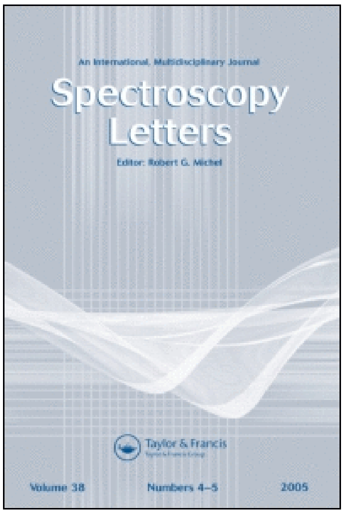

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Experimental Study of the Influence of Thickness and Wavelength on the Ultraviolet Light Scattering of Polyethylene Films

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EXPERIMENTAL STUDY OF THE INFLUENCE OF THICKNESS AND WAVELENGTH ON THE ULTRAVIOLET LIGHT SCATTERING OF POLYETHYLENE FILMS

Key Words: Ultraviolet Scattering, Polyethylene, Polymeric Film.

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ABSTRACT

A study of the influence of thickness and wavelength on the ultraviolet scattering of polyethylene films is reported in this paper. The scatter of samples was measured by considering the difference between absorbances values obtained with the sample placed in two positions at different distance from the detector in a UV/Vis Spectrophotometer.

The present work suggests that a linear relationship exists between absorbance and thickness film for the two sample positions, and also between the difference of these absorbances and wavelength. From the obtained equations it is possible to normalize scattering values for a given wavelength and a given thickness, and in this way experimental errors are minimized. This procedure represents a simple way for characterize optically these materials and, analogously, other transparent or translucent polymeric films.

INTRODUCTION

In this paper we report our results on the study of the influence of thickness and wavelength of the incident radiation on the ultraviolet light scattering by a dozen of different polyethylene films.

In the visible zone of spectrum, more interesting for optical characterization of these materials in industrial practice, as packing or greenhouse cover by example, the behaviour is analogous, although, because of the experimental procedure it should imply higher error in the evaluation of scattering, given that the magnitude of apparent absorbance is lesser for the visible wavelengths.

According to the literature [1,2], light scattering by this kind of films is due principally to the existence of irregularities on the surface, being caused mainly by complex melt flow phenomena in manufacturing processing. In a lesser extent it is due to the coexistence in the interior of the film of zones with different refractive index, as crystallites, and zones without molecular arrangement. Furthermore, the growing of crystallites near the surface has an effect on creation of surface irregularities.

EXPERIMENTAL PROCEDURE

The measurement of ultraviolet radiation scattering was carried out by means of a Pye Unicam SP 1800 UV/Vis Spectrophotometer provided with two sample positions, one of them farther (primary position) than the other one (secondary position) from the detector.

If we designate A_1 to the apparent absorbance obtained with the sample placed in primary position and A_2 to the apparent absorbance with the sample placed at the other position, the intensity of scattered radiation is related to the difference between these values, as we have analysed in a previous work [3] by considering the apparatus geometry, by the equation:

$$I_s/I_t \simeq (10^{(A_1 - A_2)} - 1) / 0.145$$

where I_s represents the intensity of scattered radiation and I_t represents the intensity of radiation transmitted in the same direction that incident light.

The experimental procedures used to collect data in the present study were similar to those reported earlier [3-5]. We have measured the absorbance, at the two sample positions, for fifteen samples (size of 3 x 1 cm lengthwise to the extrusion processing direction) of each polyethylene film. The slit width was 0.5 mm. With the aim of obtaining absorbance values more accurate, we have measured spectra (between 210 and 290 nm) point by point, each 10 nm, adjusting the zero control to zero the display previously to each measurement.

The thickness of each sample was obtained after the corresponding absorbance measurements, by means of an electronic thickness gauge Diameter SM-Digital provided with a semiconductor. Film thicknesses varied between 30 and 70 μm for samples altogether.

RESULTS AND DISCUSSION

From obtained measurements it can be observed that, for a given wavelength, the apparent absorbance value, with the film placed in the two sample positions, increases with increasing thickness of sample. With the aim of evaluating if this variation corresponds to a linear relationship we have carried out, by means of the least squares method, the respective regression analysis between absorbance values and thickness, for

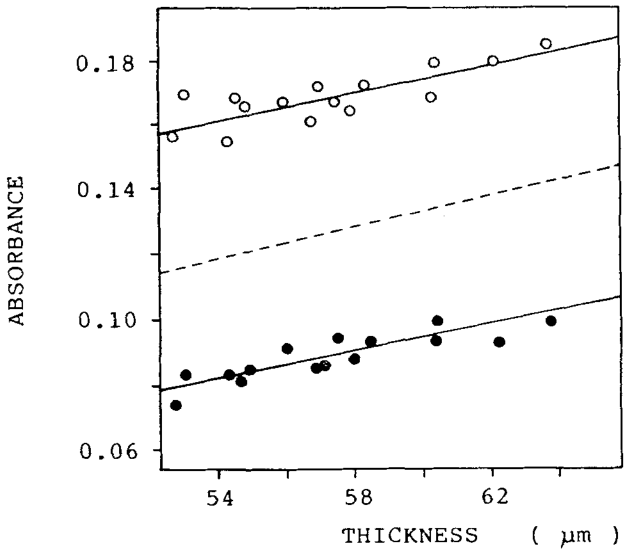

FIG. 1. Absorbance in primary sample position, ○ , secondary sample position, ● , and its difference (----), versus the film thickness. Sample 7 and a wavelength of 250 nm.

each studied film. In figures 1 and 2 we have represented, as example, these variations for two films and a wavelength of 250 nm.

We have verified that in almost every cases there is, statistically, in accordance with Fisher-Snedecor F test, a significative linear correlation, with an assurance level of 99%, although in any case the significance level descends as many as 95%.

The correlation coefficient varied between 0.80 and 0.99, thus it can be considered that, for this kind of films, the variation of thickness allows to

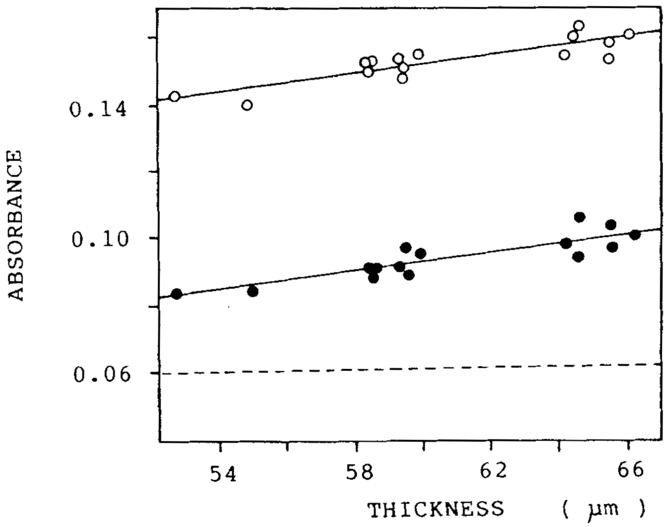

FIG. 2. Absorbance in primary sample position, ○, secondary sample position, ●, and its difference (----), versus the film thickness. Sample 8 and a wavelength of 250 nm.

explain between 64% and 98% (between 80% and 90% in most cases) the variation observed in apparent absorbance. This fact agrees with the results reported by Clampitt et al.[6] for visible radiation for similar samples.

Generally, with the primary position the correlation coefficient is higher than with the other case, that is justified because of the lesser variation of absorbance with the thickness in the secondary position than in the other position, and thus experimental errors affect on a higher extent.

The percentage for observed absorbance variations that cannot been explained by function of thickness variation by means of the regression line is due probably to the uncertainty in the thickness measurement, because the least squares method minimizes the error for ordinates but considers precise the abscise values.

Once the straight lines were calculated, we have obtained, by difference, the lines corresponding to A_1-A_2 versus thickness for each film and each wavelength. This difference represents a parameter related to the scattering radiation, as explained before. In the best parts of cases the slopes of these straight lines are positive, i.e. scattering increases with increasing film thickness. It is also to be noted that the origin intercept generally has a positive value, that is it also depends on the surface texture, given that there would produce scattering even for the hypothetical case of thickness equal to zero.

If in the obtained straight line equations we substitute certain thickness values, equal for every sample, we have the possibility of confronting the scattering radiation intensity in relation to wavelength for normalized thicknesses in every sample and furthermore the committed experimental errors are minimized.

We have procedeed like this, by choosing the 30 μm, 50 μm and 70 μm thickness values with the aim of inclu-

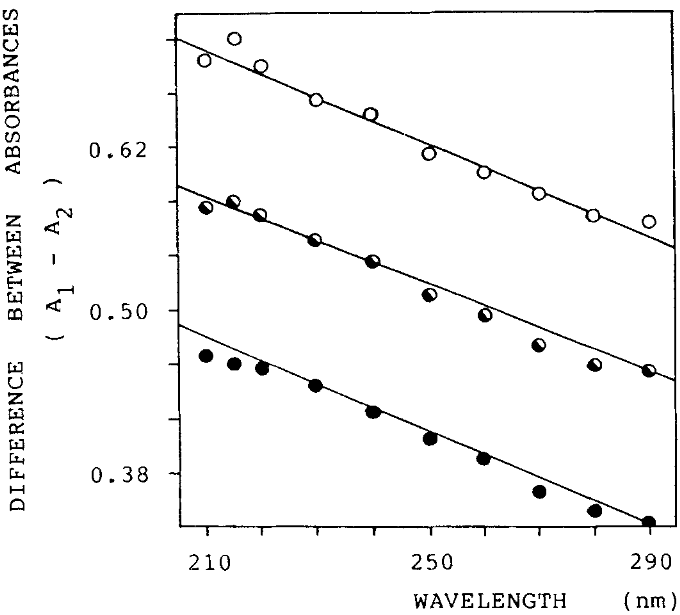

FIG. 3. Difference between absorbances (A_1-A_2) versus wavelength for normalized thickness of 70 μm (○), 50 μm (◐) and 30 μm (●). Sample 1.

ding the general range of studied thicknesses. The relationships between the normalized difference of absorbances (A_1-A_2) and the wavelength for a given thickness are also significative correlations (see figures 3 and 4 as examples), with an assurance level of 99%.

Tables 1 to 3 show the linear relationships between the difference of absorbances and wavelength for the studied samples and the normalized film thicknesses.

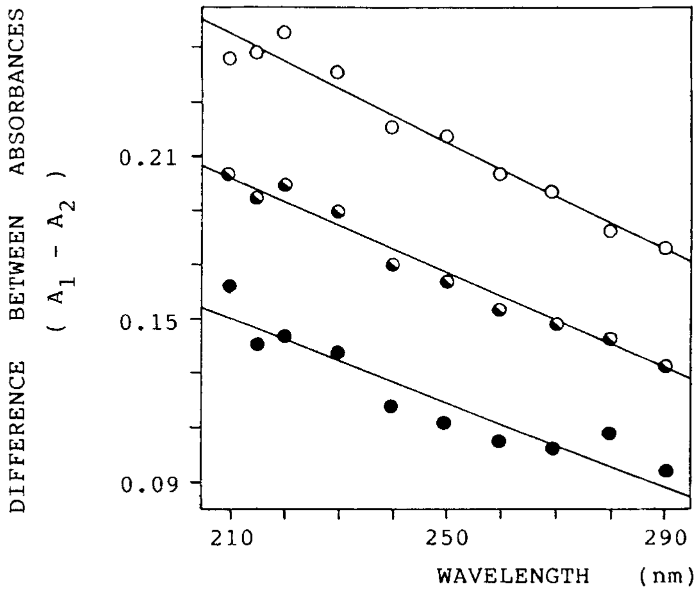

FIG. 4. Difference between absorbances (A_1-A_2) versus wavelength for normalized thickness of 70 µm (○), 50 µm (◐) and 30 µm (●). Sample 6.

The observed linear behaviour is restricted to the range of wavelength analysed (between 210 nm and 290 nm), and shows that the scattering decreases with increasing wavelength. In a higher range (as far as 700 nm) the behaviour is curve and more complex [3].

Equally to the calculation of absorbances for a given thickness, in the obtained equations we can normalize the absorbance differences (A_1-A_2) for certain wavelengths, with the aim of minimize the experimental errors [4].

TABLE 1

Coefficients of linear relationships: $A_1-A_2 = a - b \cdot \lambda$ (where A_1 and A_2 are the absorbances measured at primary and secondary positions, respectively, and λ is the wavelength in nm). Normalized thickness of 30 μm.

Sample	a	b	Correlation coefficient, R
1	0.82	$1.64 \cdot 10^{-3}$	-0.994
2	0.68	$1.48 \cdot 10^{-3}$	-0.986
3	0.75	$1.32 \cdot 10^{-3}$	-0.988
4	0.84	$1.69 \cdot 10^{-3}$	-0.995
5	0.38	$1.02 \cdot 10^{-4}$	-0.957
6	0.47	$9.94 \cdot 10^{-4}$	-0.982
7	0.21	$5.32 \cdot 10^{-4}$	-0.972
8	0.16	$3.86 \cdot 10^{-4}$	-0.954
9	0.16	$5.20 \cdot 10^{-4}$	-0.976
10	0.10	$2.74 \cdot 10^{-4}$	-0.860
11	0.08	$1.21 \cdot 10^{-4}$	-0.871
12	0.09	$2.53 \cdot 10^{-4}$	-0.831

TABLE 2

Coefficients of linear relationships: $A_1-A_2 = a - b \cdot \lambda$ (where A_1 and A_2 are the absorbances measured at primary and secondary positions, respectively, and λ is the wavelength in nm). Normalized thickness of 50 μm.

Sample	a	b	Correlation coefficient, R
1	0.94	$1.70 \cdot 10^{-3}$	-0.994
2	0.88	$1.43 \cdot 10^{-3}$	-0.936
3	0.95	$1.87 \cdot 10^{-3}$	-0.996
4	0.88	$1.63 \cdot 10^{-3}$	-0.995
5	0.40	$9.71 \cdot 10^{-4}$	-0.976
6	0.39	$8.79 \cdot 10^{-4}$	-0.986
7	0.22	$5.61 \cdot 10^{-4}$	-0.978
8	0.16	$3.93 \cdot 10^{-4}$	-0.954
9	0.22	$6.47 \cdot 10^{-4}$	-0.988
10	0.09	$2.28 \cdot 10^{-4}$	-0.910
11	0.17	$4.50 \cdot 10^{-4}$	-0.798
12	0.07	$1.73 \cdot 10^{-4}$	-0.806

TABLE 3

Coefficients of linear relationships: $A_1 - A_2 = a - b \cdot \lambda$ (where A_1 and A_2 are the absorbances measured at primary and secondary positions, respectively, and λ is the wavelength in nm). Normalized thickness of 70 μm.

Sample	a	b	Correlation coefficient, R
1	1.08	$1.83 \cdot 10^{-3}$	-0.978
2	1.08	$1.46 \cdot 10^{-3}$	-0.936
3	1.15	$2.35 \cdot 10^{-3}$	-0.992
4	0.93	$1.57 \cdot 10^{-3}$	-0.988
5	0.52	$1.26 \cdot 10^{-3}$	-0.944
6	0.47	$9.94 \cdot 10^{-4}$	-0.940
7	0.23	$5.96 \cdot 10^{-4}$	-0.979
8	0.15	$3.50 \cdot 10^{-4}$	-0.916
9	0.28	$7.63 \cdot 10^{-4}$	-0.950
10	0.13	$3.01 \cdot 10^{-4}$	-0.867
11	0.21	$5.80 \cdot 10^{-4}$	-0.847
12	0.10	$2.62 \cdot 10^{-4}$	-0.871

Besides the experimental study of the variation of scattering radiation by film thickness and wavelength, the proposed method can be used to characterize optically, by a simple way, materials of great industrial interest, as polyethylene films and other transparent or translucent polymer films.

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