Photoacoustic response of a common starfish tissue

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Abstract. A sample of common starfish (*Asterias Rubens*) tissue has been prepared in the shape of a film to study its photoacoustic (PA) response. A broad absorption band in the PA spectrum is detected in the visible region (a peak at about 570 nm), while the ultraviolet region is distinguished by the absorption bands originating from $\pi \rightarrow \pi^*$ and $\pi \rightarrow n$ charge transfer transitions. The visible PA spectrum strongly depends on decomposition of sample in the open air. The PA spectrum measured by us is very similar to those obtained earlier for the other living organisms, e.g. *Truncylariopis Trunculus* and *Sea Urchin*. The absorption band near 570 nm is similar to that found for spermidine, which is of importance in the information transfer to DNA. The results obtained in this work confirm experimentally that geologically very old organisms have been absorbing especially intensely in that part of solar spectrum for which the water is transparent.

Keywords: photoacoustic spectroscopy, common starfish, electronic transitions

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1. Introduction

A triad that consists of electron, photon and phonon corresponds to the most important particles involved in many different physical processes in the living matter. In its turn, photoacoustic (PA) spectroscopy is a very powerful tool in investigating interaction of electromagnetic radiation with biological systems [1–4]. Electronic transitions due to radiation absorption can initiate radiative and non-radiative processes. One can notice that in ancient Greece radiation of the Sun has been a major source of different therapeutic applications. At the present time, it is well known that even photons with low energies can result in a great number of excited states in the biogenic systems. Polyamines, especially spermine, play an important part in the information transfer to DNA [5–7]. A series of polyamine spermine copper (II) complexes with different concentrations of molecular water have been investigated using spectroscopic and magnetic methods [7–10]. The spectroscopic and magnetic properties of the polyamine spermine copper (II) complexes depend essentially on substitution, as well as on the presence of water molecules that could be revealed in crystalline-field splitting of electronic levels.

Recently, a broad absorption PA band in the visible region of electromagnetic radiation has been observed for the tissues of *Truncylariopsis Trunculus Sea Urchin*, with a maximum at 570 nm [3, 4]. It has been revealed that the intensity of this band is significantly lowered after dehydratation of the tissue [3]. It is also well known that the human body consists mainly of water molecules and that the longer the wavelength of electromagnetic radiation in the visible region the larger is its penetration depth into the human body. The copper and, especially, the iron complexes are important ingredients of blood. They can absorb yellow-green electromagnetic radiation and transform (or shift) it into a red spectral region [11]. The energy difference of these photons is employed in many thermal processes occurring in organisms. These processes excited by *d–d* transitions can play very important role and serve as a sort of 'channel selector' [12, 13]. It is interesting to notice that a similar PA signal could be found for the other sea organisms such as *Truncylariopis Trunculus* or *Sea Urchin* [3, 4].

The aim of this work is a PA study of *Asterias Rubens* tissue and its comparison with the PA signals detected earlier for *Truncylariopsis Trunculus* and *Sea Urchin* [3, 4]. Moreover, we suggest a symbolic radiation model attempting to interpret a so-called effect of 'God's Spark'.

2. Experimental details

An *Asterias Rubens* obtained from the region of Corinth Gulf, Greece, is shown in Fig. 1. The PA spectrum of sample *Asterias Rubens*, prepared in the shape of a film (less then 1mm) was measured at the room temperature, using a conventional equipment comprising a light source of a 1 kW Xenon arc lamp and a 0.25 m ORIEL monochromator (the bandpass width of 5 nm at 500 nm). To reduce low-frequency noises, we narrowed signal bandwidth with the aid of lock-in detection. The light output from the monochromator was mechanically chopped at the frequency 10 Hz. The acoustic signal was detected with a very sensitive microphone TREVIE M27 attached to a PA cell. A dual Stanford Research SR830 lock-in amplifier recorded the amplitude and phase of the microphone signal relative to the input excitation. With averaging over 20 modulation periods, a typical signal-to-noise ratio, dependent on the wavelength of the incident light, was at least 50, thus improving approximately five times the corresponding parameters for the non-modulated case. All the experimental data were perfectly reproducible. The raw amplitude and phase of the sample signal were normalized against the PA spectrum of a graphite blackbody reference, in order to correct for modulation-frequency dependence of the thermal diffusion length [14].

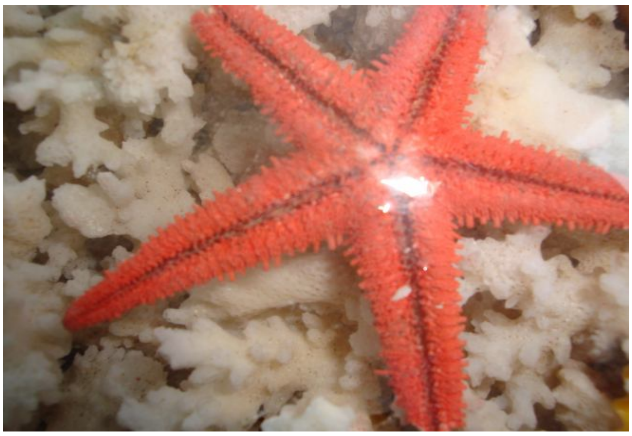

Fig. 1. A common starfish (*Asterias Rubens*) from the Corinth Gulf, Greece.

3. Experimental results and discussion

Fig. 2 shows the PA spectra of the *Asterias Rubens* tissue. An intense and broad absorption band is recorded in the visible range near the yellow-green region of the PA spectrum, with a maximum located at 570 nm. Several times higher PA intensities arising from the charge-transfer transitions ($\pi \to \pi^*$, $\pi \to n$) are observed below 350 nm.

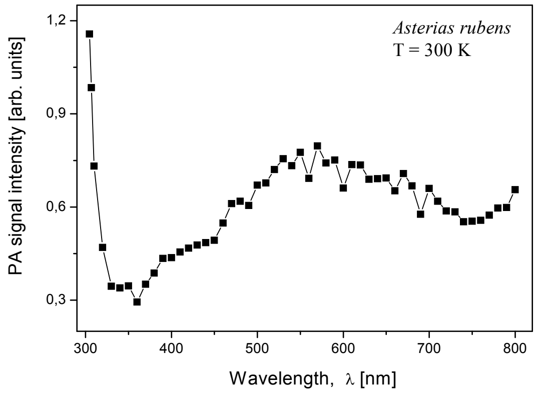

Fig. 2. PA spectrum of the common starfish (*Asterias Rubens*).

The PA spectrum is a result of heat generated through the non-radiative transitions in a sample after it has absorbed some intensity of the modulated incident light. The PA intensity I could be expressed as

$$I = \gamma k A_{abs} , \tag{1}$$

where γ is a coefficient related to thermal properties of a given sample and characteristics of the spectrometer, k the probability of non-radiative transition from the exited state, and A_{abs} the absorbance of sample [15]. Two kinds of relaxation processes should be considered, the radiative and non-radiative ones, which occur after excitation of electrons by the electromagnetic radiation. The observed PA spectra are due to the non-radiative processes which could directly involve localized levels of ions or, indirectly, molecular levels.

Table 1. Maxima of PA absorption bands observed in the visible region.

Sample	Wavelength corresponding to maximum of PA band, nm	Reference
Spn323	567	[7]
Spm323	566	[7]
Hematite	580	[14]
Trunculariopsis Trunculus	570	[3]
Asterias Rubens	570	this work
Sea Urchin	570	[4]
$[Nd(NO_3)_2(PiBH)_2]NO_3$	583	[12]

The electromagnetic radiation in the visible region is very important for the active states of a living matter, especially those related to copper (II) or iron (III) complexes. Some of the complexes which are the most vital for functioning of the living systems, in particular those of copper (II) and iron (III), show intense, very broad PA signals with a maximum in the yellow-green region [8, 16]. A similar PA absorption has been recorded for *Trunculariopsis Trunculus* and *Sea Urchin* tissues [3, 4] (see Table 1). The fact that *Asterias Rubens*, *Sea Urchin* and *Truncalariopsis Trunculus* reveal very similar PA spectra is very significant and suggests that the electromagnetic radiation from the appropriate regions could play an important role in dynamical processes occurring in the living matter.

The constituents of adult human skin are as follows: water 58.6–72.1, proteins 22–27.2, lipids 5.2–13.5, and ash ~ 0.7% [17]. It is very well known that proteins contain a lot of copper (II) and iron ionic complexes, in which the *d–d* electronic transitions occur. The relevant absorption band in the optical spectrum is in the vicinity of 570 nm [18, 19]. The optical properties of blood depend chiefly on erythrocytes, whose refractive index is about 1.402. It is also a known fact that the absorption coefficients measured for the same tissue are different *in vitro* and *in vivo* [20]. Besides of the concentration, a strong effect on the optical properties of blood arises from the shape, the velocity, aggregation and sedimentation of the erythrocytes [21].

Since ancient times, humans try to understand a so-called 'God's Spark' principle. Namely, it is well known that even a small energy dose in the form of photons can effectively trigger important energetic processes in the living matter [22]. One of the questions to be answered concerns the role of yellow-green radiation played in "εν λειτουργία" (reproduction) of the living matter in a water medium. The living matter is generally built up of water molecules. The water becomes increasingly transparent with increasing wavelength of electromagnetic radiation in the visible range. Do the other parts of human body have similar properties as an eye has in relation to photons? The answers to the above questions could help to resolve the two related mysteries concerned with formation of the living matter and amazing efficiency of the solar radiation in therapy, as used, e.g., by ancient Greeks.

We propose a symbolic radiation model which attempts to interpret a so called 'God's Spark' effect. The energy difference between the yellow-green (λ) and red (λ') radiations could be estimated by the relation

$$\Delta E = h\nu_{yellow\text{-}green} - h\nu_{red} = hc/\lambda - hc/\lambda' \simeq 3\times10^{-24}\,\mathrm{J} \simeq 2\times10^{-5}\,\mathrm{eV}\,. \quad (2)$$

In a human body with the mass of 70 kg, the amount of copper is estimated to be about 130 μg. Using the Avogadro number ($N_A \sim 10^{21}$ mole^{-1}), one can estimate that a single dose could carry on the energy of about 10^{-3} J for the processes involving the ground and the exited states of the 3*d* complexes.

4. Conclusions

The *Asterias Rubens* tissue has the spectral PA response similar to those studied earlier for *Truncalariopsis Trunculus and Sea Urchin*. The intensity maximum for the *d–d* transitions is detected at about 570 nm, i.e. in the yellow-green spectral region. This is an important result that may suggest that the influence of photons in this particular energy is essential for the living matter. The water surrounding living organisms plays a significant role in observation of the *d–d* electronic transitions in any living system.

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Анотація. *Зразки тканин морської зірки (Asterias Rubens) підготовлено у вигляді плівок для досліджень їхнього фотоакустичного відгуку. Виявлено широку смугу поглинання у видимій області (пік поблизу 570 нм), а також в ультрафіолетовій області спектру, що відповідає переходам $\pi \rightarrow \pi^*$ і $\pi \rightarrow n$ з переносом заряду. Фотоакустичний спектр у видимій області сильно залежить від розкладу зразка на повітрі. Досліджений фотоакустичний спектр подібний до раніше одержаних спектрів інших живих організмів – Truncilariopis Trunculus і морського їжака. Смуга поглинання в околі 570 нм схожа до смуги спермідину, який має важливе значення в передаванні інформації ДНК. Одержані результати важливі та експериментально підтверджують, що геологічно старі організми особливо інтенсивно поглинають сонячне випромінювання в тій частині спектру, в яких вода прозора.*