Transmittance

1. What is transmittance?

Transmittance refers to the ability of light to pass through a medium. It is the percentage of the luminous flux passing through a transparent or translucent body and its incident luminous flux. It is usually used τ Indicates that the value is percentage and the value range is 0-100%. When the pseudo beam parallel monochromatic light passes through a uniform and non-scattering medium, part of the light is absorbed, part passes through the medium, and part is reflected by the surface of the medium.

2. Classification

There are two basic transmission types: external and internal, both of which are different from light transmittance.

The external transmission is calculated based on the intensity of incident light entering the glass and the intensity of light leaving the glass. The internal transmission is determined by the intensity of light entering the glass and leaving the glass. The internal transmission mainly measures the light filtering capacity of the glass itself.

3. Conversion relationship

When the incident light intensity I_0 is constant, the greater the intensity Ia of the medium absorbing light, the smaller the intensity It of the transmitted light. I_t / I_0 is used to represent the ability of light to pass through the medium, which is called transmittance, which is expressed in τ, $\tau = I_t/I_0$.

If the light is completely absorbed by the medium, I_t = 0, τ = 0. If the light is fully transparent, then I_t = 0, τ = 100%. The reciprocal of transmittance reflects the degree of light absorption of the medium. For the convenience of calculation, the logarithm of the reciprocal of light transmittance is taken as the absorbance, which is expressed by A, that is, A = lg (1/ τ) = lg (I_0 / I_t)(Beer Lambert law), the greater the value of A, the greater the absorption of light by the substance.

According to the definition, the internal transmittance is related to the optical depth and absorbance:

$$T=e^{-\tau}=10^{-A}.$$

τ is the optical depth, A is absorbance.

For N attenuation in material samples:

$$T = e^{-\sum_{i=1}^{N}\sigma_i \int_0^l n_i(z)\,ds} = e^{-\sum_{i=1}^{N}\sigma_i \int_0^l n_i(z)\,ds}$$

σ_i is the attenuation cross section of the attenuation substance i in the material sample; n_i is the number density of the decaying substance i in the material sample; ε_i is the molar attenuation coefficient of attenuation substance i in the material sample; c_i is the concentration of attenuation substance i in the material sample; l is the path length of the beam through the material sample.

The relationship between attenuation cross section and molar attenuation coefficient is as follows:

$$\varepsilon_i = \frac{N_A}{\ln 10}\sigma_i$$

Relationship between attenuation cross section and digital density and quantitative concentration:

$$c_i = \frac{n_i}{N_A}$$

N_A is the Avogadro constant.

In the case of uniform attenuation, these relationships become:

$$T=e^{-\sum_{i=1}^{N}\sigma_i n_i l}=10^{-\sum_{i=1}^{N}\varepsilon_i c_i l}$$

Or

$$\tau=\sum_{i=1}^{N}\sigma_i n_i l \qquad A=\sum_{i=1}^{N}\varepsilon_i c_i l$$

4. Influencing factors

The greater the transmittance, the better the transmittance. However, the transmittance of any transparent material cannot reach 100%, and the highest is only about 95%. The main reasons are as follows:

4.1 Light reflection

Due to the different composition and structure of substances, the incident light is reflected from the object surface, resulting in the loss of transmitted light and the decrease of transmittance. The reflection degree is expressed by reflectivity R, and the calcula-

tion formula is:
$R=(n-1)^2 / (n+1)^2 \times 100\%$, n is the refractive index of the test medium material. The greater the reflectivity, the greater the reflection loss and the smaller the transmittance.

4.2 Light absorption

When the incident light enters the interior of the dielectric material, due to the molecular structure and composition, the transmission of light in the channel is blocked, and the light stays in the material and is absorbed, thereby reducing the transmittance.

4.3 Light scattering

When the incident light contacts the rough and uneven product surface, or the material with uneven molecular structure distribution or disordered coexistence with crystal phase, the incident light dissipates in the form of scattering without transmission, reflection and absorption, and the direction of light changes, resulting in the decrease of transmittance. The loss proportion of this part is small, which is more serious in crystalline polymers and better in amorphous materials.

4.4 Material structure

The greater the number of bubbles or grain boundaries in the material, the repeated refraction from crystal to air, and then from air to crystal, resulting in reflection loss. The more bubbles, the greater the reflection loss, the smaller the transmittance and the greater the thickness, the more bubbles and the greater the loss of transmission.

5. Test method

For example, determine the light transmittance of glass with spectrophotometer:

（1）When the spectrophotometer is powered on, preheat for 20 minutes.

（2）Hold the edge of the flat glass sample and put it into the second grid on the side of the monochromator in the colorimetric base. Put the colored glass into the third grid near the monochromator side in the colorimetric base, and fix the elastic clamp with a positioning clamp to make it close to the wall of the colorimetric base.

（3）Select the measuring wavelength by adjusting the spin red.

（4）Open the cover of the colorimetric cassette and adjust the light transmittance "0".

（5）Place the color comparator base at the air blank correction position, and gently close the dark box cover of the color comparator. At this time, the dark box cover will open the light door baffle, the photocell receives light, and adjust the light transmittance to "100%".

（6）If there is no change after continuously adjusting "0" and "100" in steps 4 and 5, the measurement can be carried out.

（7）Push the sample to be tested into the optical path, and the display value is the transmittance under a certain wavelength of light τ, or absorbance, that is, $A = -\lg(\tau)$.

（8）The transmittance of flat glass at the wavelength of 560nm was measured τ.

（9）When the wavelength of monochromatic light is 360 ~ 1000mm, measure the optical density a of color glass samples every 20nm.

5.1 Spectrophotometer test

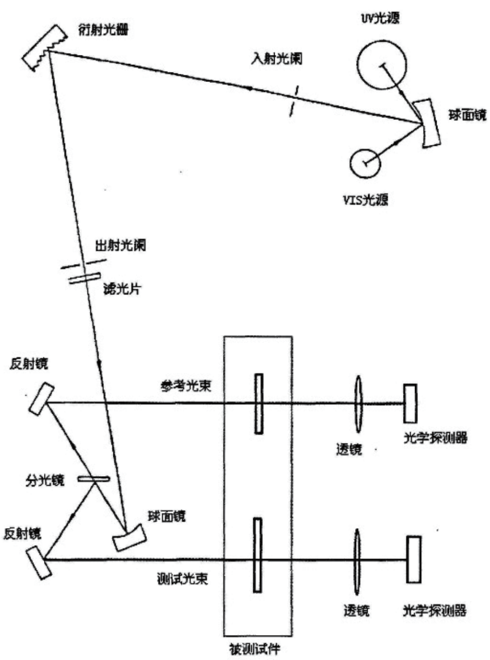

Fig. 1 Schematic diagram of Spectrophotometry

5.2 Single channel method

（1）Photoelectric transmittance tester

After passing through the condenser 2, the point light source 1 enters the small aperture 3, and then to the collimator objective lens 4. The light beam can be adjusted through the aperture 5. The light beam passes through the detector 6 and is received by the selenium photocell 7, and the galvanometer 8 displays the corresponding reading. In aerial measurement, the photocell can receive the luminous flux as close as possible to the diaphragm. Put in the detection object and measure the photocurrent I_0 corresponding to the luminous flux of the incident light of the galvanometer, remove the measured object and obtain the empty measured value I. therefore, the transmittance is: $\tau = I_0/I$.

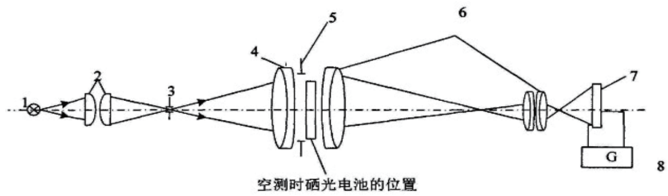

Fig. 2 Test method of damage threshold

（2）Tgy-2 transmittance tester

Tgy-2 transmittance tester detection schematic diagram stable power supply 1 provides power to bulb 2. The light emitted passes through condenser 3 and then is filtered by ground glass or filter 4. Different filters detect the transmittance of different spectral bands and enter small aperture 5. Aperture 6 adjusts the beam. Objective lens 7 adjusts in the axial direction. Variable aperture 8 restricts the test beam. The beam enters the measured object 9 and is received by integrating ball 10, A selenium photocell is installed in the integrating sphere and connected with the galvanometer. This method also needs to be tested in early and dark conditions, as well as air test and actual measurement.

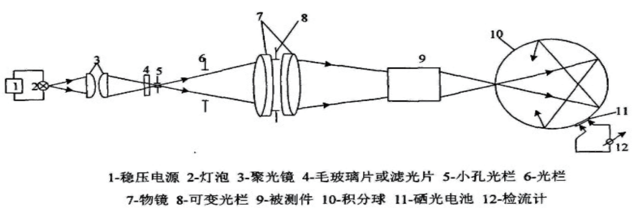

Fig. 3 Testing schematic diagram of tgy-2 transmittance tester

（3）BJ type transmittance detector

The instrument adopts an additional lens. The light emitted by the power supply 1 enters the small aperture 3 through the condenser lens 2 to form a point light source, and then enters the parallel light objective lens 4 to obtain the parallel light. The aperture 5 adjusts the size of the light beam. During air measurement, the additional lens 6 adjusts the size of the light spot on the battery so that the light can fully irradiate the selenium light surface. During the actual measurement, the additional lens also adjusts the light spot to fully irradiate the selenium photocell.

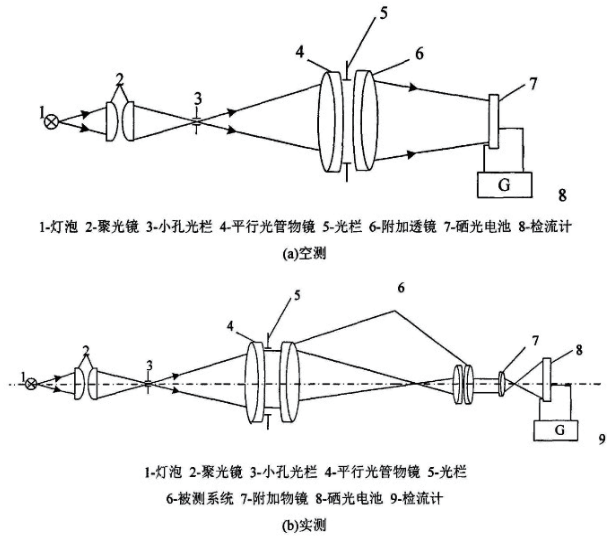

Fig. 4 Measurement schematic diagram of BJ transmittance detector

The above three methods need to be carried out in dark conditions, and noise and manual operation will cause errors. The photoelectric transmittance tester is easy to operate and widely used, but the error is large, and the accuracy is ± 3%; Tgy-2 transmittance tester has high accuracy, but it has high requirements for integrating sphere, which is about ± 0.5%; BJ transmittance tester is troublesome to measure due to the addition of additional lens.

6. Principle of Transmittance Measuring Instrument

The principle of transmittance measuring instrument adopts ultraviolet light source, infrared light source and visible light source to irradiate the measured transparent material. The inductor detects the incident light intensity of the three light sources and the light intensity after passing through the measured transparent material respectively. The ratio of the transmitted light intensity to the incident light intensity is the transmittance, which is expressed as a percentage.

The wavelength range of visible light is 380nm-760nm. In principle, it is necessary to measure the transmittance curve of the whole wavelength range, and then obtain the transmittance of the whole band through integration. However, the spectrometer, a precise and expensive component, must be used to realize the integration. Therefore, in fact, most low-cost Transmittance Measuring instruments do not use the spectrometer, but use the light source with wide spectral line and the receiver with wide wavelength response. This is a feasible, low-cost and scientific approach. EDTM company in the United States and LinShang technology in China have adopted this approach.

Another way to achieve light transmittance is to use the LED with a wavelength near 550nm as the visible light source, and use the receiver to receive the light intensity of this band. This scheme requires that the samples such as the glass to be tested cannot be colored, that is, they can only be black, white and gray, because only the samples of this color have a spectral curve similar to a horizontal line, and the 550nm light source has a certain representativeness.

7. Test standard

GB/T 16864-1997 test method for crystal transmittance at low temperature

GB/T 36403-2018 test method for infrared transmittance of infrared optical glass Fourier transform method

8. Transmittance curve

Draw the light of different wavelengths and its corresponding transmittance into a curve, which is called the transmission spectrum curve of materials. Generally, the abscissa represents the wavelength of light and the ordinate represents the transmittance at that wavelength. Different materials, different wavelengths of light, different transmittance curves.

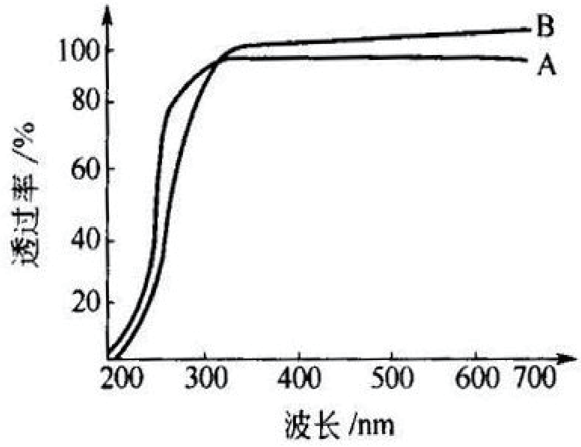

Fig. 5 Transmittance curve

9. Comparison of transmittance, reflectivity and absorptivity

Reflectivity: the ratio of the reflected energy incident on the surface of an object to the total incident energy, which is defined as the reflectivity of the object. This reflectivity is not specific to a specific wavelength. It is called the total reflectivity of the object ρ express:

$$\rho = \frac{I_\rho}{I_0}$$

Absorptivity: the ratio of the part of energy absorbed by the object to the total incident energy, which is defined as the absorptivity of the object. This is also for the whole wave band. It is called the total absorptivity, which is usually referred to as the absorptivity α express:

$$\alpha = \frac{I_\alpha}{I_0}$$

Transmittance: the energy incident on an object. After the reflection and absorption of the object, some energy can still be transmitted through the object. The ratio of this part of transmitted energy to the total incident energy is defined as transmittance. Light transmittance is the ability of a material to be penetrated by light. The quality of light transmittance can be measured by the transmittance index. For transmittance τ express:

$$\tau = \frac{I_\tau}{I_0}$$

Reflectivity, absorptivity and transmissivity are related to the properties of the medium, such as the type, surface state and uniformity of the material, and temperature. If the light projected onto the medium is monochromatic light with a wavelength of, the reflected, absorbed and transmitted light is also monochromatic. This leads to:

Spectral reflectance is:

$$\rho(\lambda) = \frac{I_{\rho\lambda}}{I_{0\lambda}}$$

Spectral absorptivity is:

$$\alpha(\lambda) = \frac{I_{\alpha\lambda}}{I_{0\lambda}}$$

Spectral transmittance is:

$$\tau(\lambda) = \frac{I_{\tau\lambda}}{I_{0\lambda}}$$

10. Transmittance and haze

Haze: the ratio of scattered light flux to transmitted light flux that deviates from the direction of incident light through the sample, expressed as a percentage (for this method, only the scattered light flux that deviates from the direction of incident light by more than 2.5° is used to calculate haze). The greater the haze, the stronger the scattering ability of the material to light, and the more invisible it is to the human eye.

Transmittance: the ratio of the luminous flux passing through the sample to the luminous flux emitted on the sample, expressed in percentage.

The absolute value of transmittance specified by the state is 0-100%, the absolute value of haze is 0-30%, and the haze above 30% is extended by each instrument manufacturer according to the linearity of 0-30%, which is called the relative value.

Reference

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