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High Resolution of Diffusion Reflection and Transmission Spectrum of Hails Potato

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The mechanism in which electromagnetic radiations interacts with material objects, is a major interesting, investigating, applicable process. Historically, interaction of light with material was first peaked by some of the natural phenomenon of the blue sky, the rainbow and the transparency of some liquids and solids material, whereas some are not showing such observations. Recently with the improvements of laser, it has become more important to understand how electromagnetic radiations, especially optical wavelength travel through biological tissues. The significance of this paper is that the high resolution diffusion reflection and transmission spectrum of Hails potato as a biological sample was completed using the integrating sphere for measuring all the forward transmitted light and the backward reflected light.

Key Words: One dimentional approximation, Transmission coefficient, Reflection coefficient, Attinuation of Radial Flux, Integrating sphere spectrophotometer.

INTRODUCTION

The one dimensional diffusion approximation for calculation of the microscopic optical constants from diffuse transmission and reflection measurements is the object of this work. An integrating sphere[1-3] provides a means for measuring all light transmitted or reflected in the forward or backward hemispheres[4].

For numerical calculations the diffuse transmission and reflection are given by the two following equations:

$$T = I(z = d)(1 - r_2) / E_O$$

$$R = J(z = 0)(1 - r_1) / E_O$$

where T is the transmission coefficient, R is the reflection coefficient, r_1 is the internal reflection coefficient for diffuse flux at the front face and r_2 is the internal reflection coefficient for diffuse flux at the rear face, I is the forward flux, J is the backward flux, E_O is incident original flux, d is the maximum boundary depth and z is the variable depth.

The calculation of one dimensional diffusion approximation assumes that the phase function consists of the two leading terms of the Legendre expansion, a constant term for the isotropic flux plus an isotropic term proportional to the cosine of the angle to the forward direction. Although this is a satisfactory approximation for many systems it does not represent accurately the high forward scattering properties of biological tissues. The delta Edenton phase function consists of the first order Leander polynomial plus a forward projected solid angle delta function as developed by Joseph *et al.*[5], This phase function can be introduced without resolving the equation of transport by means of the following transformation:

$$\begin{aligned} & k \rightarrow k \\ & s \rightarrow s(1-g^2) \\ & g \rightarrow \frac{g}{(1+g)} \end{aligned}$$

g is the mean cosine of the scattering angle.

Generally the diffusion approximation requires three microscopic parameters[6] k. s and g. In order to determine these three parameters it is necessary to measure three microscopic properties, usually the diffuse transmission, diffuse reflection and the third quantity such as the one-axis transmission. In many cases it is difficult to obtain the third quantity measurement, especially in case of the very thick sample where the one-axis transmission is negligible, as the solution stands one can not the three unknown optical constants from only two experimental parameters. A useful procedure is to apply the similarity relation developed by Van de Hulsy[7], as follows:

$$\begin{aligned} & k \rightarrow k \\ & g \rightarrow 0 \\ & s \rightarrow s(1-g) \end{aligned}$$

This transformation reduces the number of unknowns from 3 to 2 although only s (1-g) = s' can be determined. The similarity transformation assumes a hypothetical layer with the same flux profile as the physical system in the anisotropy of hypothetical system equal to zero and k and z adjusted appropriately. The present work supported the use of this approximation for biological media.

Another situation that is often encountered is appearance of an optically thick sample in which the transmission can not be measured. If the solution for R above is extrapolated to $x \rightarrow \infty$ than we find the value of R_∞ follows:

$$R_\infty = \frac{s'}{(\sigma + \kappa_d)\{1 + \frac{2\kappa_d(1+r)}{3\sigma(1-r)}\}}$$

where, $\sigma = k + s'$.

The best value that can be obtained for the optical constants in this case the ratio of k/s'. One can still obtained an approximation result for the absorption spectra over a limited wavelength range if the reduced scattering coefficient s' is assumed to be approximately constant.

EXPERIMENTAL

In all other similar works the choosing tissue is preferred to be with known optical characteristics that are to safely compare the accuracy of the experimentally obtained characteristics results.

In the present work Hails potato is been choose because it is the very famous kind of potato available in Saudi Arabia local markets. Present sample is of the *in vitro* tissue kind, a large number of Hails potato tissue samples, these samples were cut. After the tissue has slowly thawed to near potato freezing point. All measurements were made at room temperature. A parallel study for the same samples were being completed using Photofrin II as a photodynamic therapy drug, through out incubating the prepared sections of potato for 24 h in a concentrated solution. The potato sections where (3 cm × 3 cm × 3 cm) cut and used immediately from fresh Hails potato. A 100 tungsten-halogen lamp with high aperture one over eight diffraction grating monochromator was used to provide radiation from the near ultraviolet to the near infrared-full spectrum- with adequate intensity output. Gratings blazed at a 500 and 1000 nm were used to obtain the desired wavelength range. The light exiting the monochromator was collimated with a lens system and split into two beams. The beams were individually chopped by 220 light chopper and sent to the two integrating spheres. The light was sampled by optical cables that were coupled to a pair of photo detectors. Along the total spectra a three compatible photomultiplier was used, i.e. Hamamatsu, red- enhanced and germanium photomultipliers, starting from the near infrared to the near ultraviolet region. The signals were coupled to a pair of lock-in amplifiers; one was equipped with a ratio box that provides the ratio of the two signals. This ratio signal was read into the same computer used to control the monochromator stepping motor using a Data Acquisition A to D card. For diffuse transmission measurements a reflecting plate was placed over the reflection part of the sphere. A black plate was placed behind the sample a beam stop while the diffuse reflection was being measured. The data obtained for each sample were stored by the computer in the DIF file which was converted to a Lotus file for data processing. The data file was used as the source file for the data fitting program. The program uses a two dimensional Newton's method for emiterating the system of algebraic equations obtained in the one dimensional diffusion approximation. The starting point for each successive data set was the solution to the previous data set. The out put file produced by the program provides calculated values of k.s, R and T for each data set.

The reflection and transmission full spectra were measured for potato cubs as an *in vitro* biological tissue using an integrating sphere spectrophotometer as an advanced and sophisticated apparatus. The absorption and scattering spectra were then calculated using the one dimensional diffusion approximation with the similarity transform at 1 nm separation resolution.

Another approach has been made to determine how the beam of incident light propagate and spread radially in the biological tissue[8]. A two dimensional solution of the diffusion approximation was used to analyze the data. Fig. 1 shows the radially average flux profile of Hails potato tissue.

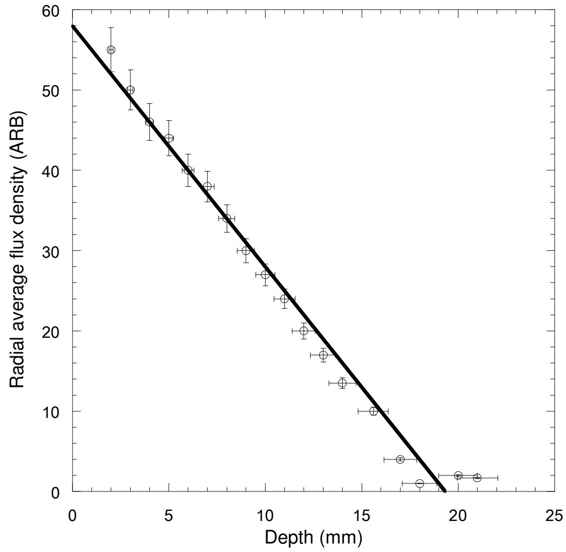

Fig. 1. Attenuation of radial flux in potato tissue

Fig. 2 shows typical result for Hails potato in the full wavelength range starting from 350 nm ending at 1350 nm. Obviously weak absorption appears in the range 530 nm extended to 930 nm. This fact is attributed to cytochromes as an essential component of this biological tissue, sample thickness was 3 mm while the wavelength separation was 5 nm.

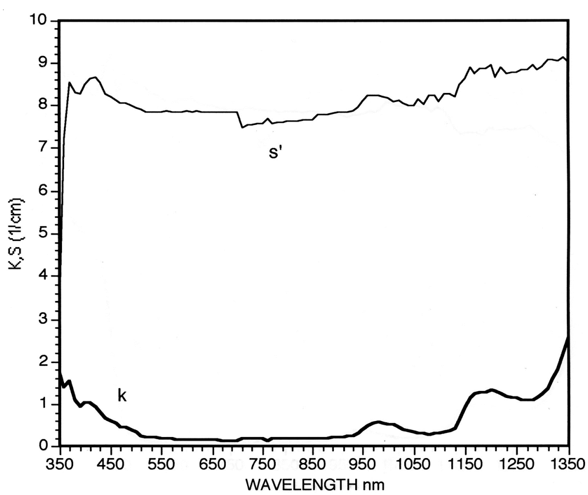

Fig. 2. Absorption and scattering spectrum of Hails potato

Fig. 3 shows typical result for Hails potato incubated in photofrin II in the full wavelength range starting from 450 nm ending at 1050 nm. Obviously there is a tissue water band at the wavelength 970 nm and in the visible wavelength region four of the Photofrin II are present at 510, 540, 580 and 630 nm. They are in good agreement with absorption spectra of dihematopopyyrin ether in aqueous surfactant, sample thickness was 3.0 mm while the wavelength separation was 5 nm.

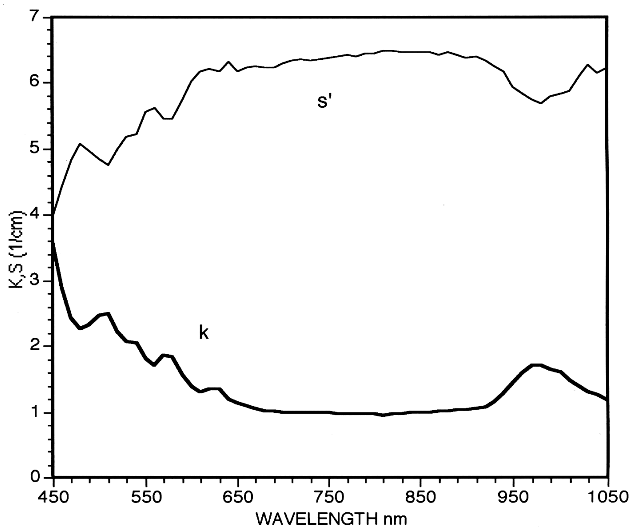

Fig. 3. Absorption and scattering spectrum of Hails potato incubated in photofrin II

RESULTS AND DISCUSSION

In the present work Hails potato sample, the two dimensional flux density profile was fit to the numerical integration of its equation using the method of Fourier transform, with the function equation of Fourier space and zeroth order Bessel function of the first kind. Fig. 1 shows the radially average flux profile for Hails potato at the wavelength 1064 nm, in calculated results the value of k_d was (1.15 ± 0.015) cm^{-1}, while at the wavelength 633 nm it was (1.88 ± 0.04) cm^{-1}. Figure shows that accurate values of the attenuation depth in large tissue section can be calculated from the exponential attenuation of the radial average flux density distribution. The intrinsic accuracy of the integrating sphere spectrophotometer was tested once more in calculating the values of k and s' using 10 mm laser beam for the same thickness of potato sample, the results was (0.42 ± 0.01) cm^{-1}, (4.5 ± 0.7) cm^{-1}, while in using the monochromator they were (0.46) cm^{-1}, (5.5) cm^{-1}, respectively.

In both Figs. 2 and 3, one dimensional diffusion approximation with a similarity transformation is capable of providing accurate absorption spectra of the biological tissue in the present work, which is classified as a highly turbid sample. Fig. 2

shows a complete absorption spectrum of Hails potato. It is clear that the absorption band is very low below the wavelength 500 nm, while there are three strong absorption bands at the wavelengths, 975, 1200 and 1200 nm, respectively. This absorption is attributed to the water content in potato.

Fig. 3 shows the spectrum Hails potato dyed with photophrin II clearly show that there is a tissue water band at the wavelength 975 nm. In addition to four other bands at the wavelength 510, 540, 580 and 630 nm, which is in agreement with of dihematoporphyrin ether in aqueous surfactant and a clear curve showing the effect of the photosensitizer[9,10].

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