R

Reflectivity

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Synonyms

Reflectance; Reflection coefficient

Definition

Fraction of incoming light that is reflected at an interface.

Theory and Application

The most general definition of a reflection quantity is the bidirectional spectral reflectivity. The relevant angles are defined in Fig. 1, where the surface is in the x-y plane (see Fig. 1, Haitjema 1989):

This is expressed in Eq. (1):

$$R(\theta_r, \phi_r, \theta_i, \phi_i, \lambda) = \frac{I_r(\theta_r, \phi_r, \lambda)}{I_i(\theta_i, \phi_i, \lambda)}, \quad (1)$$

where the radiant intensity I_i of the incoming radiation is defined for an infinitesimal

wavelength interval $d\lambda$, a surface area dA , and a pencil of solid angle $d\Omega_r$. The *specular spectral reflectivity* is defined as the part of the incoming radiation that is reflected specularly in Eq. 2:

$$R_s(\theta_i, \phi_i, \lambda) = \frac{I_r(\theta_i, \phi_i - \pi, \lambda)}{I_i(\theta_i, \phi_i, \lambda)} \quad (2)$$

This is reduced to the *normal specular spectral reflectance* when the incident radiation is normal to the surface ($\theta_i = 0$ in (2)). The part of the incoming radiation which is reflected from the surface, indifferent in which direction, is called the *directional hemispherical spectral reflectance* and is obtained by integrating the bidirectional spectral reflectance over a hemisphere, see Eq. 3:

$$R_h(\theta_i, \phi_i, \lambda) = \frac{1}{2\pi} \int_0^{2\pi} \int_0^\pi R(\theta_i, \phi_i, \theta_r, \phi_r, \lambda) \sin(\theta_r) \cos(\theta_r) d\theta_r d\phi_r \quad (3)$$

When taking the total intensity of a light source where the intensity over a wavelength interval $d\lambda$ is given by $I(\lambda)d\lambda$, the total directional hemispherical reflectivity is given by Eq. 4 (Siegel and Howell 1972):

$$R_{i,h}(\theta_i, \phi_i) = \frac{\frac{1}{2\pi} \int_{\lambda} \int_0^{2\pi} \int_0^{\pi} I(\lambda) \cdot R(\theta_i, \phi_i, \theta_r, \phi_r, \lambda) \sin(\theta_r) \cos(\theta_r) d\theta_r d\phi_r d\lambda}{\int_{\lambda} I(\lambda) d\lambda} \quad (4)$$

This is what is normally considered as “reflectivity.”

Reflectivity at a Plane Interface

If an interface is mathematically flat, the reflectivity at that interface can well be described using Fresnel coefficients. The “mathematically” flat implies that the flatness deviations are negligible compared to the wavelength of the reflected radiation involved and that the area considered is much larger than the beam size of the radiation. If these conditions are met, the interface will be specularly reflecting (see Eq. 2).

If the complex refractive index of this flat surface is given by $\mathbf{n} = n - ik$, and the light propagates in air ($n_{\text{air}} \approx 1$), the normal specular reflectivity is given by Eq. 5 (Heavens 1990):

$$R_{\perp}(\lambda) = \frac{(n(\lambda) - 1)^2 + k^2(\lambda)}{(n(\lambda) + 1)^2 + k^2(\lambda)} \quad (5)$$

If the light enters under an angle, the reflectivity will depend on the polarization state of the radiation. The measurement of this polarization state can be used to derive conclusions about the refractive index of this material and even about thin films present. This is called ellipsometry.

Reflectivity at Stratified Planar Structures

The reflectivity at stratified planar structures becomes more complicated if thin film structures are present. Still methods are available to make a straightforward calculation of the reflectivity. For thin film structures, a matrix method has been developed that still gives an analytical solution for the calculated reflectance (Azzam and Bashara 1977; Jackson 1998).

Reflectivity at a Rough Surface

A rough surface will give a more diffuse reflection. For a general calculation, the Maxwell equations need to be solved for the geometry that is extremely tedious. With some approximation, the reflectance can be calculated for periodic profiles or for rather smooth surfaces where the roughness is much smaller than the wavelengths involved. This is further treated by Ogilvy (1991).

Reflectivity, Fig. 1 Parameters used in the definition of bidirectional reflectance

Cross-References

- [Ellipsometry](#)
- [Roughness](#)
- [Surface Texture](#)

References

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