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A new method to retrieve spectral absorption coefficient of highly-scattering and weakly-absorbing materials

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ABSTRACT

A significant uncertainty in the absorption coefficient of highly scattering dispersed materials is typical in the spectral ranges of very weak absorption. The traditional way to identify the main absorption and scattering characteristics of semi-transparent materials is based on spectral measurements of normal-hemispherical reflectance and transmittance for the material sample. Unfortunately this way cannot be used in the case of *in vivo* measurements of optical properties of biological tissues. A method suggested in the present paper is based on thermal response to the periodic radiative heating of the open surface of a semi-transparent material. It is shown that the period of a variation of the surface temperature is sensitive to the value of an average absorption coefficient in the surface layer. As a result, the monochromatic external irradiation combined with the surface temperature measurements can be used to retrieve the spectral values of absorption coefficient. Possible application of this method to porous semi-transparent ceramics is considered. An example problem is also solved to illustrate the applicability of this method to human skin. The approach suggested enables one to estimate an average absorption coefficient of human skin of a patient just before the thermal processing.

1. Introduction

A review of experimental methods and identification procedures for optical properties of disperse media is available in [1]. Determination of the complete set of these properties, namely, absorption and scattering coefficients and scattering phase function requires bi-directional intensity measurements with fine angular resolution and application of sophisticated identification techniques. A simpler and computationally more efficient approach involves using directional-hemispherical transmittance and reflectance [2–5], often coupled with the transport approximation [3,6]. The transport approximation reduces the set of optical properties to be determined to the absorption and transport scattering coefficients. It has been shown that absorption coefficient and transport scattering coefficient are sufficient for engineering heat transfer analysis [3].

Unfortunately, traditional methods are sometimes not applicable because of very low transmittance of highly scattering samples. One of the known examples in the case of porous ceria ceramics when a relatively complex combined approach was suggested to retrieve both the absorption coefficient and transport scattering coefficient of this material in the spectral range of especially weak absorption [7,8]. There are also some other situations when the measurements of transmittance cannot be made. The known example is *in-situ* measurement of optical properties of living biological tissues [9]. In both cases, one needs an alternative approach to retrieve the spectral absorption coefficient of semi-transparent media.

The method suggested in the present paper to retrieve the absorption coefficient is based on solution for the combined radiative-conductive problem at periodic irradiation of the material under investigation. The resulting

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Nomenclature

c	specific heat capacity
d	thickness of sample
D	radiation diffusion coefficient
E	function introduced by Eq. (3)
G	function introduced by Eq. (4a)
h	heat transfer coefficient
I	radiation intensity
J	diffuse radiation intensity
k	thermal conductivity
q	radiative flux
$\vec{r}$	spatial coordinate
R	reflectance
t, Δt	time interval
T	temperature
W	absorbed power
z	normal coordinate

Greek symbols

α	absorption coefficient
β	extinction coefficient
θ	angle measured from the normal
λ	radiation wavelength
μ	cosine of an angle
$\overline{\mu}$	asymmetry factor of scattering
ρ	density
σ	scattering coefficient
τ	optical thickness
ξ	eigenvalue determined by Eq. (7)
ω	scattering albedo

Subscripts and superscripts

0	initial
1, 2	side number
e	external
min	minimum
max	maximum
n-h	normal-hemispherical
tr	transport
λ	spectral

periodic variation of the hot surface temperature depends on the penetration depth of the monochromatic incident radiation which leads to the material heating. The surface temperature can be measured to determine the period of these temperature variations as it was done in paper [10]. Note that exact values of temperature are usually not important because the effect of a systematic error in temperature on the period of temperature oscillations due to periodic irradiation is relatively small. It should be recalled that it is insufficient to know the temperature at the irradiated surface. On the contrary, it is important to know the transient temperature profiles in the material layer. A computational study of these profiles is impossible without the data for volumetric optical properties of the material under consideration.

This period, Δt, depends on many parameters of the problem. At the same time, some of these parameters can be determined independently. Particularly, the medium scattering albedo can be estimated using the spectral measurements of reflectance of optically thick samples. It is also important that a special thermal regime of laboratory experiments can be chosen to minimize the effect of natural uncertainty of the heat transfer parameters on the value of Δt. As a result, the measured period of quasi-steady surface temperature variations can be used to identify the spectral absorption coefficient $\alpha_\lambda$of the material.

The computational model presented in the paper enables one to obtain a dependence of $\Delta t(\alpha_\lambda)$ which is monotonic and sufficiently strong for the reliable identification of α_λ in some important practical problems. Possible application of the method developed to weakly absorbing but highly scattering porous ceramics and to human skin, which is characterized by a significant uncertainty in spectral absorption coefficient in the so-called therapeutic window, is illustrated below by using numerical solutions for two example problems.

2. Radiative transfer problem

A one-dimensional (1-D) radiative transfer problem is considered. The external monochromatic radiation illuminates uniformly a plane-parallel layer of an isotropic and homogeneous material along the normal. Following [3,6] we use the transport approximation for the scattering phase function to simplify significantly the scalar radiative transfer equation (RTE). After integration over an azimuth angle, the RTE and the boundary conditions for the optically thick layer can be written as follows [3] (subscript λ is hereafter omitted for brevity):

$$\mu\frac{\partial \bar{I}}{\partial z}+\beta_{\rm tr}\bar{I}=\frac{\sigma_{\rm tr}}{2}\int_{-1}^{1}\bar{I}(z,\mu)d\mu \quad \mu=\cos\theta \quad z>0 \tag{1}$$

$$\bar{I}(0,\mu)=\delta(1-\mu) \quad \bar{I}(\infty,-\mu)=0 \quad \mu>0 \tag{2}$$

where $\bar{I}(z,\mu)=I(z,\mu)/q_{\rm e}$ is the normalized (per unit incident radiative flux) spectral radiation intensity at point $\vec{r}$ in direction μ, $\sigma_{\rm tr}=\sigma\cdot(1-\overline{\mu})$ is the transport scattering coefficient (σ is the ordinary scattering coefficient, $\overline{\mu}$ is the asymmetry factor of scattering), $\beta_{\rm tr}=\alpha+\sigma_{\rm tr}$ is the spectral transport extinction coefficient, α is the spectral absorption coefficient. Note that transport approximation is widely used in radiative transfer calculations during many years. It was confirmed that hemispherical characteristics of radiation field in scattering materials characterized by multiple scattering are well described using this approximation. The first of boundary conditions (2) is written for the simplest case of a nonrefracting medium. Fortunately, the latter assumption is not important because the reflectance from weakly absorbing media is determined mainly by volumetric scattering [7,8]. The second of conditions (2) is correct for optically thick layers when the real geometrical thickness makes no difference for the radiative transfer problem.

Following the usual technique [3,11,12], consider the radiation intensity $\bar{I}$ as a sum of the diffuse component $\bar{J}$ and the term, which corresponds to the transmitted and reflected directional external radiation:

$$\bar{I}(\mu) = \bar{J}(\mu) + E_{tr}\delta(1-\mu) \quad E_{tr} = \exp(-\tau_{tr}) \quad \tau_{tr} = \beta_{tr} z \tag{3}$$

The mathematical problem statement for the diffuse component of radiation intensity is as follows:

$$\mu\frac{\partial\bar{J}}{\partial z} + \beta_{tr}\bar{J} = \frac{\sigma_{tr}}{2}(G + E_{tr}) \quad G = \int_{-1}^{1} \bar{J}\, d\mu \tag{4a}$$

$$\bar{J}(0,\mu) = \bar{J}(\infty, -\mu) = 0 \quad \mu > 0 \tag{4b}$$

The normalized spectral radiation power absorbed in the medium is expressed as

$$\overline{W} = -\int_{-1}^{1} \frac{d\bar{I}}{dz}\mu\, d\mu = \alpha(G + E_{tr}) \tag{5}$$

The above formulated problem for the diffuse component of the radiation intensity is still very complex. To simplify this problem one can use simple analytical representations of the angular dependence of radiation intensity. It is known that the latter leads to the so-called differential approximations [3,6]. According to [13,14], the modified two-flux approximation can be used to obtain a sufficiently accurate solution for the diffuse component of the radiation field in the case of an arbitrary refracting medium. In the case of a nonrefracting medium, this approach coincides with the ordinary two-flux method [3]. Integrating Eq. (4a) separately over the intervals $-1 < \mu < 0$ and $0 < \mu < 1$, after simple transformations, one can obtain the following boundary-value problem for the above introduced function $G(z)$:

$$-DG'' + \alpha G = \sigma_{tr} E_{tr} \quad D = 1/(4\beta_{tr}) \tag{6a}$$

$$DG'(0) = G(0)/2 \quad G'(\infty) = 0 \tag{6b}$$

The problem (6) has the obvious analytical solution at $0.75 < \omega_{tr} = \sigma_{tr}/\beta_{tr} < 1$:

$$G = \frac{4}{4 - 3/\omega_{tr}}\left[\frac{3}{2+\xi}\exp(-\xi\tau_{tr}) - \exp(-\tau_{tr})\right] \quad \xi = 2\sqrt{1-\omega_{tr}} \tag{7}$$

where ω_{tr} in the transport scattering albedo of the medium. The resulting profile of normalized absorbed radiation power can be written as follows:

$$\overline{W}(\tau_{tr}) = \frac{12\alpha}{4 - 3/\omega_{tr}}\left[\frac{1}{2+\xi}\exp(-\xi\tau_{tr}) - \frac{1}{4\omega_{tr}}\exp(-\tau_{tr})\right] \tag{8}$$

The dimensionless profiles of $\overline{W}(\tau_{tr})/\alpha$ calculated by Eq. (8) at various ω_{tr} are presented in Fig. 1. One can see a considerable deformation of the absorption profile with the medium scattering albedo in the range of $\omega_{tr} > 0.9$ typical for weakly absorbing materials. This effect is accompanied by appearance of the absorption maximum at some distance from the irradiated surface.

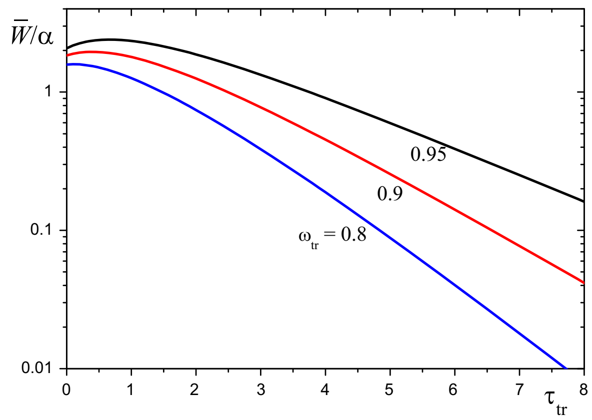

Fig. 1. Typical profiles of normalized absorbed radiation power in a layer of weakly absorbing medium.

According to [13], the normal-hemispherical reflectance of an optically thick non-refracting medium is determined by the medium transport albedo:

$$R_{n-h}(\omega_{tr}) = \frac{\omega_{tr}}{1-\omega_{tr}}\frac{\xi^2/2}{(1+\xi)(2+\xi)} \tag{9}$$

which reduces to the following one in the limit of $1 - \omega_{tr} < < 1$:

$$R_{n-h}(\omega_{tr}) = \omega_{tr} \tag{10}$$

It is quite clear that one can use the spectral measurements of normal-hemispherical reflectance to estimate the transport albedo of the medium, whereas the values of both the spectral absorption coefficient and the spectral transport scattering coefficient cannot be determined independently.

Note that a qualitatively similar solution can be obtained in the case of a refracting medium. The mathematical transformation and analytical solution for the general case of an arbitrary (but constant) index of refraction can be found in papers [15,16]. Therefore, this material is not reproduced here.

3. Transient heat transfer problem

The transient heat transfer problem in a sample of semi-transparent material is formulated in the present paper as a traditional 1-D radiative-conductive problem:

$$\rho c\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right) + \overline{W}(z)q_e(t) \tag{11a}$$

$$t = 0 \quad T = T_0(z) \tag{11b}$$

$$z = 0 \quad k\frac{\partial T}{\partial z} = h_1(T_{e,1} - T) \quad z = d \quad k\frac{\partial T}{\partial z} = h_2(T - T_{e,2}) \tag{11c}$$

In contrast to the radiative transfer problem, we should specify the finite thickness of the material layer and conditions (11c) on both sides of this layer. Formally, one needs also initial condition (11b) to complete the parabolic problem (11a)–(11c). Nevertheless, the main attention will be paid to the time period when the problem solution does not depend on this initial condition. To make our objective clear, consider the case of a uniform initial temperature $T_0 = \mathrm{const}$, the symmetric and independent of time boundary conditions ($T_{e,1} = T_{e,2} = T_e = \mathrm{const}$ and $h_1 = h_2 = h = \mathrm{const}$), and constant thermal properties of a uniform sample ($\rho c = \mathrm{const}$ and $k = \mathrm{const}$).

The specific of the problem under consideration is a periodic time variation of the incident radiative flux. The radiation source of constant power is switched off when the surface temperature of the irradiated surface of the sample ($z = 0$) reaches the value of $T_s = T(t, 0) = T_{max}$ and switched on again at $T_s = T_{min} < T_{max}$.

Generally speaking, the solution to transient radiative-conductive problem depends on many parameters such as the initial temperature profile, the convective heat transfer coefficient, the heat capacity and thermal conductivity. Fortunately, the solution degenerates as usually in some limiting or other specific cases when the values of some parameters appear to be not important.

Let us consider the computational results obtained for the typical example problem. The parameters of this problem are specified in Table 1, and the results of calculations are presented in Figs. 2 and 3. The value of $\sigma_{tr} = 2\ \mathrm{mm}^{-1}$ and two alternative values of α were used in these calculations.

One can see in Fig. 2 that almost periodic variation of the surface temperature takes place after the heating stage. The period of these temperature oscillations is an important parameter of the quasi-steady regime of the temperature variation. Typical temperature profiles presented in Fig. 3 indicate that a thickness of surface layer characterized by considerable temperature variations decreases with the increase in spectral absorption coefficient. This effect is explained by obvious changes in the profile of absorbed radiation power. As a result, the period of temperature oscillations, Δt, decreases in the case of a greater value of α (see Fig. 2). It should be noted that Δt increases with time in the case of a relatively large absorption coefficient. Therefore, an average value of Δt for the time interval $5 < t < 30$ min is considered in subsequent analysis.

To retrieve the value of α from the temperature measurements, one can use the computational data for one of two close values of heat transfer coefficient presented in Fig. 4. One can see that the effect of small variations of heat transfer coefficient may be also considerable. Therefore, it is interesting to consider the dependences $\Delta t(h)$ at constant values of α (see Fig. 5). It is physically clear that this dependence is strong at small values of h and decreases in the limit of large values of this parameter. The expected degeneration of the solution at high values of the heat transfer coefficient (a self-similar regime) is really observed

Table 1
Parameters of the example problem.

d (mm)	8	$T_e = T_0$ (K)	300
k (W m^{-1} K^{-1})	0.4	h (W m^{-2} K^{-1})	10
ρc (MJ m^{-3} K^{-1})	4	T_{min} (K)	313
q_e (kW m^{-2})	2	T_{max} (K)	315

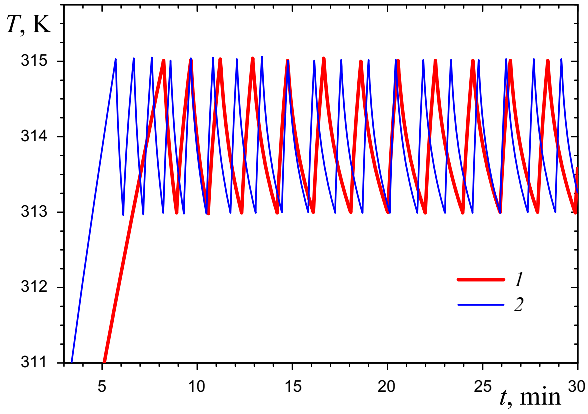

Fig. 2. Time variation of the surface temperature at the irradiated side of the sample: (1) $\alpha = 0.1\ \mathrm{mm}^{-1}$, (2) $0.2\ \mathrm{mm}^{-1}$.

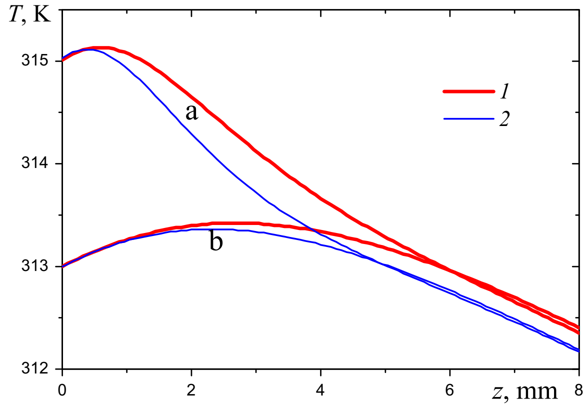

Fig. 3. Typical temperature profiles in the sample (a) at the maximum and (b) at the minimum of surface temperature: (1) $\alpha = 0.1\ \mathrm{mm}^{-1}$, (2) $0.2\ \mathrm{mm}^{-1}$.

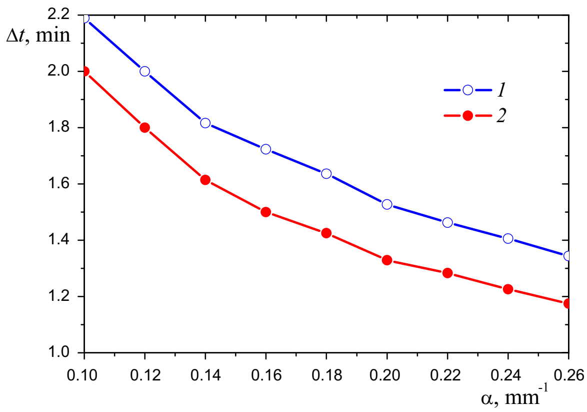

Fig. 4. The relation between the average period of temperature oscillations and the absorption coefficient: (1) $h = 8\ \mathrm{W\ m^{-2}\ K^{-1}}$, (2) $10\ \mathrm{W\ m^{-2}\ K^{-1}}$.

in the calculations. It appears that the value of Δt is independent of h in the range of $h > 15\ \mathrm{W\ m^{-2}\ K^{-1}}$ typical for the forced convection. In other words, the range of convective heat transfer rate favourable for the identification of spectral absorption coefficient is found. Of course, this range depends on other parameters of the problem.

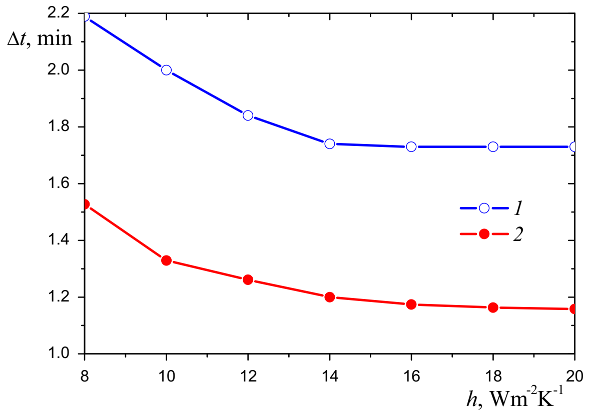

Fig. 5. The relation between the average period of temperature oscillations and the heat transfer coefficient: (1) $\alpha = 0.1\ \text{mm}^{-1}$, (2) $0.2\ \text{mm}^{-1}$.

It should be noted that similar experiments in a combination with the solution for the transient radiative-conductive heat transfer problem can be used to retrieve the heat transfer coefficient in the natural convection regime, which is characterized by small values of h. The samples of semi-transparent materials with the known optical properties should be used in such experiments. This heat transfer study may be a subject of a separate analysis, but it is beyond the scope of the present paper focused on identification of the spectral absorption coefficient.

Two examples of potential applications of the above idea to different practical problems are considered below.

4. Spectral absorption coefficient of semi-transparent porous ceramics

Highly scattering porous ceramics are encountered in several engineering applications including the high-temperature solar thermochemical processing. The spectral radiative properties of the advanced materials such as porous ceria ceramics are critical for the analysis of thermal transport-chemistry interactions and also for the design of solar thermochemical reactors [17–19]. Absorption and scattering of the incident solar radiation as well as emission, absorption, and scattering of thermal radiation by ceramics at high temperature contribute to combined heat transfer [20]. Therefore both visible and near-infrared radiative properties are required for heat transfer modeling and optimizing morphology of ceria ceramics for maximum efficiency of the solar reactors [21].

Recent experimental studies [7,8] have shown that porous ceria ceramics is characterized by very week absorption in the wavelength range of $0.6 < \lambda < 2\ \mu\text{m}$, and it is difficult to determine accurately the spectral absorption coefficient in this range. Therefore, it is interesting to consider an alternative way to retrieve the absorption coefficient of porous ceria ceramics. Let us consider the sample of highly porous ceria ceramics similar to that used in [7,8]. The typical values of parameters used in solving the radiative-conductive problem for the sample of porosity 0.72 are specified in Table 2. The values of $T_e = T_0$, $T_{\min}$, and $T_{\max}$ were taken from Table 1. An acceptable level of heat transfer coefficient, h, was found to minimize the effect of this value uncertainty on the sample temperature in the regime of quasi-steady temperature oscillations. It is clear from Fig. 6 that the range of $16 < h < 20\ \text{W m}^{-2}\,\text{K}^{-1}$ is appropriate.

Table 2
Parameters of the model problem for porous ceria ceramics.

d (mm)	1	α (m^{-1})	5–10
k ($\text{W m}^{-1}\,\text{K}^{-1}$)	0.6–0.8	σ_{tr} (mm^{-1})	20
ρc ($\text{MJ m}^{-3}\,\text{K}^{-1}$)	1	q_e (kW m^{-2})	50

It is important that effect of thermal conductivity (this value is also not well known) is relatively small, especially for the above recommended range of heat transfer coefficient. This result is explained by very small thickness of the ceramics sample.

The dependences of $\Delta t(\alpha)$ at $h = 18\ \text{W m}^{-2}\,\text{K}^{-1}$ at two values of thermal conductivity are presented in Fig. 7. One can see that effect of thermal conductivity at the parameters of an imaginary experiment is very small in the range of $5 < \alpha < 7\ \text{m}^{-1}$ and increases considerably at larger values of the spectral absorption coefficient. Note that one can use another experimental procedure (without any irradiation of the sample) or theoretical approach to obtain independently the effective conductivity of a porous ceramics [18].

The above particular problem is sufficient to show that one can find the range of the problem parameters favorable for identification of the spectral absorption coefficient of porous ceria ceramics without exact data for both thermal conductivity of this ceramics and heat transfer coefficient at the sample surfaces. Of course, an optimization process should be used to find the best ranges of several parameters such as the incident radiative flux, the conditions of heat transfer with ambient air, and the sample thickness. Note that solution to the mathematical optimization problem taking into account natural uncertainties of all parameters is beyond the scope of the present paper.

5. An average spectral absorption coefficient of human skin in therapeutic window

It is known that human skin has a complex layered structure, and the following different layers of biological tissues are usually considered: epidermis, dermis, and subdermis (or fat layer). The thicknesses of these layers, thermal properties of the specified biological tissues and spectral optical properties of tissues in the so-called therapeutic window (in the wavelength range from about 0.6 to 1.4 μm) are not universal for patients of different age and depend on many parameters [9,22–26]. Therefore, it is important to estimate the local properties of the patient skin *in situ*, just before the thermal treatment with the use of near-infrared irradiation. This can be done on the basis of a very simplified spectral model based on spatially averaged thermal and optical properties of the skin. Note that the effect of index of refraction is relatively small for highly scattering human tissues and can be neglected. It

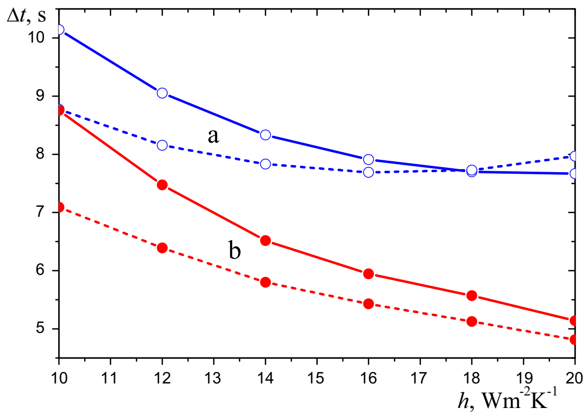

Fig. 6. The relation between the oscillations of surface temperature and heat transfer coefficient: (a) $\alpha = 5\ \mathrm{m}^{-1}$, (b) $10\ \mathrm{m}^{-1}$; solid lines – $k = 6\ \mathrm{W\ m^{-1}\ K^{-1}}$, dashed lines – $8\ \mathrm{W\ m^{-1}\ K^{-1}}$.

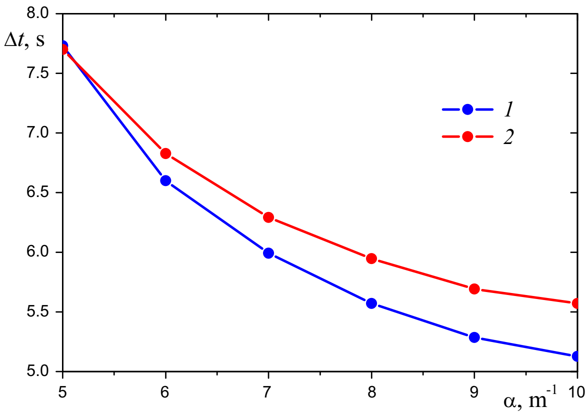

Fig. 7. The predicted relation between the absorption coefficient of porous ceria ceramics and the period of temperature oscillations: (1) $k = 6\ \mathrm{W\ m^{-1}\ K^{-1}}$, (2) $8\ \mathrm{W\ m^{-1}\ K^{-1}}$.

means that one can use the analytical solution (8) for the absorbed radiation power.

The computational estimates of papers [15,27] showed that contributions of both the metabolic heat generation and volumetric heat transfer between arterial blood and ambient tissues are not usually significant in the human skin and can be neglected. As a result, the transient heat transfer problem in a superficial layer of a body can be approximately treated as a conduction problem with the volumetric heat generation due to absorption of the external radiation. Of course, the conductive heat flux from the internal part of the living body should be included in the boundary condition at the “shadow” side of this layer. It is important that 1-D mathematical problem statement (9) remains to be correct in many practical cases [14,16].

In the case of a human body, $T_{e,2}$ is the temperature of the internal part of the body, and the thickness of the computational region, d, should be chosen greater than the depth of the external radiation penetration because relatively deep layers of the body are heated during the thermal treatment. The initial condition for the body temperature

Table 3
Typical average parameters of human skin used in calculations.

d (mm)	7	T_{e1} (K)	300
k ($\mathrm{W\ m^{-1}\ K^{-1}}$)	0.3	T_{e2} (K)	310
ρc ($\mathrm{MJ\ m^{-3}\ K^{-1}}$)	4	h_1 ($\mathrm{W\ m^{-2}\ K^{-1}}$)	5
q_e ($\mathrm{kW\ m^{-2}}$)	1.5–1.7	h_2 ($\mathrm{W\ m^{-2}\ K^{-1}}$)	50
α ($\mathrm{mm^{-1}}$)	0.06–0.18	$T_{\min}$ (K)	314
σ_{tr} ($\mathrm{mm^{-1}}$)	2	$T_{\max}$ (K)	315

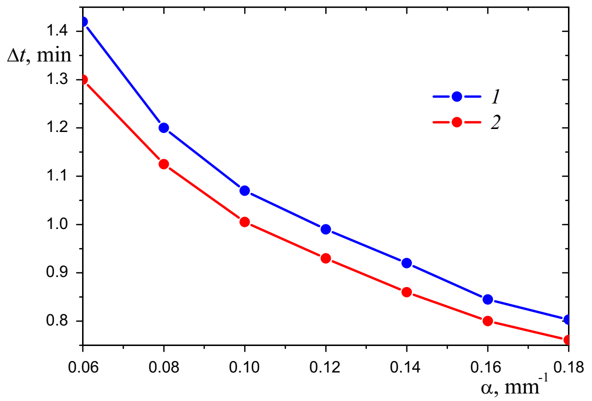

Fig. 8. The relation between the average absorption coefficient of human skin and the period of surface temperature oscillations: (1) $q_e = 1.5\ \mathrm{kW\ m^{-2}}$, (2) $1.7\ \mathrm{kW\ m^{-2}}$.

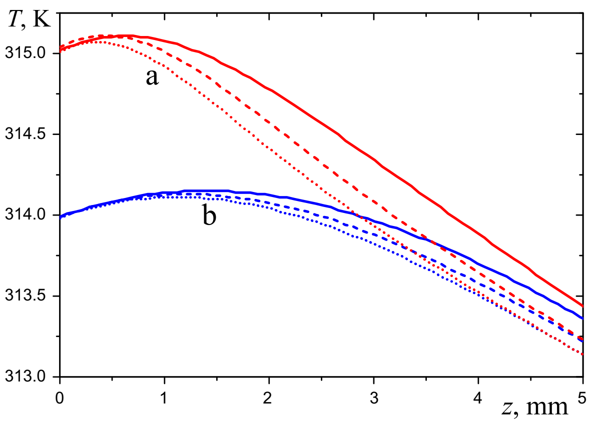

Fig. 9. Typical temperature profiles (a) at the maximum and (b) at the minimum of the body surface temperature: solid curves – $\alpha = 0.06\ \mathrm{mm^{-1}}$, dashed – $0.12\ \mathrm{mm^{-1}}$, dotted – $0.18\ \mathrm{mm^{-1}}$. Calculations at $q_e = 1.5\ \mathrm{kW\ m^{-2}}$.

can be obtained as a solution to the steady-state heat conduction problem without external irradiation as it was done in [15,16,27]. At the same time, the effect of initial temperature profile on the quasi-steady oscillations of the body surface temperature is very small and can be neglected.

The values of optical and thermal parameters used in heat transfer calculations for human skin as applied to the wIRA thermal treatment [10,28,29] are specified in Table 3 (see paper [16]). It was found in [16] that Δt are practically insensitive to both the thermal conductivity k (in the range typical for human skin) and the heat transfer coefficient h_1 at the natural convection of ambient air [30]. Therefore, there is no need in calculations for different values of these parameters and one can consider the constant values of k and h_1 specified in Table 3.

The computational results for the dependences $\Delta t(\alpha)$ at two values of the incident radiative flux presented in Fig. 8 indicate that average spectral absorption coefficient of human skin, α, can be estimated using the measurements of Δt. Note that measurements at various values of the incident radiative flux can be recommended to improve the accuracy of the absorption identification.

The temperature profiles presented in Fig. 9 illustrate the effect of spectral absorption coefficient on the position of temperature maximum inside the body. It is also clear that cooling of overheated superficial tissues is determined by heat conduction to the internal region of the body. The latter makes clear a very small effect of both convective heat transfer conditions and thermal conductivity of a thin surface layer on transient temperature field in the body. It is important that a similar analysis can be done for only one (the most uncertain) parameter of the complex tissue (like radiative properties of dermis layer). A solution to such a particular problem, which is closer to the medical practice, has been considered recently in paper [16].

6. Conclusions

A novel method was suggested to estimate spectral absorption coefficient of weakly absorbing and highly scattering media. This method is based on thermal response of the medium to the periodic radiative heating in the spectral range of the medium semi-transparency. It was shown that the period of surface temperature variations is sensitive to the average spectral absorption coefficient in the surface layer. A combination of the monochromatic external irradiation with the measurements of both reflectance and surface temperature can be used to retrieve the spectral values of the spatially average spectral absorption coefficient in the surface layer.

Two potential applications of the method developed were considered. The calculations showed that this method can be used to retrieve the spectral absorption coefficient of porous ceria ceramics in the spectral range of an extremely weak absorption. It appears that the effect of thermal conductivity is not large for thin samples and one can obtain good estimates of absorption without exact data for the effective conductivity of porous ceramics. An example problem for superficial human tissues was also solved to examine if the method suggested can be used to obtain *in situ* the input data for the recently developed computational model for the wIRA-based hyperthermia of superficial human tissues. It was shown that a very similar (but more particular) approach enables one to estimate the spectral absorption coefficient of a patient dermis just before the hyperthermia.

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