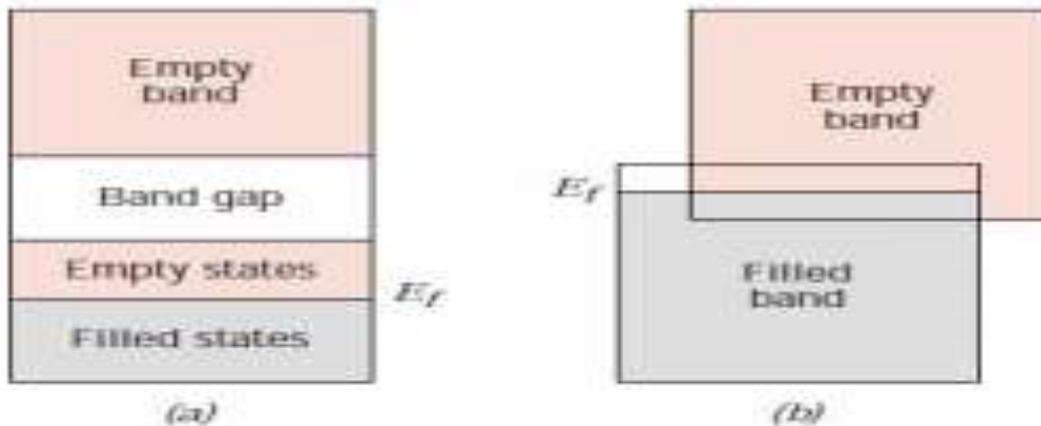


# INTRODUCTION

- ▶ Optical materials are substances used to manipulate the flow of light
- ▶ Optical properties of a material is defined as its interaction with electromagnetic radiation in the visible region.
- ▶ Visible light is one form of electromagnetic radiation with wavelengths ranging from 0.39 to 0.77 $\mu\text{m}$

# OPTICAL PROPERTIES OF METALS

## The electron energy band schemes for metals



- solids at 0 K.
- (a) The electron band structure found in metals such as copper, in which there are available electron states above and adjacent to filled states, in the same band.
- (b) The electron band structure of metals such as magnesium (Mg), wherein there is an overlap of filled and empty outer bands.



# Absorption phenomenon

If a light beam of certain wavelength is focused on a metal, the radiation is attenuated due to energy loss from lattice vibrations (heat) and excitation of electrons from the valence band to conduction band.

In metals, there is an overlap between valence band and conduction band or a partially-filled valence band, which leads to conduction of electrons to energy levels above the Fermi level. This phenomena is shown in Figure 1.

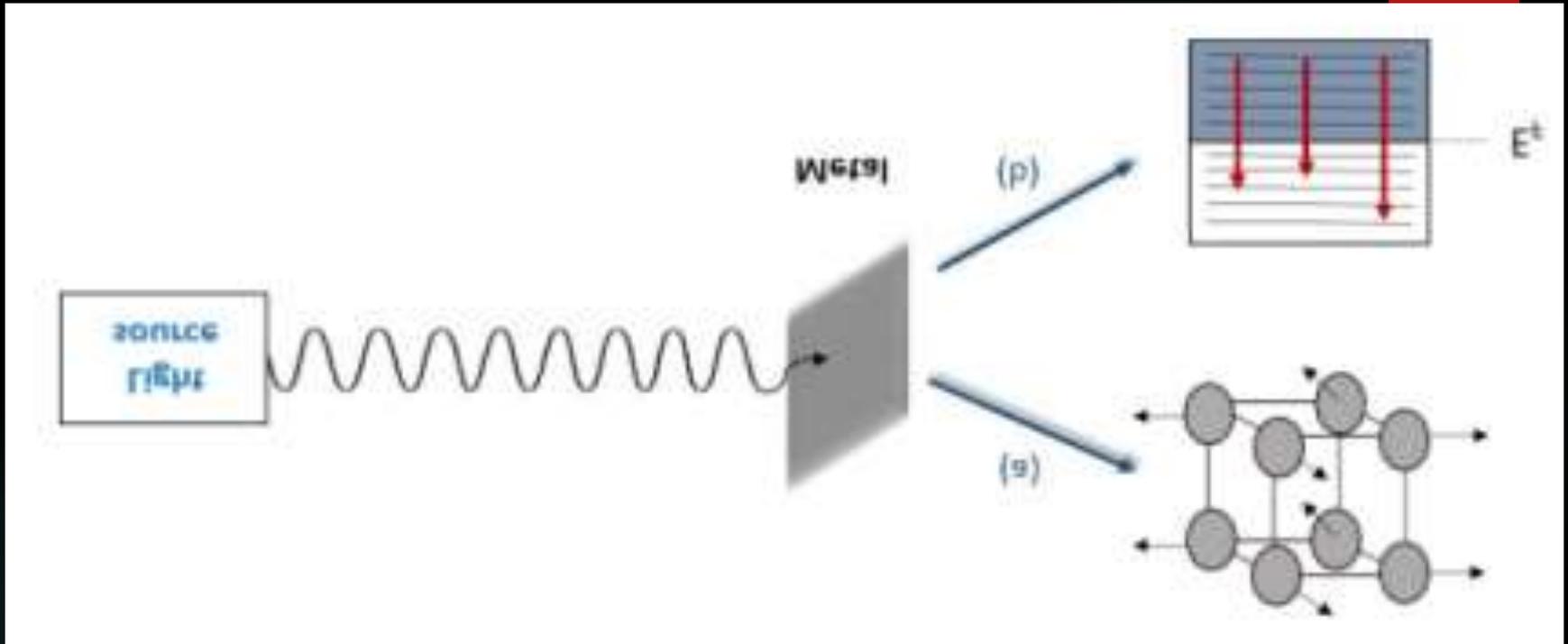


Figure 1. Scheme of the absorption of light by a metal, occurring lattice vibrations (a) and electron promotion to higher energy levels (b).

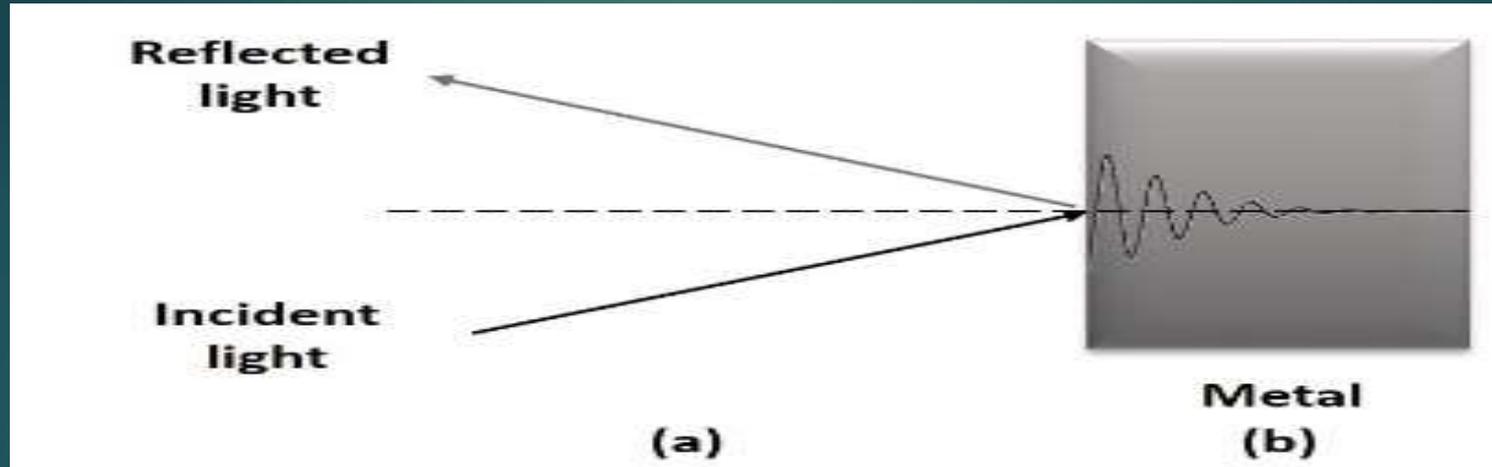
- 
- When electromagnetic radiation encounters the metallic surface, the intensity of the incident light ( $I_0$ ) decreases exponentially while it travels through the metal, leading to a transmitted light ( $I$ ) of lower intensity.

$$I = I_0 \exp\left(\frac{-4\pi kz}{\lambda}\right)$$

# Metallic Reflection

- Metals have high reflectivity, reflecting almost all wavelengths in the visible region of the spectrum. This is related to their high damping constant, which leads to a short distance crossed by the light.
- In addition, some metals have low refractive index and, according to Snell's Law, when light passes through a medium of higher refractive index to a medium of low refractive index, the refracted ray will have a large deflection in relation to the normal. This features explain the behavior of some metals such as silver, gold and copper towards incidence of electromagnetic radiation. F

A schematic representation of this process is shown in Figure 3.

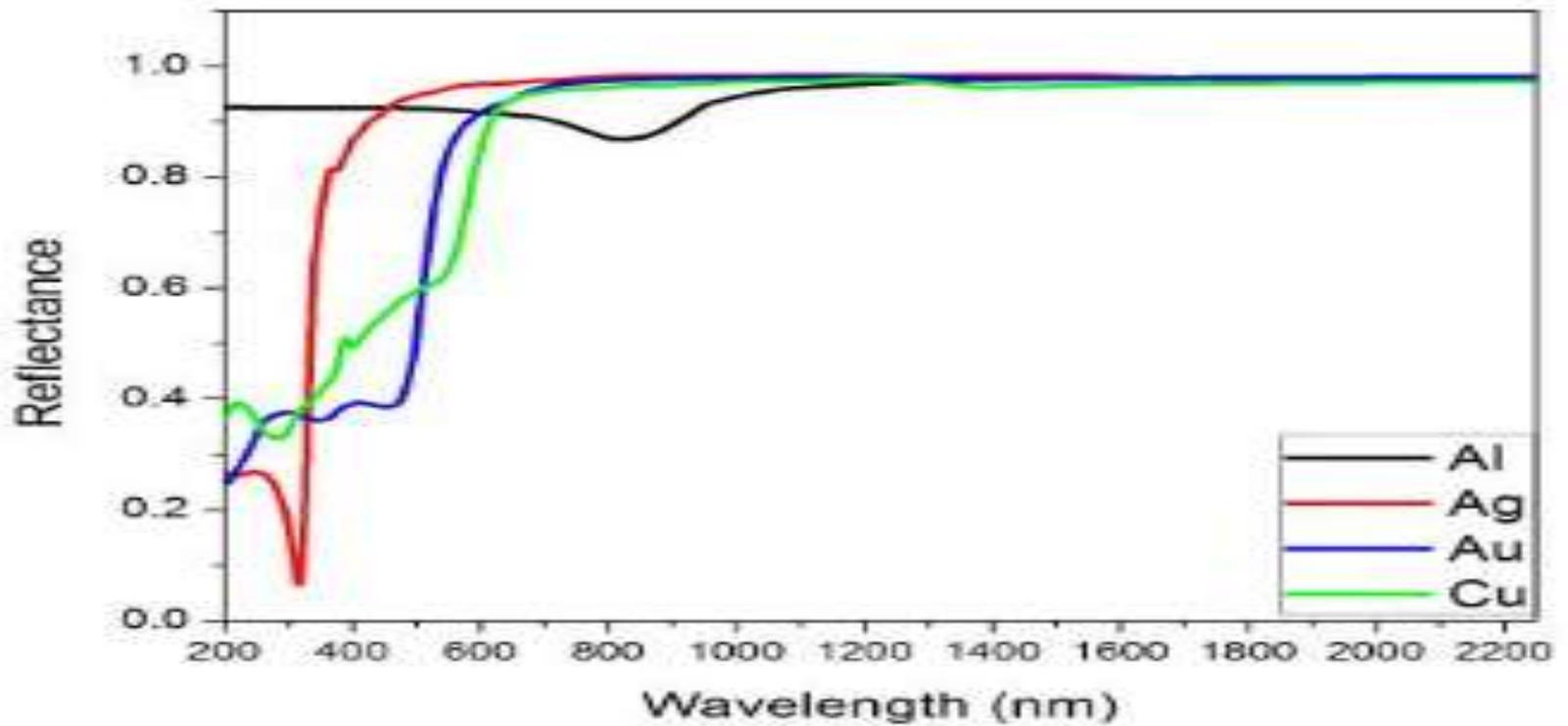


*Figure 3. Reflectance phenomena where the incidence of light in metal leads to metallic reflection (a) and light attenuation or absorption (b).*



➤ Therefore, the Reflectance (R) of a material can be defined as the efficiency of a material to reflect incident light. This value depends only on the complex refractive index (n) and the damping constant (k), which is shown in Equation 44.

$$R = \frac{(n - 1)^2 + k^2}{(n + 1)^2 + k^2}$$



*Figure 4. Reflectance spectra of the metals: aluminum(black line), silver(red line), gold(blue line) and copper.*

- The study of metallic reflectance can be applied on metallic coatings, which is expected that the metal reflect light in a wide range of wavelengths.
- it can explain the colors displayed by the metals. Silver, for instance, has high reflectivity over the visible range of the spectrum, which makes it colorless when white light is focused on the metal.
- Gold, however, absorbs the blue and violet regions of the spectrum, leading to a yellow color when illuminated with white light.

# OPTICAL PROPERTIES OF NON METALIC MATERIALS

- ▶ Refraction
- ▶ Reflection
- ▶ Absorption

# Refraction:

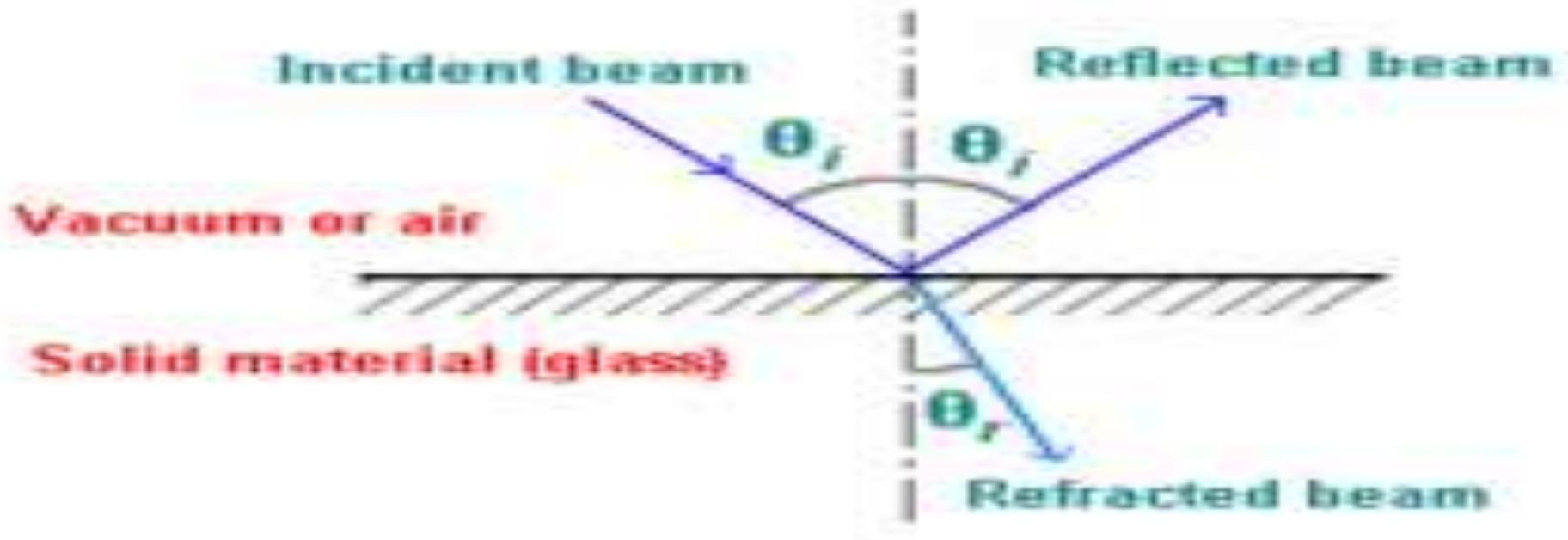
- When light photons are transmitted through a material, they cause polarization of the electrons and by interacting with the polarized materials, photons lose some of their energy. As a result of this, the beam of light changes direction. The relative velocity of light passing through a medium is expressed by the optical property called the index of refraction ( $n$ ), and is defined as:

$$n = \frac{c_0}{c}$$

- where  $c_0$  – speed of light in vacuum,  $c$  – speed of light in the concerned material. If the angle of incidence from a normal to the surface is  $\theta_i$ , and the angle of refraction is  $\theta_r$ , the refractive index, is given by

$$n = \frac{\sin \theta_i}{\sin \theta_r}$$

provided that the incident light is coming from a phase of low refractive index such as vacuum or air. Reflection and refraction of light is shown in *figure 17.2*.



**Figure-2:** *Reflection and refraction of light.*

The speed of light in a material can be related to its electrical and magnetic properties as:

- 
- where  $\epsilon$  – electrical permittivity, and  $\mu$  – magnetic permeability. Thus,

$$c = \frac{1}{\sqrt{\mu \cdot \epsilon}}$$

$$n = \frac{c_0}{c} = \frac{\sqrt{\mu \cdot \epsilon}}{\sqrt{\mu_0 \cdot \epsilon_0}} = \sqrt{\mu_r \cdot \epsilon_r}$$

- Since most substances are only slightly magnetic i.e.  $\mu_r \approx 1$ , then

$$n \cong \sqrt{\epsilon_r}$$

- *Snell's law of light refraction* – refractive indices for light passing through from one medium with refractive index  $n$  through another of refractive index  $n'$  is related to the incident angle,  $\theta$ , and refractive angle,  $\theta'$ , by the following relation



- If light passes from a medium with a high refractive index to one with a low refractive index, there is a critical angle of incidence,  $\theta_c$ , which if increased will result in total internal reflection of the light. This angle is defined as  $\theta'$  (refraction) =  $90^\circ$ .

$$\frac{n}{n'} = \frac{\sin \theta'}{\sin \theta}$$

# Reflection

- When a beam of photons strikes a material, some of the light is scattered at the interface between the two media even if both are transparent. Reflectivity,  $R$ , is a measure of fraction of incident light which is reflected at the interface, and is given by

$$R = \frac{I_R}{I_0}$$

- Where  $I_0$  and  $I_R$  are the incident and reflected beam intensities respectively. If the material is in a vacuum or in air:

$$R = \left( \frac{n-1}{n+1} \right)^2$$



- If the material is in some other medium with an index of refraction of  $n_i$ , then:

$$R = \left( \frac{n - n_i}{n + n_i} \right)^2$$

- 
- The above equations apply to the reflection from a single surface and assume normal incidence. The value of  $R$  depends upon the incidence.
  - Materials with a high index of refraction have a higher reflectivity than materials with a low index. Because the index of refraction varies with the wavelength of the photons, so does the reflectivity.

# *Absorption:*

- When a light beam is impinged on a material surface, portion of the incident beam that is not reflected by the material is either absorbed or transmitted through the material. The fraction of beam that is absorbed is related to the thickness of the materials and the manner in which the photons interact with the material's structure. Thus, according to *Bouguer's law*:

$$I = I_0 \exp(-\alpha \cdot x)$$



➤ *Photoelectric effect* occurs when photon energy is consumed to release an electron from atom nucleus. This effect arises from the fact that the potential energy barrier for electrons is finite at the surface of the metal. Absorption occurs at particular levels of photon energies, which are equal to that of binding energies. The energy at which this occurs is called the absorption edge.



**THANKS FOR  
YOUR ATENTTION**

**IF YOU HAVE ANY  
QUESTION..ASK THE TEACHER**