POLARIZATION MECHANISMS

1

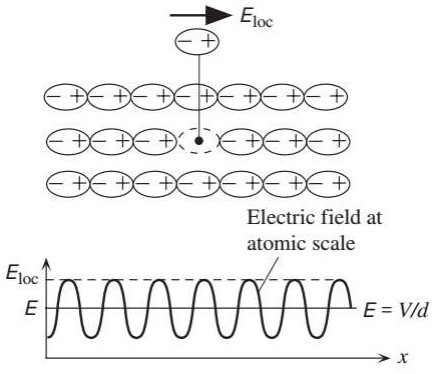
Local Field

- As soon as the dielectric becomes polarized, the field at some arbitrary point depends not only on the charges on the plates (Q) but also on the orientations of all the other dipoles around this point in the dielectric → E changes.

- Lorentz field:

$$E_{\text{loc}} = E + \frac{1}{3\varepsilon_0} P$$

$$p_{\text{induced}} = \alpha_e E_{\text{loc}}$$

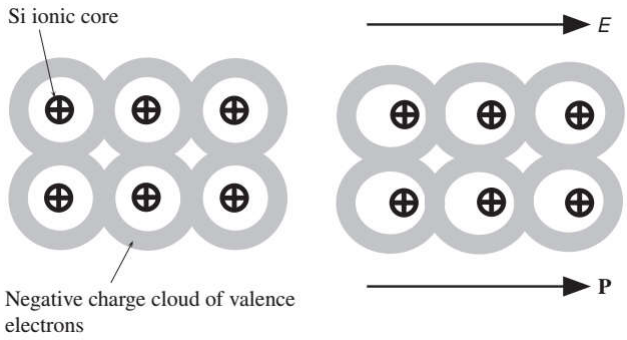


2

2

Electronic Polarization

- Electron clouds within each atom become shifted by the field → quite small.
- Valence electrons in covalent bonds can easily tunnel from bond to bond → significant shift under an electric field.
- Large dielectric constants in covalent crystals → $\varepsilon_r = 11.9$ for Si and $\varepsilon_r = 16$ for Ge.



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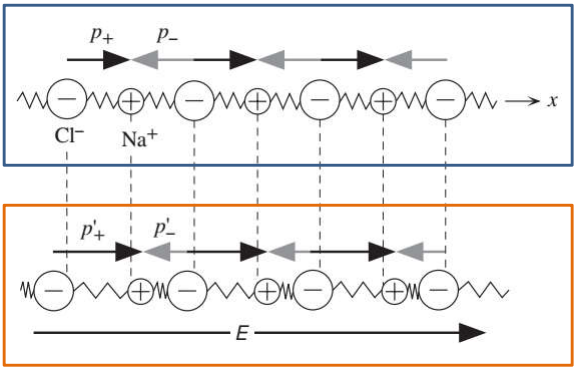
Ionic Polarization

- This type of polarization occurs in ionic crystals such as NaCl, KCl, and LiBr.



$E = 0$

$$p_{\text{net}} = p_+ - p_- = 0$$

$E \neq 0$

$$p_{\text{net}} = p_+ - p_- \neq 0$$

$$p_{\text{av}} = \alpha_i E_{\text{loc}}$$

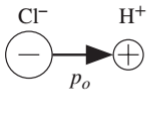
$$P = N_i p_{\text{av}} = N_i \alpha_i E_{\text{loc}}$$

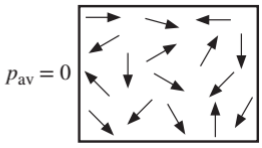
4

4

Orientational Polarization

- Certain molecules possess permanent dipole moments → HCl molecule has a permanent dipole moment p_o from the Cl^- ion to the H^+ ion.
- When $E = 0$, dipole moments are randomly oriented as a result of thermal agitation.





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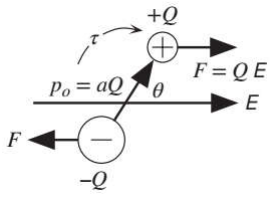
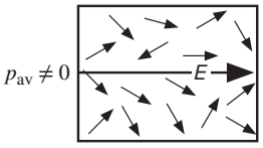
Oriental Polarization

- When $E \neq 0$: Cl^- and H^+ experience forces in opposite direction.
- The molecule experiences a torque τ about its center of mass.
- For full alignment → $P = Np_0$
- The collisions due to thermal energy destroy dipole alignments.
- Net average dipole moment depends on temperature:

$$p_{av} = \frac{1}{3}\frac{p_0^2 E}{kT}$$

$$\alpha_d = \frac{1}{3}\frac{p_0^2}{kT}$$





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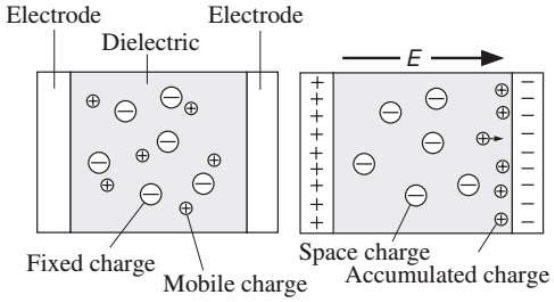
Interfacial Polarization

- **Interfacial polarization** occurs whenever there is an accumulation of charge at an interface between two materials or between two regions within a material.



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7

Interfacial Polarization

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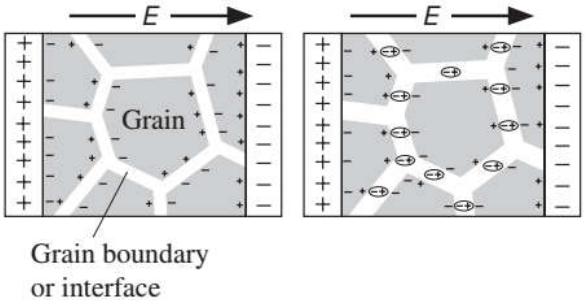

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Total Polarization

- In the presence of electronic, ionic, and dipolar polarization mechanisms, the average induced dipole moment per molecule will be the sum of all the contributions in terms of the local field

$$p_{\text{av}} = \alpha_e E_{\text{loc}} + \alpha_i E_{\text{loc}} + \alpha_d E_{\text{loc}}$$

- Interfacial polarization cannot be simply added to the above equation as $\alpha_{if} E_{\text{loc}}$ because it occurs at interfaces and cannot be put into an average polarization per molecule in the bulk.

9

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Class Test – 3

Day: 31 July 2019

Syllabus: Lectures 19–21

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