TEMPERATURE DEPENDENCE OF POLYMER FILM EMISSIVITY

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The effect of heating upon transparency and emissivity of polymer films is studied.

The emissivity of semitransparent bodies is calculated by Kirchhoff's law with consideration of transmission of a portion of the radiation and multiple reflection from the bounding surfaces [1].

In this case, emissivity, or the ratio of energy radiated by the semitransparent body to that radiated by a blackbody at the same wavelength and temperature is equal to

$$\varepsilon_\lambda = \frac{[1-R_\lambda(T)][1-\tau_\lambda(T)]}{1-R_\lambda(T)\tau_\lambda(T)}. \tag{1}$$

Here $R_\lambda(T)$ is the reflection coefficient from a single surface; $\tau_\lambda(T)$ is the true transmission of the material.

When the experimentally determined quantities $R^*_\lambda(T)$ and $\tau^*_\lambda(T)$ are used in calculations, the emissivity can be defined by the expression [1]

$$\varepsilon_\lambda(T) + \tau^*_\lambda(T) + R^*_\lambda(T) = 1. \tag{2}$$

The present study will calculate the emissivity of polyethylene terephthalate and polyethylene films for varying temperature.

It should be noted that [1] proposed a method for calculating the emissivity of semitransparent nonscattering materials, while the polyethylene considered here has definite scattering properties, in contrast to polyethylene terephthalate. Thus, in [2] it was shown that τ_λ measurements of polyethylene in the thickness range under consideration by normal methods with no consideration of scattering led to errors of up to 10-15%. However, approximate evaluations of the emissivity of such films are of obvious interest.

Figure 1 presents transmission spectra of 60-μm polyethylene and 20-μm polyethylene terephthalate films, taken with an IKS-14 spectrograph.

The effect of heating upon transmission of the two films was studied experimentally. Measurements were made with a UR-20 spectrometer located in a temperature-controlled chamber with specimen films. The chamber permitted heating of the specimens to the desired temperature and maintained this temperature over the entire measurement time.

Figure 2 shows transmission spectra of polyethylene at 270 and 135°C and polyethylene terephthalate spectra at 26 and 266°C.

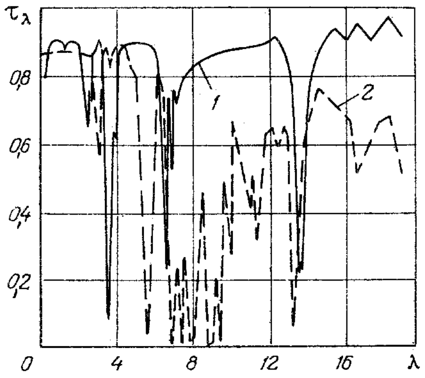

Fig. 1. Transmission spectra of 60-μm polyethylene (curve 1) and 20-μm polyethylene terephthalate (curve 2) films.

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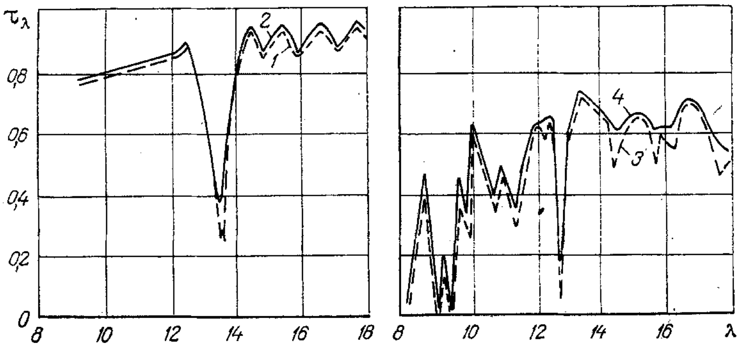

Fig. 2. Transmission spectra for polyethylene film at temperatures of 1) 27 and 2) 135°C; polyethylene terephthalate at 3) 26 and 4) 266°C. λ, μm.

It can be concluded from the spectra obtained that over the temperature range examined the films in question show practically no change in their transmission spectrum. Only at certain resonant frequencies does absorption decrease by ≈10%, with fine structure of certain absorption lines also disappearing with increase in temperature.

Thus, over the temperature range considered, the temperature dependence of transmission may be neglected.

From measurements presented in [2] it is apparent that the reflection coefficient of polyethylene films at room temperature is practically constant over a wide wavelength range.

Using the method described in [3], measurements were made of the reflection coefficients of polyethylene and polyethylene terephthalate films for wavelength $\lambda = 6328$ Å at various temperatures up to the film melting point. The experiments revealed that the reflection coefficient does not change with temperature within the limits of experimental error. In further calculations, the reflection coefficient was assumed constant over the wavelength and temperature ranges considered. Hence the spectral emissivity of the film given by Eq. (2) is temperature independent.

The integral emissivity of the films was calculated with the expression

$$\varepsilon(T) = \frac{\int\limits_{\lambda_1}^{\lambda_2} \varepsilon_\lambda(T)\, U_\lambda(T)\, d\lambda}{\int\limits_{\lambda_1}^{\lambda_2} U_\lambda(T)\, d\lambda}, \tag{3}$$

where $U_\lambda(T)$ is the intensity of monochromatic blackbody radiation, calculated by Planck's law (see, e.g., [1]).

The steps used in calculating $\varepsilon(T)$ were the following. Initially, for a given film temperature λ_{max} was determined with Wien's displacement law [1], this wavelength being the maximum of the spectral density curve of blackbody radiation. Then, using the universal blackbody radiation curve, the wavelength range (λ_1–λ_2) in which not less than 85% of the total radiated power is located was determined. The integral emissivity $\varepsilon(T)$ was then calculated with Eq. (3), with $\varepsilon_\lambda(T)$ values determined by Eq. (2).

TABLE 1. Film Emissivity $\varepsilon(T)$

Material	T, °C			
	20	130	270	350
Polyethylene terephthalate, 20 μm	0,38	0,41	0,39	0,36
Polyethylene, 60 μm	0,11*	0,13*	0,15*	—

*The error in determination of polyethylene film emissivity in the spectral range considered comprises 10-15% due to neglect of scattering in measurement of the material's transmission.

The final results of the integral emissivity calculations for polyethylene and polyethylene terephthalate are presented in Table 1. The following values of reflection coefficient R^* were used in the calculations: polyethylene, 0.08; polyethylene terephthalate, 0.12.

It is evident from Table 1 that with increase in temperature the emissivity of the polyethylene film, calculated with the above assumptions, increases, while $\varepsilon(T)$ of the terephthalate film first increases, then falls. This is because with increase in temperature the maximum of the Planck radiation for the polyethylene film moves into a spectral region where transmission decreases. The polyethylene terephthalate transmission spectrum is more "broken," so that the temperature dependence of its emissivity is more complex in character.

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ELECTRODIFFUSION ANEMOMETRY OF POLYMER SOLUTIONS

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Theoretical and experimental studies are reported for the convective diffusion occurring at the electrode of an electrodiffusion anemometer, particularly with regard to the measurement of average and fluctuation velocities in rheologically complex liquids and weak polymer solutions.

Information on the velocity pattern in laminar or turbulent flow is of decisive importance in research on convective heat and mass transfer. The thermoanemometer method may be applied to rheologically complex liquids, which may have various properties: viscoelasticity, pseudoplasticity, viscoplasticity, mechanodestruction, and thermodestruction, which involves various difficulties. In particular, there is a marked fall in sensitivity in measurements on polymer solutions of WSR-301 type [1, 2] and also the occurrence of anomalous signals unrelated to turbulent velocity fluctuations [3]. Very promising methods such as laser anemometry [4, 5] and other optical methods become largely unsuitable if the fluid is opaque or strongly scattering. It is also of little value to use Pitot tubes with piezoelectric conversion at low speeds, although they can be used to measure velocity fluctuations in turbulent flows of polymer solutions in pipes [6] and enclosed jets [4, 7].

Electrochemical measurement of velocity has some major advantages such as high sensitivity, long working life in the electrodes, comparative simplicity in the equipment, and scope for using the transducer for several purposes [8, 9, 13, 19].

The theory and practice of the electrodiffusion anemometer have been considered [10, 11], particularly when the sensitive surface is a continuous cone or wedge. Such an electrode can be used with a nonlinearly viscous power-law liquid in the following rheological equation of state:

$$\tau = k\left|\frac{\partial u}{\partial y}\right|^{n-1}\frac{\partial u}{\partial y} \tag{1}$$

and the equation for convective diffusion can be solved analytically to give expressions for the static and dynamic characteristics [10, 11].

The solution to

$$u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} = D\frac{\partial^2 c}{\partial y^2} \tag{2}$$

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