points. So, let me, this is one plane. So, this is a one set of parallel planes this is one set of parallel planes this is another set of parallel planes and then this third set of parallel planes say; I can take this another set of parallel planes.

So, taking 3 sets of parallel planes we have divided this box now you see the inter sector intersecting at each intersect if you put point. So, basically this and these points together will form a space lattice or point lattice. So, these all points together forms the space lattice just if you ignore these guided lines, then the only points will be there, they are nicely arranged and these are this is the space lattice or point lattice.

Now, here you can see that this so they divided this whole space now is divided into a mini small boxes so this we tell the basically unit cell. So, this repetition of unit cell basically will give you this is the whole structure whole lattice. So, repetition of this box will give right. So, if you know about the unit cell then we can get all information about the crystals. So, basically crystal structure when will tell about called lattice whenever this; we study basically this unit cell.

So, unit cell is a self contain all information about the lattice. So, if we pick up this one unit cell. So, this is the unit cell this is one of them all are identical. So, this unit cell if we define the axis a axis; sorry, I think this I will take a axis, then b axis, and c axis;

these are crystallography axis. Now angle between the 2 axis so this between a and c axis angle is beta b and c angle is alpha and a and b angle is gamma.

So, this a, b, c along this axis the distance of lattice point distance of lattice point if this distance we take this magnitude a this only and along this length if we take a and along this if we take length as c. So, we have a, b, c, these are length distance between 2 lattice point along a axis, along b axis and along c axis and their corresponding angle alpha beta gamma. So, these are called basically lattice parameters or lattice constant lattice constant.

So, this value of this lattice parameter it may be it may vary and it will give us different unit cell. So, it will represent different lattice. So, choosing the different value of a, b, c and alpha beta gamma, we can get basically many lattice point lattice or space lattice, but due to symmetry; this number become limited that we will discuss. So, before that I will discuss another way to generate the space lattice or point lattice using the translational vector.

So, if I take a translational vector t equal to l a plus m b plus n c where l, m, n are whole number 0 as well as plus minus number. So, then also we can generate this space lattice choosing all combination of all combination of l m n values. So, just if I consider here this point as a origin and say this a this is a a axis this is a this is a b axis and say this is a c axis.

Now, for this origin so it is basically this a b and c value here this length a b c value here this length that is 0. So, for l equal to 0, m equal to 0, and n equal to 0. So, it will represent this point. So, that is 0 0 0 and then this point will be represented by for l equal to 1 along the x axis 1 m and n will be 0. Similarly choose so this point we can generate choosing the m equal to 1 and l and n equal to 0.

So, this point is basically a 0 1 0 similarly this point n equal to 1 and l and b are 0 so this 0 0 1. So, taking all combination of l m n value we can generate we can get all points, just take any point. So, say this point so these point what will be the l m n value. So, this along c axis and this side you have to come this 1 b right 1 b m equal to 1 and a will be 0. So, along a; this distance is 0 because this is on this yeah this is basically on the b c plane; on the b c plane. So, this point will be 0 1 m equal to 1 and n equal to 1 2 3. So, this is 3.

So, taking all combination of l m n, we can get all points; that means, using this translational vector we can generate points in space and this will form the space lattice. So, space lattice we have already generated dividing the space taking 3 sets of plane and got this points. So, they form the space lattice or point lattice. So, using this translational vector we are getting all these points for different value combination of l m n values.

So, this way also using this translational vector we can generate space lattice. So, just from mathematics one can one can do this. So, now, how many space lattice are required to describe all crystalline materials. So, that we would like to see now so I think I am not need this. So, from the value of lattice constant or varying the value of lattice constant lattice parameter we can generate different unit cells means different space lattice.

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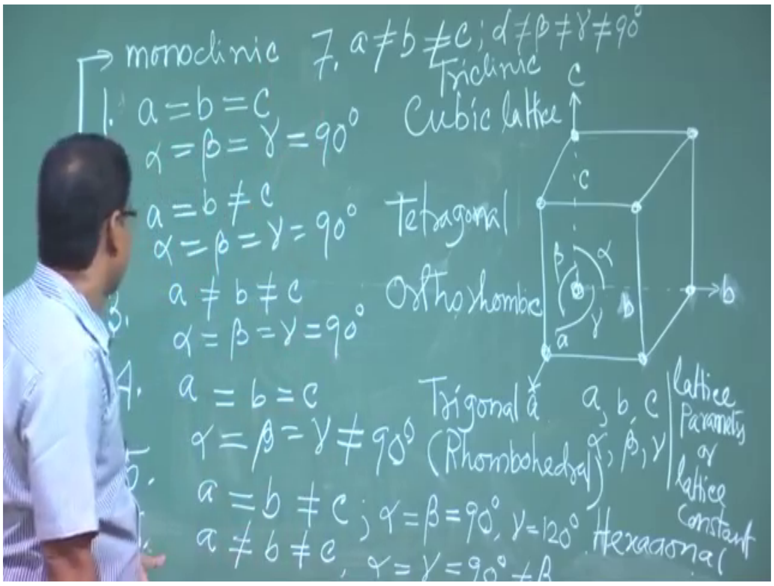

So, 1 value we can take like this a equal to, b equal to, c; that means, this along a along b along c this that lattice distance the distance between 2 lattice point along these 3 axis are same and then alpha this angle alpha beta and gamma are equal and they are equal to say 90 degree this can be one set of value if. So, then this is called this represent a space lattice point lattice and this point lattice is called cubic lattice cubic lattice.

Then second option would be a equal to b is not equal to c, but alpha equal to beta equal to gamma equal to 90 degree this can be another lattice. So, this lattice is is called the tetragonal lattice is tetragonal lattice and this third is a is not equal to b is not equal to c.

But alpha equal to beta equal to gamma equal to 90 degree. So, this is another lattice and it is called orthorhombic is called orthorhombic lattice and then third fourth option would be a equal to b equal to c, but alpha equal to gamma beta equal to gamma is not 90 degree they are equal, but not 90 degree.

So, this lattice is called the Trigonal lattice or Rhombohedral, also it is called Rhombohedral lattice. Then fifth option would be a equal to b is not equal to c, alpha equal to beta equal to 90 degree and gamma equal to 120 degree.

So, this can be another lattice and this lattice is called hexagonal lattice and sixth option is a is not equal to b, n is not equal to c, alpha equal to gamma equal to 90 degree is not equal to beta is not equal to beta if so then this type of lattice will be called Monoclinic I think it is not visible I will write on top this.

So, this basically, for this option is Monoclinic, another options is there so I think I have to 7th option let a is not equal to b is not equal to c alpha is not equal to beta is not equal to gamma is not equal to 90 degree. So, then this called this will represent another lattice. So, that is called triclinic lattice.

So, here whatever we are seen is basically 7 lattice 7 type of lattice. So, this basically called it is 7 crystal system this crystal system. So, if you want to know the structure of any material. So, that structure of that material will be one of them will be one of them. So, all material can be grouped structure wise into 7; 7 groups so 7 system. So, that is why these are called 7 crystal systems. So, any material will be will be under one of this 7 crystal system.

Now, this here whatever I have discussed is all lattice points are at the at the corner of the of the of the unit cell, but Bravais; again he considered some off corner lattice point, off corner lattice point means not on this corner it is somewhere else and he found that from those 7 crystal system we can get 14 lattice system 14 lattice not system 14 lattice type of lattice 14 type of lattice and these 14 type of lattice basically called the Bravais lattice after his name.

So, this Bravais lattice of 14 types.

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System	Axial lengths and angles	Bravais lattice
Cubic	Three equal axes at right angles $a = b = c,\ \alpha = \beta = \gamma = 90°$	Simple Body-centered Face-centered
Tetragonal	Three axes at right angles, two equal $a = b \neq c,\ \alpha = \beta = \gamma = 90°$	Simple Body-centered
Orthorhombic	Three unequal axes at right angles $a \neq b \neq c,\ \alpha = \beta = \gamma = 90°$	Simple Body-centered Base-centered Face-centered
Trigonal (Rhombohedral)	Three equal axes, equally inclined $a = b = c,\ \alpha = \beta = \gamma \neq 90°$	Simple
Hexagonal	Two equal coplanar axes at 120°, third axis at right angles $a = b \neq c,\ \alpha = \beta = 90°,\ \gamma = 120°$	Simple
Monoclinic	Three unequal axes, one pair not at right angles $a \neq b \neq c,\ \alpha = \gamma = 90° \neq \beta$	Simple Base-centered
Triclinic	Three unequal axes, unequally inclined and none at right angles $a \neq b \neq c,\ \alpha \neq \beta \neq \gamma \neq 90°$	Simple

So, I will just summarised in this table you can see this table system has discussed this Cubic, Tetragonal, Orthorhombic, Trigonal, Hexagonal, Monoclinic, Triclinic; already I have mentioned here corresponding this value of a b c and angle. So, everything I have written on the board and now Bravais lattice you see this in case of cubic there are 3 types of Bravais lattice are there so is called Simple Body-centered, Face-centered.

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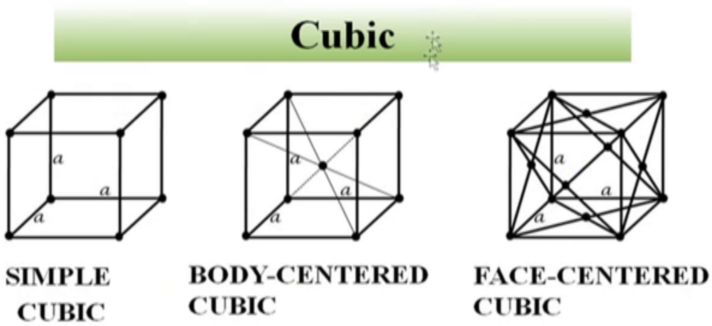

So, simple in case of cube so I can show here this is the cubic these 3 types this simple cubic and this is Body-centered is in simple cubic additional one lattice point is there at the body, at the center of the body. So, that is why Body-centered cubic and Face-centered cubic on each face at the center of each face. So, there are 6 faces. So, this additional lattice point. So, off on the lattice; so these are called Face-centered cubic.

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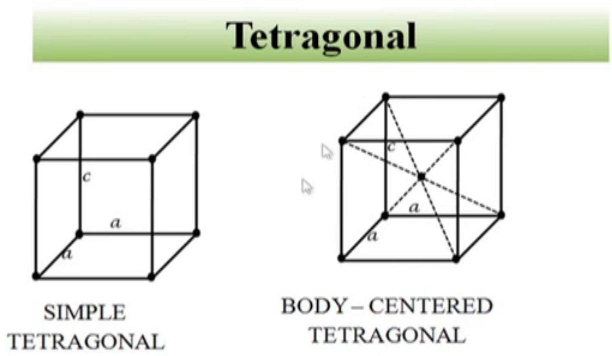

Similarly, for tetragonal 2 types are there; simple only at the corner and Body-centered at the body.

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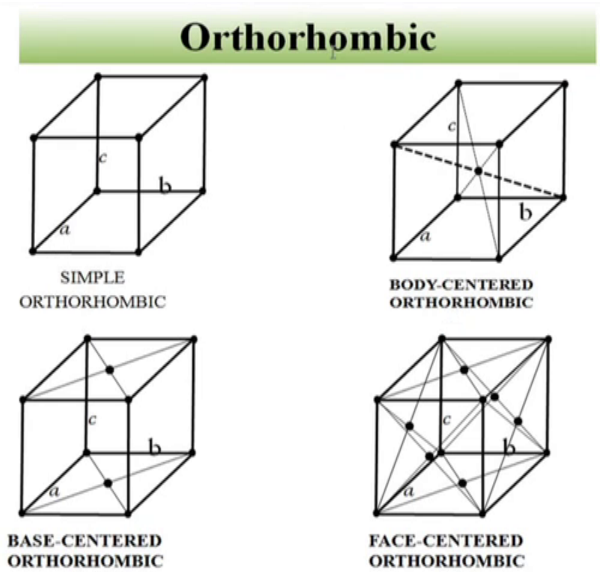

So, orthorhombic there are 4 types simple body-centered, face-centered this is same as we have seen for cubic and additional one is base-centered on the base here and here. So, the lattice points are there. So, this is called base-centered.

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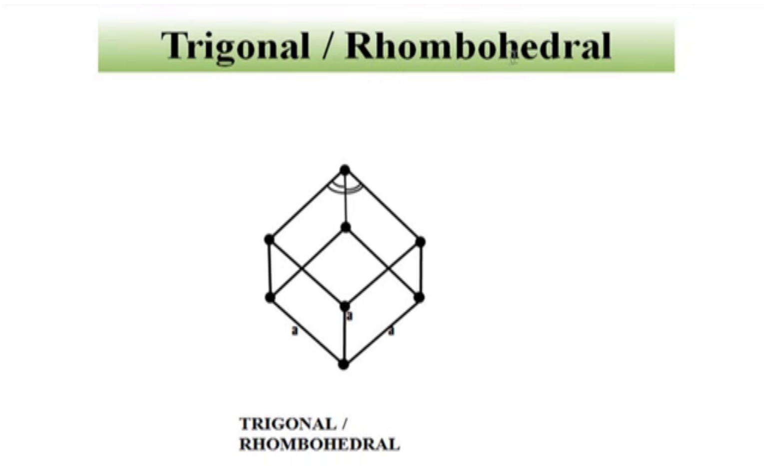

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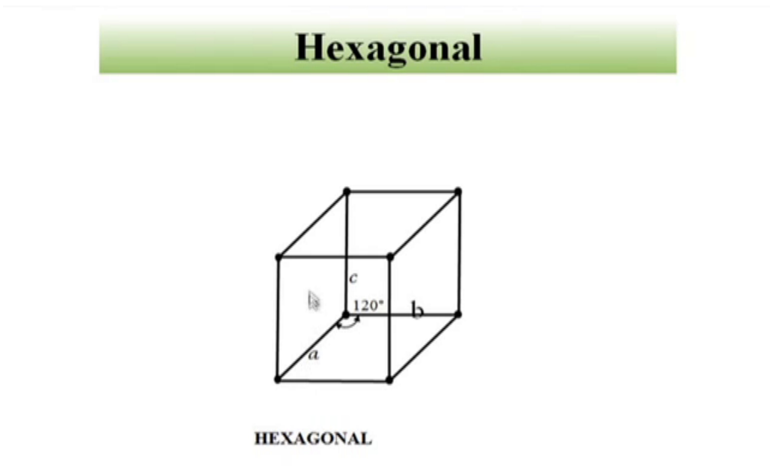

And Trigonal or Rhombohedral; so this is one type; only simple trigonal and this is the Hexagonal only this a one type only simple type and Monoclinic. So, here it has 2 types simple and base-centered and last is triclinic. So, it has only one simple type. So, these lattice points are present.

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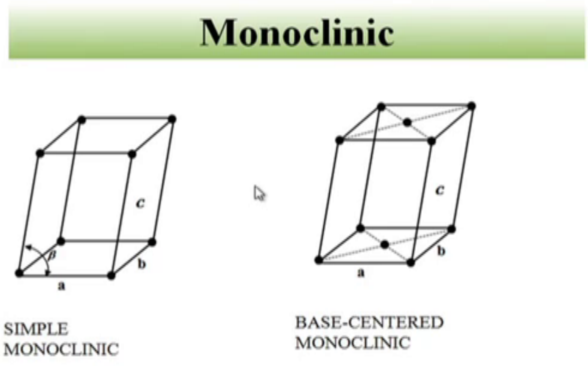

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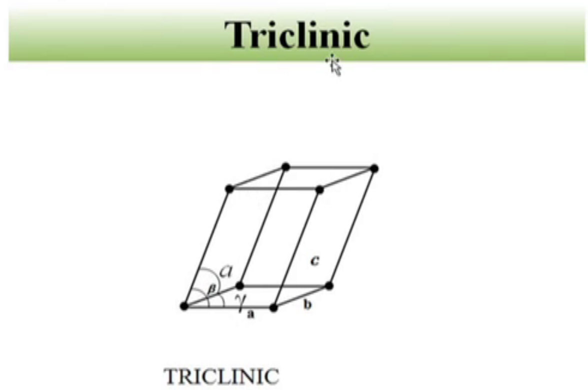

So, these are the 14 Bravais lattice and it is. So, any material structure of any material it will described by one of these 14 Bravais lattice.

So, I will stop here. So, then we will continue in next class.

Thank you very much.