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Solar Energy Materials & Solar Cells
ELSEVIER
Solar Energy Materials & Solar Cells 89 (2005) 319–349
www.elsevier.com/locate/solmat

Solar spectral optical properties of pigments—Part I: model for deriving scattering and absorption coefficients from transmittance and reflectance measurements

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Received 15 June 2004; received in revised form 5 November 2004; accepted 12 November 2004
Available online 24 February 2005

Abstract

The suitability of a pigment for inclusion in "cool" colored coatings with high solar reflectance can be determined from its solar spectral backscattering and absorption coefficients. Pigment characterization is performed by dispersing the pigment into a transparent film, then measuring spectral transmittance and reflectance. Measurements of the reflectance of film samples on black and white substrates are also used. A model for extracting the spectral backscattering coefficient S and absorption coefficient K from spectrometer measurements is presented. Interface reflectances complicate the model. The film's diffuse reflectance and transmittance measurements are used to determine S and K as functions of a wavelength-independent model parameter σ that represents the ratio of forward to total scattering. σ is used to estimate the rate at which incident collimated light becomes diffuse, and is determined by fitting the measured film reflectance backed by black. A typical value is $\sigma = 0.8$. Then, the measured film reflectance backed by white is compared with a

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0927-0248/$ - see front matter Published by Elsevier B.V.
doi:10.1016/j.solmat.2004.11.012

Nomenclature

English symbols

a	defined as $(S+K)/S$
b	defined as $(a^2-1)^{1/2}$
f	film
g	background
i	intensity of total downflux
i_c	intensity of collimated downflux (incident direction is downward)
i_d	intensity of diffuse downflux
j	intensity of total upflux
j_c	intensity of collimated upflux
j_d	intensity of diffuse upflux
K	absorption coefficient
m	relative refractive index or wavelength index
M	total number of wavelengths
n	refractive index
N	observed near-infrared reflectance
q	fraction of total flux that is diffuse
R	reflectance
$\tilde{R}_c$	observed reflectance of collimated light
R_f	CRI (continuous refractive index) reflectance of film (absent interface reflectances)
$\tilde{R}_f$	observed reflectance of film
$R_{f,\ell}$	CRI reflectance of film with background ℓ
$\tilde{R}_{f,\ell}$	observed reflectance of film with background ℓ = b (black), w (white), or v (void)
R_g	CRI reflectance of background
$\tilde{R}_g$	observed reflectance of background
$R_{g,\ell}$	CRI reflectance of background ℓ
$\tilde{R}_{g,\ell}$	observed reflectance of background ℓ
R^i	reflectance to downflux
R^j	reflectance to upflux
R_u	CRI reflectance of opaque undercoat
$\tilde{R}_u$	observed reflectance of opaque undercoat
$R^\star$	intermediate value used in computation of reflectance of complex backgrounds
S	backscattering coefficient (scattering into opposite hemisphere)
T	internal transmittance
$\tilde{T}$	observed transmittance
T^i	downflux transmittance
T^j	upflux transmittance
$\tilde{T}_c$	observed collimated flux transmittance
z	distance from bottom of film