Solid State Chemistry
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Lecture – 60
Summary of Week 12, Practice Questions

Now, I will come to the 5th and last lecture of week 12 of this course. And in this lecture, I will give a short summary of what we learned during this week. And then do a few practice questions ok. Now, the practice questions in this topic will basically be related to the interpretation of the band structure and so these will be pictorial questions. So, week 12, lecture 5 will be Summary of Week 12 and Practice Problems.

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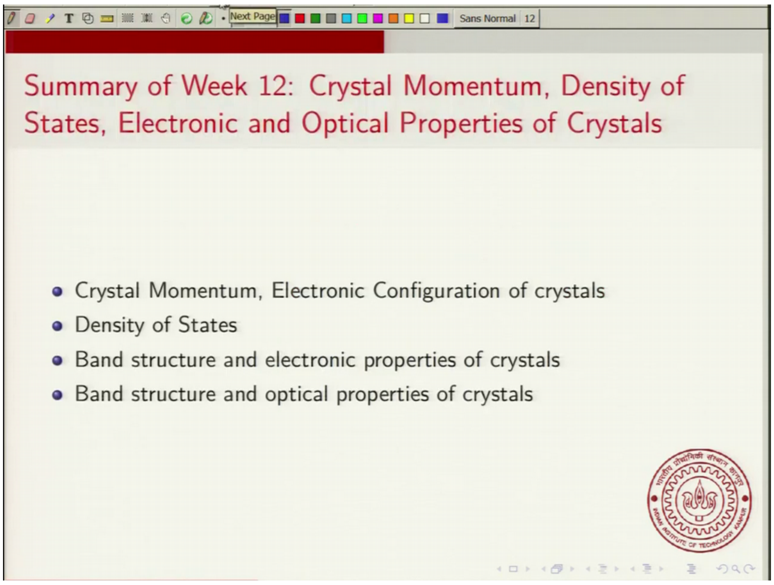

So, what do we learn in week 12? So we first learned about crystal momentum, then we learned about the electronic configuration of crystal, how to fill electrons into bands in crystals. Then we learned the very interesting and important concept of the density of states ok. And we saw how the density of states you has the advantage that you do not have to pick a direction in like the in the band structure, you have to pick a certain direction in which the wave vector is changed. But when you are looking at the density of states, you do not have to do any such thing. Then we saw how the band structure is related to the electronic properties of crystal. And finally, we saw how the band structure is related to the optical properties of crystals.

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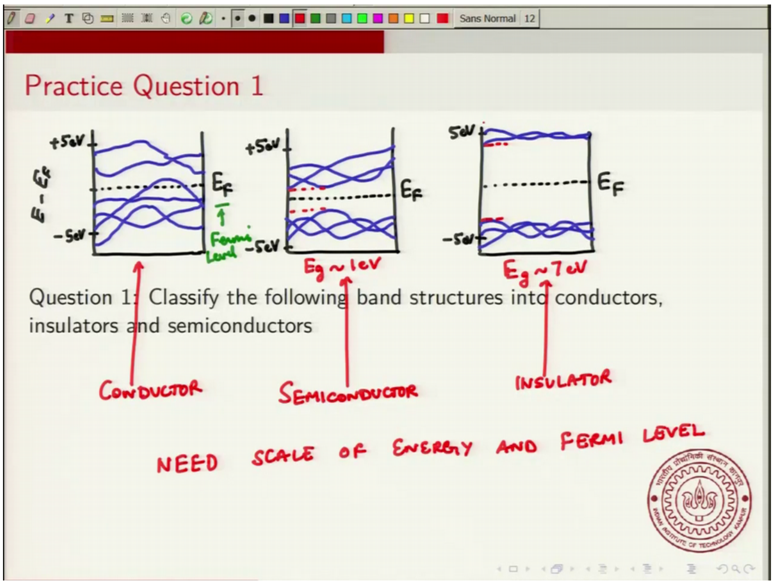

So, now, let us look at a few practice questions. Now, the first question I am saying is classify the following band structures into conductors, insulators and semiconductors ok. So, I have given all these band structures. And this axis is energy minus the Fermi energy or actually truly it should be the Fermi level ok, because we are looking at the finite temperature ok. So, this E F actually refers to the Fermi level ok. So, Fermi level and Fermi energy are the same at T equal to 0, but at finite temperature the Fermi level is used. And notice that the Fermi level can be where there is no band also, it can be in between bands ok.

So, E minus E F and so this minus 5 electron volts ok, so this minus 5 electron volts below the Fermi energy, this is 5 electron volts above the Fermi level. And similarly in these cases ok. So, I have given an axis, ok, I have said that this is plus 5 and this is minus 5 ok. Again that means, it is E minus E F is plus 5; that means, it is 5 electron volts above the Fermi level; and this is 5 electron volts below the Fermi level ok.

So, classify the structures into conductors. Now, here we see that the Fermi level is passing through one band ok. So, clearly the first one should be a conductor ok. Now, these two ok, now here we see that the band gap, band gap is just of the order of is of order 1 electron volt ok. So, this is clearly a semiconductor ok. Here the band gap is almost of the order of about if you just estimate it, it looks like about 7 electron volts, and this would be an insulator ok.

So, what is important is you need to know you need to know the if you want to know whether material is a semiconductor, conductor or insulator, you really have to have this scale, you really have to have this energy scale on the axis ok. And you have to know where the Fermi energy is ok. So, you need scale of energy and Fermi level ok. So, suppose I had just given you any of these without telling you where the Fermi level is, then you would not be able to tell whether it is conductor, semiconductor or an insulator ok.

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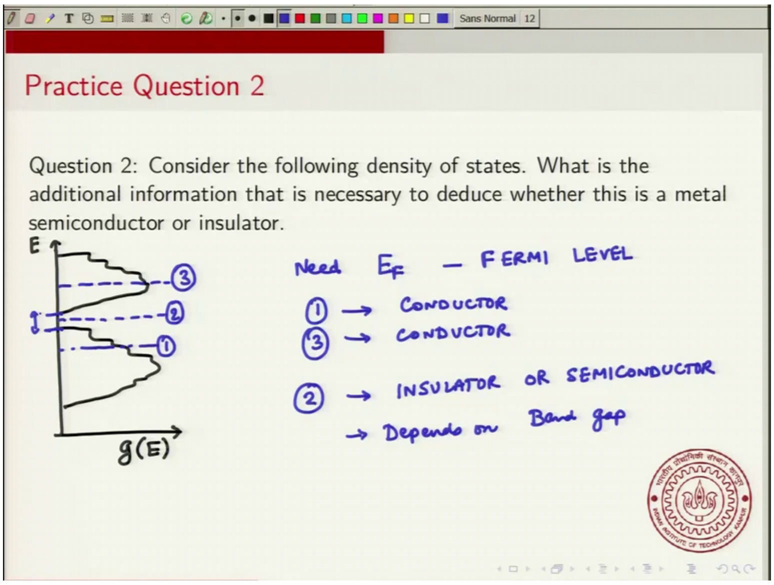

Now, let us look at the next question. So, this question is a theoretical question, it says that consider the following density of states. What additional information is need to deduce, whether this material is semi conductor, conductor or insulator ok. And this goes back to what we said last in the in the last question. So, you need E F that is a Fermi level ok.

So, if E F is somewhere here, then you immediately know that it is going to be conductor. So, if it is either in one of these regions, then it would be a conductor ok. Now, what if E F is in between these two ok, then it can be either a conductor or an insulator. So, 1, 2, so case 1, ok, it is a conductor. Let us take case 3, which is somewhere here in the middle of this ok. Similarly, for case 3 is also a conductor; case 2 can be insulator or semiconductor, or semiconductor ok, whether it is insulator or semiconductor depends on the band gap, so depends on band gap ok.

So, the additional information you need to know is you need to know how much this band gap you need to know a scale of energy here. So, this energy should need to have a scale. So, you need to know this band gap, and to know that you need a scale of energy on this axis ok. So, if you just have a density of states, you cannot immediately say I mean the density of states has to have a proper scale, and you have to say where the Fermi level is, only then you can tell whether the material is a conductor, a semiconductor or an insulator.

So, again I want to emphasize that you know understanding things like density of states, I mean these are regularly shown in various literature to explain properties of metals, semiconductors and insulators. And so it is important that you understand the basics of the density of states, and then you can you can go to you can use it for more advanced materials.

So, in these two problems, we have seen how to understand whether a material is a conductor insulator or semi conductor by looking at the looking at either the band structure or the density of states ok. Let me emphasize that if you I mean band structure just shows one direction in k ok. So, it just shows one of the directions in k ok, it is possible that in along some other directions the bands might actually go higher in k ok, but we are assuming that the at least we do not have, we do not have dramatic differences in the other directions ok. And so usually it is a band structure plus the density of states that really helps us decide on the properties.

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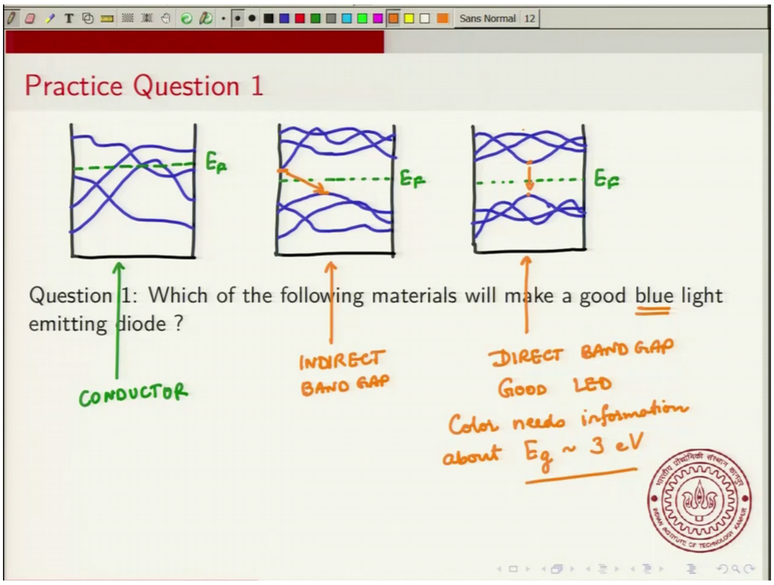

Now, one more question, so I here have shown a few materials in your ask to see which will make a good light emitting diode, and I should draw the Fermi level for the others. So, these are the Fermi levels ok, the green is the Fermi level. So, clearly in the first case ok, you have a conductor ok. So, obviously, if you if you want a light emitting diode, it has to be a semi conductor, ok. So, you cannot have a light emitting diode, the second case ok.

Now, now in the second case, you have to identify what the band gap is. So, if you look at the structure ok, then what you see is that the bottom of the conduction band is actually here, and the top of the valence band is here ok. And what you have is in indirect band gap, indirect band gap ok. This is just based on this band structure. Whereas, in this case you have the these two the bottom of the conduction band in the top of the band, top of the valence band are aligned, and this is a direct band gap ok.

So, it is this that will make good, well I do not want to say blue light I mean you know it; I meant it will just make a good light emitting diode. Now, whether it is blue or not ok, whether it is blue depends on the color needs information about E g. So, what is the value of the band gap? So, for blue led, we saw that you typically need about 3 electron volts ok. So, if E g is of the order of 3 electron volts, then we will get a good blue light emitting diode ok.

Now, but in any case this is the material that will make a good light emitting diode. Whether it is blue or not depends on the exact value of the band gap. So, these are the kind of ways in which you can analyze the band structure and the density of states ok. And with this I will conclude this lecture. And we will come to the end of lecture 12. And with that we have also come to the end of this course on solid state chemistry. And it is it is been 12 weeks. And I know there are lot of things that we that we covered during this course and some of them were I would say fairly intense mathematically like the topics of symmetry and band theory ok.

So, but overall I what I have tried to do in this course is to is to give you a very general feel of some of the important concepts relating to solid state chemistry. And what you can do with this basic knowledge ok, you can you can you can delve deeper into topics of your interest. So, if you are interested in certain kind of materials or certain kind of properties, then this basic background should help you carry out whatever study you want to do in those materials ok. And I hope you have enjoyed taking this course as much as I have enjoyed teaching it ok. And with this I will conclude this course.

Thank you.