Semiconductor Devices and Circuits
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Lecture - 24
Schottky Contact: Small Signal Impedance

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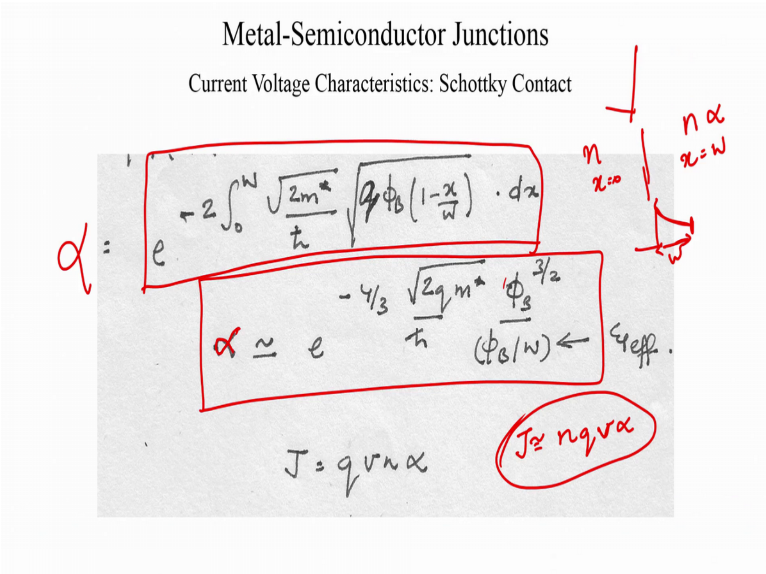

So, we have seen in the Schottky Contact we have looked at the basic pan bending diagram you have looked at the electrostatics, we have derived the current voltage characteristics when we apply a certain bias. And we will now try to define the impedance, the small signal impedance the Schottky contact based on all our studies.

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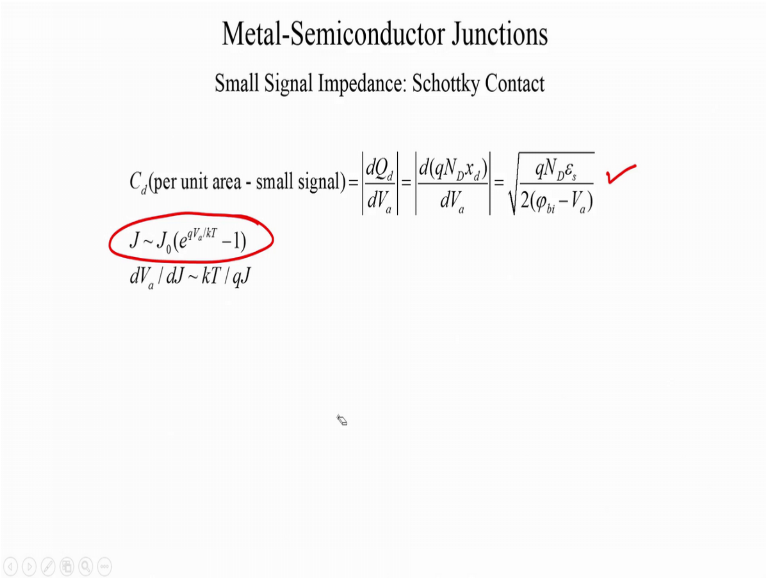

So, the small signal impedance basically has got 2 terms. So, you can think of so, we are all talking about low frequency aspects here.

So, in forward bias the Schottky contact behaves like a diode. And, you know, it can be imagined to have a small signal impedance. So, just like we measured small signal capacitance, you know, we are interested in the small signal parameters; which means you have your metal semiconductor contact, you have got these 2 terminals. And we have applied a small signal voltage V a. And in order to measure the capacitance, small signal we wanted to measure the fluctuations in the charge with due to the applied voltage. And in order to measure there is something called as a small signal resistance ok, we measure the fluctuations in the current with respect to the applied voltage.

So, therefore, this these 2 terms give you the small signal impedance parameters for the diode. So, the capacitance per unit area small signal is dQ d by dV a which we have already derived and found to be that. And since the current voltage characteristics due to diffusion and thermionic emission, you know, could be a written as sum J naught e to the power q V a by kT minus 1, dJ by dV a is the per unit area conductance. And that is given by J naught q by kT e to the power q V a by kT. And if it is in forward bias, this term would dominate and therefore, in forward bias this would be dJ by d V a; which implies a dV a by dJ, that is the which is basically the resistance term is approximately kT by q that is the thermal voltage divided by J naught into e to the power q V a by kT which is approximately your J.

So, therefore, we just say it is of this order. It is a diode essentially, it is a diode and we are looking at the small signal resistance of the diode. So, this is the small signal resistance. And of course, there are many, there are lot more details to this, this is got we look to the diffusion current, we looked at the thermionic current, you look to the tunneling current and this does not take into account the tunneling current. But based on the diffusion and thermionic currents, this J naught can be this factor J naught can be defined slightly differently.

So, that is with that we conclude our discussions on the Schottky contact. We say that, the Schottky contact is a metal semiconductor contact which has a diode like or rectifying nature, simply because of this kind of a relation. I mean now proceed to discussing the ohmic contact. Now ohmic contact is, you know, the impedance of an ideal ohmic contact is quite simple because it has to be just a resistance.

So, therefore, we will not spend time discussing the current voltage characteristics of an ohmic contact; instead, we will look at the electrostatics of an ohmic contact. And you know, look at the, you know, what the Poisson's equation is and, you know, how you solve it, how do you go about solving that.

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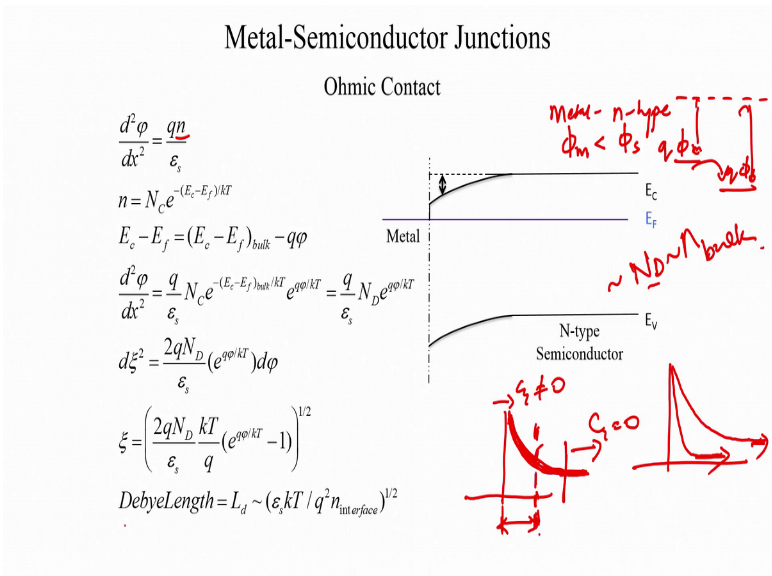

And this is something we have already it is it is familiar territory, because there is there is there is nothing new here; is just that you need to be careful in looking at the ohmic contact.

So, if you this is the band bending for an ohmic contact, right so, if you have an N type semiconductor and you have a metal. And the metal N type semiconductor was such that the work function the metal is now less than the work function of the semiconductor; which means that you have q phi m there, and q phi s here. And you create this contact. The metal will donate electrons to the semiconductor, and the bands in the semiconductor will bend downward, you know, the conduction band will get closer to the fermi level and the electron population here is greater than the electron population in the bulk.

Where the electron population the bulk is about N D; my apologies from writing very small. So, this is the electron population at the interface. So, that is going to be greater than n bulk. So, clearly we cannot make the depletion approximation here, absolutely not, because we know that this region is filled with a lot of mobile carriers. And therefore, this is a more accurate representation of our Poisson's equation. So, you have your rho is equal to minus q n, because n is the number of electrons per unit volume and q is the negative charge in the electron and therefore, a Poisson's equation takes this form.

Now, n is definitely dependent on phi and how does it depend on phi we have already gone through this exercise once before, when we try to write down the Poisson's equations more correctly for the Schottky contact. So, it is a same exercise. So, n is nothing but N c into e to the power E c minus E f by kT and therefore, all I need to do is identify what is this is E f that is E c and identify what E c minus E f is and that is that that depends upon x in this region.

So, this is going to be my, let us define that as my phi. So, E c minus E f at any location is the E c minus E f in the bulk minus phi right. So, if I if I call that as A B and C, C is equal to A minus B ok. So, therefore, E c minus E f in the region where the band is bending, I will call that as E c as a function of x. So, that is what I have written there, E c minus E f in the region where the band is bending is E c minus E f in the bulk minus q phi. So, that is q phi, and we use that expression and plug it in to your expression for n, and say that q by epsilon N c e to the power, you know, all these terms is your Poisson's equation.

So, what we have done now is we have represented n in terms of phi. And this is nothing but this expression here. So, what this is, is that. So, that is phi so, at this location at that location phi is 0. So, if you think about it be now redefined our reference point so, that is that is a point to note, there is no barrier height. So, it is a new problem, we have redefined our reference point such that my potential is now 0 at in the bulk. So, that is my 0 potential and that is my potential, it is a little different from what we did before. But as I told you can choose an appropriate reference so, here I am choosing a different reference point.

So, phi is 0 here and as we head towards the interface phi increases, and it is maximum at the interface. So, that is the way I have defined my potential. So, therefore, as we approach the interface so, at phi equal to 0, this term is one and you can see that the electron concentration is same as the bulk electron concentration. But as we approach the interface phi increases, and the electron concentration increases; which is as expected in the case of an ohmic contact. And we are now familiar with the tools to solve an expression of this kind a differential equation of this kind right. So, we multiply both sides by d phi by dx and we will end up with a differential equation that we need to solve and then obtain your electric field.

So, this is the there is an introduction to the ohmic contact and this is the electrostatic this is how you approach electrostatics of this case. The current voltage characteristics is clearly defined by, you know, just a resistance that is a good it is a good approximation to define the current voltage characteristics of an ohmic contact.

And as and by definition ohmic contact can be represented by a small signal model of it just being a resistor on the region of operation, all right. One thing which I would like to define before we close this topic is; the concept of something called as a Debye length, ok. Now when you have an electric field and you have say carriers or some kind screening this electric field off.

So, based on the electric field that you have applied, the charges respond to the electric field leading to a charge distribution inside. And essentially the point is after a certain length this electric field needs to be screened off, the electric field beyond a certain length is 0. Now in order to measure this, in order to get an estimate on the screening distance, we have a parameter called as the Debye length. It is an estimate of the screening distance; it is not the complete screening distance. It is an estimate ok, and that length is given by this particular term ok, and you can see that most of the parameters are constant except for the charges available.

So, in this particular case, if n if the interface electron concentration is n interface, that is the electron concentration, it is these carriers that are going to be available for screening, and if I increase this carrier concentration I can reduce the screening length. So, which means that if I have a large carrier concentration, the electric field will be screened off much sooner, there will be no electric field seen beyond a certain point.

But if I reduce this carrier concentration, then I need to penetrate the electric field penetrates deeper into the material and the screening will happen after a much larger distance. So, it is a measure of the screening length of a electric field and that is something called as a Debye length,. With this we will close our discussions on the metal semiconductor junctions, and from this point on we will look at another junction that is quite popular which is something called as the P-N junction.