Solid State Physics
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Lecture - 73
Dielectric property of Solid (Contd.)

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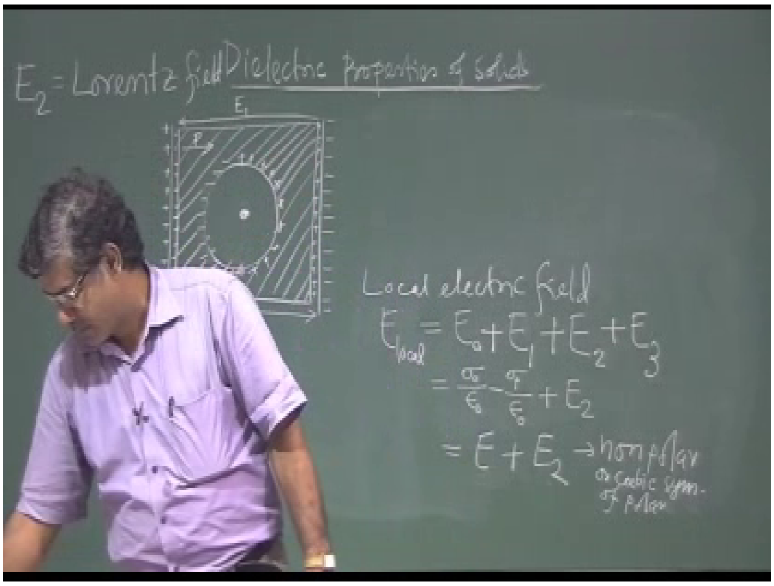

So, we will continue our calculation. So, this so what I got this E local field which this atom c is, say atom at the center c it seize. So, that is E that is macroscopic field, we see the material in general E 2. So, E 2 is called the Lorentz field, it is called the Lorentz field. Now and this E that I have just it is there sigma 0 by epsilon 0 minus sigma s by epsilon 0.

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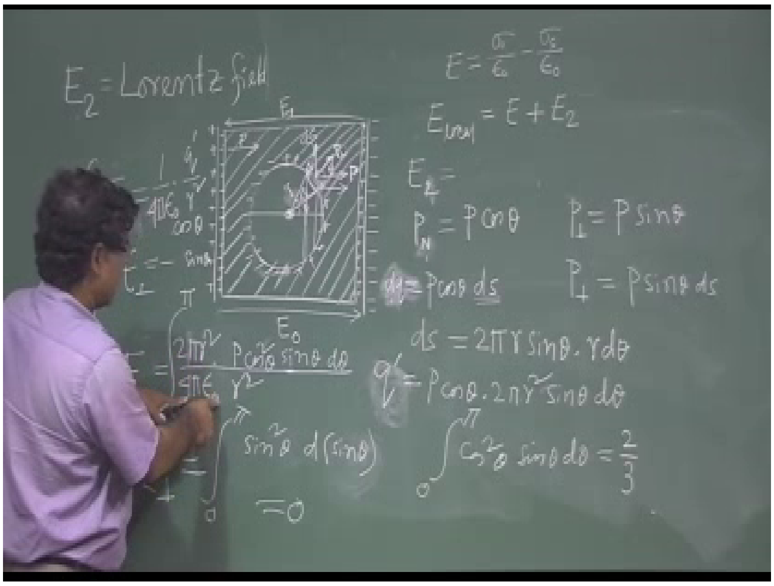

So, as I told that now you have to calculate E 2 Lorentz; Lorentz field at c. So, as you know that this polarization is basically it is it is equal to the surface charge density, but that surface charge density, it is areal density; it is the that surface charge is the on the surface, but polarization direction will be the perpendicular to the that surface. So, here this polarization whatever I have written is the plane surface. So, this polarization direction is perpendicular to this surface. Now in case of this for plane it is fine, so all the time this polarization direction will be perpendicular of this of this plane.

But in case of curve surface it is not the case, right. So, perpendicular so polarization direction will be different direction, right. That is perpendicular to this to this surface. So, it is if it is this direction. So, here it will be this direction, here this direction, here it will be this direction right. So, this direction will vary. So, polarization that is equal to the surface charge density here right. So now, since surface charge density is there, so what will be the net total polarization along this field direction, right? Along this field direction, along this E field direction. So, E 2 we would like to find out he along this field direction.

Now here so what we can write that this if I just take the surface, if I take the surface here. So, with here so this angle here ds surface, I have taken small surface area I have taken. So, this is ds surface area ds. Now small area we have chosen. So, the theta now this surface area that is basically between theta and theta plus d theta that is d theta and this radius of this sphere is say r. So now, here this; what will be the polarization for this surface charge? This surface charge what will be the polarization? This surface charge that will be the polarization, no, this into surface charge density into this area. So, that will be the charge total charge on this and that will be the equal to the polarization direction will be the perpendicular to this.

So, this the polarization, right. Now I what I want to do? I want to get the polarization along this direction because polarization related with the electric field. So now, I have to find the polarization along this direction. So, polarization so the if this is theta, so this will be also theta, this will be also theta right. So, P polarization P this is parallel to the that component parallel to this electric field that will be the P cos theta, and another component perpendicular to this electric field. So, that perpendicular component P perpendicular, P the perpendicular P it will be P sin theta right, P sin theta. So, for, so is basically this equal to sigma, now for this area so polarization I will get. So now, polarization I will get for this area, that I will get P cos theta into ds. This is the parallel direction, it is a parallel component P parallel direction, and P perpendicular direction P per, it is not equal you know it is not equal.

So now this so if you consider this if I define this for a now total polarization for this charge; surface charge; surface charge ds for ds surface charge, so that will be the parallel component of polarization. And perpendicular component of polarization will be P sin theta ds. Now if I take this you see if I take a so this is sphere right. So, this the radius r. So, with radius r on the sphere that if I vary this angle right, I will get the stripe on this sphere, stripe on the sphere, right. If now if ds is the area of the stripe, so what will be the ds; ds will be so basically so this the circle for theta angle this is the circle on this sphere, and what will be the circumstances? What will be the that is 2 pi this radius. So, that is that is r sine theta this r sin theta right. So, radius of this circle, now this width of this stripe from this on the surface that will be basically r b theta that one right. So now, your area will be this r d theta, right.

So, this will be the area of this stripe right, between theta and theta plus d theta that is the area of this stripe. So, for this stripe you will get. So, if you replace ds here. So, you will get this 2 component one is for P parallel you will get P cos theta P cos theta right, ds is 2 pi r into 2 pi r 2 pi r square sin theta d theta sin theta d theta right. Now you see that is the P it is the parallel to the electric field. Now polarization if I want to find out the polarization for the whole surface of the sphere.

So, what I have to do? So, I have to that P is will give you the electric P you will give you. So, here whatever I am getting. So, parallel to this to this field. So, this it is it will give the charge density basically, it will give the charge density no. So, I can write charge density right, now here whatever you are getting? Charge density for the for the stripe. So, corresponding electric field you will get, what is the electric field? Electric field from charge you will get from coulomb law you can get 4 pi epsilon 0 into q by r square right. So, this is the direction of polarization, now we have taken 2 component one is parallel to the electric field another perpendic to the electric field.

So, polarization is equal to the surface charge density, now on if surface area is ds. So, what will be the total charge on the surface? See this is q if this is q or q dash whatever q or q dash now this (Refer Time: 13:26) extended on a strip on a stripe, right, and what is the area of this stripe? This is the area of the stripe see if they put here. So, what this stripe this is the charge density charge total charge on the stripe, if because of this charge what will be the electric field here? So, I can write that is de say in case of one in case of that is parallel one, and another I will get d E perpendicular one right. So now, if I integrate them, so then I will get electric field, one is parallel another is perpendicular.

So, I have to so here this is this is my charge, but parallel to the this is my charge parallel to the electric field, and now this electric field parallel to this and so corresponding E I can write, I think I will, so corresponding E I can write. So, in case of parallel in case of parallel. So, ps in case of parallel. So, that will be one more thing I have to tell you here this is P no that is fine. So, that ds is there. So, this I will write 2 pi 2 pi r square r square P cos theta. So, I missing on cos theta. So, that cos theta comes basically in this is one, another electric field density. So, field intensity along hours that electric intensity at are due to q that is fine, and the electric field intensity along r along r therefore, the 2 component. One is the polarization component P n perpendicular to this that is P cos theta, and now it is component is this is P perpendicular, P perpendicular polarization depends at the surface charge per unit area charge on this dq thus equal to P n ds P cos theta that is also fine. Now electric field is this now field intensity is along r, oh field intensity along r and therefore, component en perpendicular component of E r. So, yes now it is along r is this.

So, this and (Refer Time: 17:53) here this is one this is the ds area. So, my P actually is the my P here actually it is it will be along this direction, it will be along this direction. So, this P.So, normal to the surface that will be this P. And so, what I did mistake here, this is the polarization direction right. So, this is not the polarization this is termed the polarization direction P perpendicular to this surface, what I did mistake so this is the original polarization this is the original polarization. Now that whatever here I have written P cos theta, that is basically perpendicular to this P cos theta that is basically perpendicular to this surface. So, here what I am writing? So, this P is basically normal to the surface I can write P n. So now, my P n is along this direction normal to the surface. So, then charge total charge are there then this this P normal P n is basically this equal to the surface charge density, P n surface charge density now if surface area ds.

So, then this total charge on the surface will be say dq or q whatever dq will be this. So, that that P that is that is the part charge density we are getting on this. Now, but these P is along this this direction, now here ds as I find out that is fine on this stripe area of this stripe is this is fine. This is fine now electric field electric field here. So, here these are this the component along this you know perpendicular component this perpendicular to these. So, electric field will be also corresponding electric field here whatever I wrote this formula right. So, this electric field electric field will be in this direction in this direction right. That is P n direction, now electric field here this one using P n direction.

So now, there to a we are taking 2 component one is parallel to this electric field parallel to this external electric field or this field, and another is perpendicular component of this. So, this will be. So, that whatever this we got the charge or corresponding electric field in this direction. So, it is parallel component will be this that cos theta.

So, whatever here we are getting this charge we are putting here, and then corresponding electric field in this direction along the radius along the distance r right, this along the radius. Now it is component along this will be another we have to take cos theta; cos theta and this perpendicular part will take this one into sin theta. So, that is what the problem. So, electric component now if I integrate. So, I will get this parallel component and perpendicular component. So, this parallel component of electric field that is that will be equal to so of 1 by 4 pi epsilon 0, and then q is this q is P cos theta P cos theta, here I can write 2 pi r square here I can write 2 pi r square 2 pi r square P cos theta sin theta d theta.

Now this cos theta term will come here. So, it will be cos square theta right, it will be cos square theta. And then one r square is there pi r square is there. And perpendicular component so this we have to integrate over theta 0 to pi. And the perpendicular component perpendicular component this component that will be equal to I think everything will be there only it will be sin terms will be there. So, here it will be sin square theta cos theta d theta.

So, this I can write this I can write d sin theta, now here you can show there will be 0 0 to pi 0 to pi that will be 0. And here you can show that here you can show that if you take d cos theta. So, then it will be yeah. So, that is x square dx kind of things x square dx kind of things, and if you integrate over it 0 to pi cos theta it will give. So, here 1 minus will come and then from this limit minus 2 will come. So, here this factor this integration factor integration factor 0 to 0 to pi cos square theta sin theta d theta it will give you 2 by 3 it will give you 2 by 3 just check it. So, then. So, this part will be 0 this part will be 0 basically only this part will be there. So, that we can write E 2 that we can write E t 2 yeah, I think E 0 have taken E 2 that will be E 2 E 2. So, finally, what I am getting E 2? So, here r square r square will go pi go 2 pi.

So, by 2 will be there by 2 epsilon 0 by 2 epsilon 0 and that 2 by 3 that 2 also go. So, I will have this by 3 epsilon 0. So, from here I will get P by 3 epsilon 0. So, E 2 I will get P by 3 epsilon 0. So, that is the total field because perpendicular component has done. So, this E 2 whatever it is parallel to the electric field. So, here this is our applied field macroscopic field E plus E 2 that is P plus 3 epsilon 0. So, that is the local electric field for automate sector. So, yeah just you should try to calculate yourself. So, just initially I confused with this. So, here basically polarization direction is this so, but by mistake I took in this direction then component this is a.

So, that is not the case this is the initial polarization is direction is this. So, perpendicular component of this polarization P n is this and that is equal to the surface density perpendicular component surface density. Now this so this total charge on this ds surface dq, that will be that will be this P nth which is equal to surface density into this area of this surface. So now, this area if you extend it that is on a stripe. So, that we have find out this stripe area. So, for corresponding charge on this stripe is this. Now from coulomb law one can write get electric field, but that electric field will be in this direction right in this direction. Because charge density or this yes, and this polarization that component P n is in this direction. Now we have taken electric component of electric field parallel to this electric field and perpendicular to this electric field.

So, perpendicular part it is become 0 only this part is there. So, that is the Lorentz field E 2 and you have calculated this one. So, local field whatever we have seen. So, local field whatever we are seen that is basically this that is a local field. Now you know this already E is a E is a macroscopic electric field, that is there as a whole this material will see and locally more additional contribution will be there. So, that is a Lorentz field. So, total field at the site at the center or at a atom will see this one. So, this we can we can correlate with the with other parameter this permittivity of this of this dielectric material.

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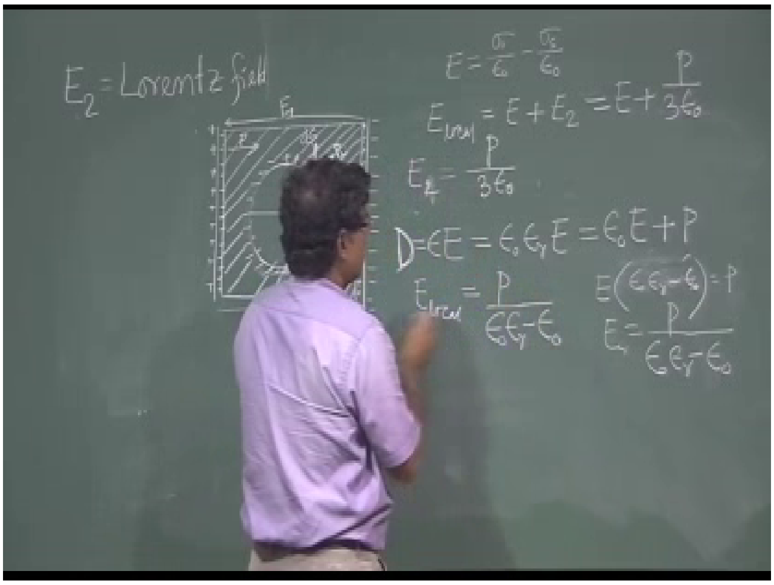

What is the relation with this permittivity of the dielectric vector medium. So, the this d is basically epsilon E right. So, it is macroscopic so this general definition. So, this equal to this equal to basically epsilon z epsilon r into this macroscopic electric field this E right yes. So now, local E local will be, that is oh that that I want to convert to the polarization.

So, this E equal to this d is equal to what we write that is epsilon 0, this d also we can write epsilon 0 E plus this polarization right, plus this polarization. So, from here E is basically E is basically you can find out E will be epsilon 0 epsilon r no. So, what I want to find out? I want to replace this E. So, E equal to I will get epsilon 0 epsilon r minus epsilon 0, right, equal to P. So, this E equal to P by epsilon 0 epsilon r minus epsilon 0. So now, E local I can write E local I can write. So, this epsilon this E I can replace with this P by epsilon 0 epsilon r minus epsilon 0 plus E 2 is this plus E 2 is this P by 3 epsilon 0, right.

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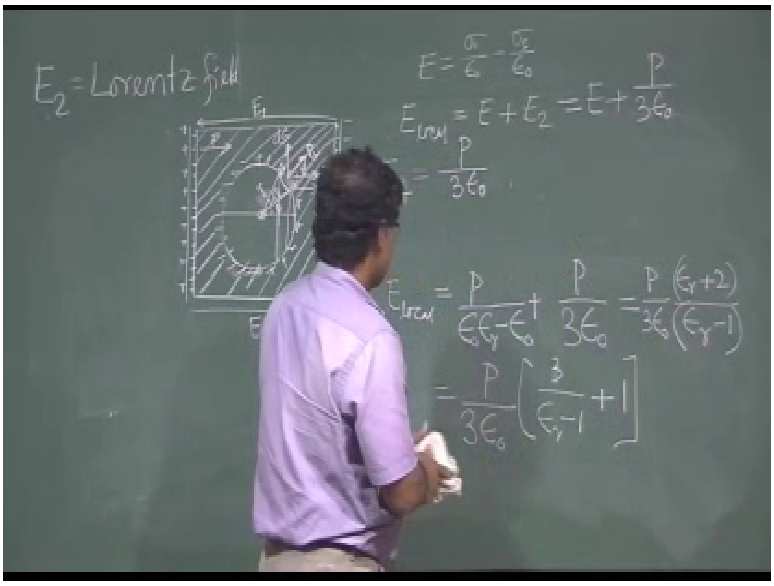

So, here I can take P 3 epsilon 0 common, then what I will get? 1 by epsilon r minus 1 plus 1 right plus 1.

So, this will give me epsilon sorry, yeah. So, P I have taken 3 epsi 3 I have taken here 3 epsilon 0 I have taken. So, that is why that will be 1, but here if epsilon 0. So, I have to put 3 here right, I have to put 3 here that is true. So, this will give me what it will give? 3 plus epsilon r minus 1. So, epsilon r plus 2. So, this will give me E local I will get basically epsilon r plus 2 divide by epsilon r minus 1 right, and P 3 epsilon 0 P 3 epsilon 0. So, that will be the P local. So, this of this E local basically acts on the on the on the acts on the atom or molecules of the materials, now that is the electric field acting on the atoms or molecules? So, electric field acting on the atoms or molecules. So, what will happen? So, that we define as a. So, it will polarize that to me basically that that electric field whatever we call local electric field that will polarize the atom.

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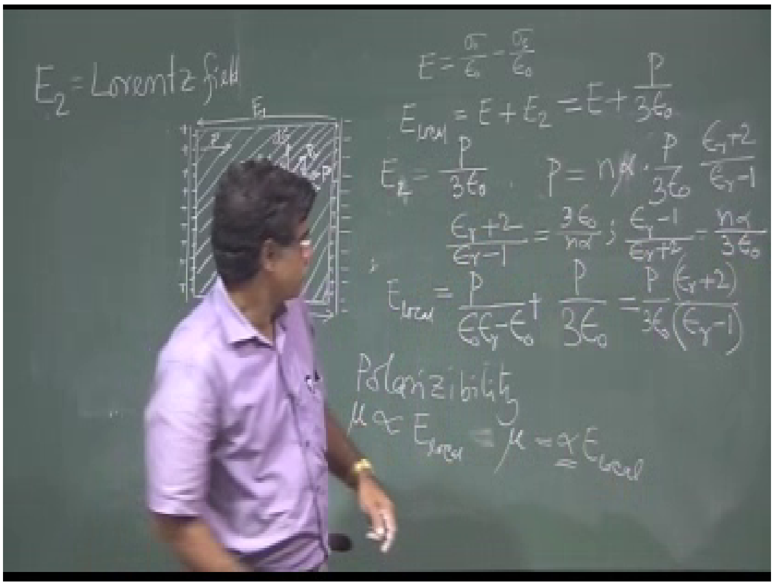

So, this is called polarizability.

So, electric field whatever local field acting on the atom or molecule see it will polarize the electron. So, it will form, then atoms will have the dipole moment. So, that that dipole moment whatever formed due to this local electric field so that dipole moment strength of the dipole moment it will be proportional to this field ok. So, this constant mu equal to; so this we can write mu equal to some constant alpha E local. So, this alpha is called atomic polarizability or molecular polarizability. And that is defined as the dipole moment per unit electric field. So, polarizability is defined as the moment for unit electric field per unit electric field. So, and this polarizability means this local field polarize this electron.

So, from induced dipole moment mean, how much strength of this polarized dipole moment is that is defined in terms of polarizability. So, this moment per unit electric field. So now, this polarization then now from atomic point of view polarization we define polarization P we defined as the number of number of dipole moments per unit volume. So, if n number of molecules or atoms are there then the density, then I can write P equal to n mu then I can write P equal to n mu and mu equal to alpha E local. So, I can write in alpha E local and then that E local is basically this value E local is basically this value P by 3 epsilon 0, right. And E local so this the what we have found from here? Already this I do not need to write basically already I have I have expressed this one in this term this. So, I will write P by 3 epsilon 0, and then epsilon r plus 2 epsilon r minus 1 right.

So, then P will go. So, what I will get? Epsilon r plus 2 divide by epsilon r minus 1 equal to I think something. So, n alpha by 3 epsilon 0. So, it will be 3 epsilon 0 sorry, 3 epsilon 0 divide by n alpha. So, generally this we write in this form that this also you can write epsilon r minus 1 divide by epsilon r plus 2 equal to n alpha divide by 3 epsilon 0.

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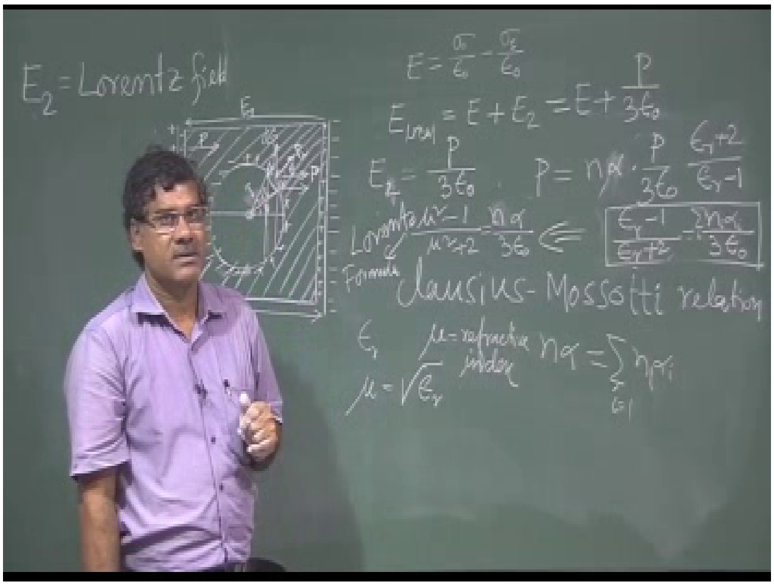

So, this is the relation between the dielectric constant epsilon the relative it is relative permittivity, or also it is called dielectric constant. So, this dielectric constant is related with the with the atomic dipole moment or polarizability. So, with origin of this is the basically atom or molecules. So, this is the relation famous relation, and this relation is called this relation is called ultimately this relation is called Clausius Mossotti double, so Mossotti relation. So, these are very useful relation for the dielectric material. So, this we can write in different form.

Now, this n alpha if is not one type of materials atoms or molecules. So, this n alpha n alpha we write generally summation over n i alpha i. So, I is equal to is will vary. So, if different kinds of atoms or molecules are there. So, their polarizability will be different and this number density will be different. So, this one can replace here for in general. So, one can replace here by like this. So, from this relation one can extend in extend in different form extend it different form to find out the some suitable parameters for the dielectric material. So, one relation you know this dielectric constant and the refractive index. So, this is refractive index now mu again refractive index, see it is different from that do not be confused confuse this the refractive index it is a refractive index. It is not dipole moment here it is dipole moment say in generally people write n also.

So, then this relation between these 2 is mu equal to square root of epsilon r square root of epsilon r, as long as this relation is valid as long as this epsilon r is independent of frequency. So, in this case one can write this one can write from the here one can write mu square minus 1 divide by mu square plus 2 equal to sum over n i forget sum one sum over just n alpha, whenever necessary one can put epsilon. So, this is another form of this relation. And this relation is called the Lorentz formula, it is a Lorentz formula, this the Lorentz formula. And this the Clausius Mossotte relation from here itself one can find out this. So, this from where this what is the origin of this polarizability what is the origin of this polarizability, right. Means, due to electric field local electric field these atoms are polarized and gives the dipole moment. So, what is the origin of this polarizability that that we will discuss in next class. So, I will stop here.

Thank you.