Rev.Adv.Mater.Sci. 23(2010) 76-79

# PHOTOACOUSTIC RESPONSE OF SEA URCHIN TISSUE

**N. Guskos[1,2], G. P. Papadopoulos[1], J. Majszczyk[2], J. Typek[2], J. Rybicki[3], A. Guskos[2], I. Kruk[2], K. Aidinis[4] and G. Zolnierkiewicz[2]**

[1]Solid State Section, Department of Physics, University of Athens, Panepistimiopolis, 15 784 Zografos, Athens, Greece
[2]Institute of Physics, West Pomeranian University of Technology, Al. Piastow 48, 70-311 Szczecin, Poland
[3]Department of Solid State Physics, Faculty of Technical Physics and Applied Mathematics, Gdansk University of Technology, Narutowicza 11/12, 80-952 Gdansk, Poland
[4]Applied Physics Section, Department of Physics, University of Athens, Panepistimiopolis, 15 784 Zografos, Athens, Greece

*Received: December 10, 2009*

**Abstract.** A sea urchin tissue in the form of a thick film was prepared for a photoacoustic (PA) study. A broad absorption band in the visible region (with the maximum near yellow/green color at about 570 nm) of the PA spectrum was registered. A very intense PA band arising from the $\pi \rightarrow \pi^*$, $n \rightarrow \pi^*$ charge transfer transition was observed below 350 nm. PA spectra in the visible part of electromagnetic spectrum strongly depended on the decomposition or dehydration processes of the organic matter. The registered PA spectra were very similar to those of other living organisms, Trunculariopis Trunculus and Asterias Rubens obtained earlier. The absorption band near 570 nm was also very similar to that obtained for spermidine copper complexes which play an important role in the transfer of information to DNA. The obtained results might be interpreted as experimental evidence of a law stating that evolutionally older living creatures absorb more intensely that part of the solar radiation that is transparent in water. The human body is composed mostly of water molecules and the same part of solar radiation penetrating deep inside the body might play a crucial role in many physical and chemical processes.

## 1. INTRODUCTION

Two important questions concerning the living matter are still unanswered despite many attempts: the first question concerns the beginnings of life, the second - the beginning of intelligence (thinking). Electromagnetic radiation seems to play a significant role in answer to the first question. Water acts as a filter for electromagnetic radiation, especially for short wavelengths which are important for the $\pi \rightarrow \pi^*$ electron transitions. These transitions are very important for the formation or distraction of organic compounds.

Highly sensitive photoacoustic spectroscopy (PAS) technique has been often used as detector of acoustic waves that originate after electromagnetic irradiation of an investigated sample. Thirty years ago a great progress was made in the trace analysis of condensed matter after developing suitable electronic possibilities [1-3]. PAS is very useful for investigating the matter in vitro or in vivo by non-invasive online measurements. PAS has found frequent use in study of organometallic complexes which are very important for the living matter [4-8]. Biogenic amines including copper(II) complexes (spermine) play an important role in many biological processes [9]. Two absorption bands are observed in PAS, one below 400 nm and the other very broad band with the peak centered at the yel-

Corresponding author: N. Guskos, e-mail: ngouskos@phys.uoa.gr

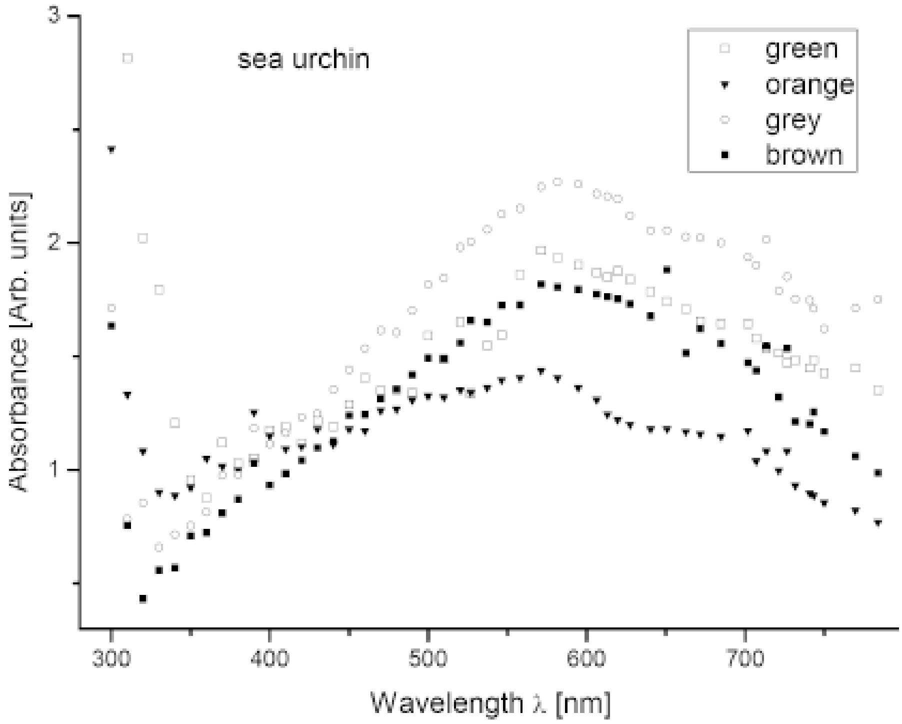


**Fig. 1.** PA spectra of sea urchin tissues. The color of investigated samples is given in the box.

**Table 1.** Maximum of the PA absorption peak for a few sea living organisms and a few important biogenic compounds.

| Sample | Spn323 [5] | Spm [5] | Hematite [13] | Trunculariopsis Trunculus [11] | Asterias Rubens [11] | Sea Urchin |
|---|---|---|---|---|---|---|
| λ [nm] | 567 | 566 | 580 | 570 | 570 | 570 |

low/green region of the electromagnetic radiation [5]. The first band arises from the charge transfer transitions and the second is due to the d-d transitions (with intensities lower by over three orders of magnitude). The PAS absorption lines and their magnetic behavior essentially depend on substitution of distant groups in studied complex as well as on the presence of water molecules [5,9]. The electron d-d transitions in the living matter could take part in the “channel selector” phenomenon and it has been proposed that the yellow/green electromagnetic transition could be important in processes occurring in the living matter [8]. Recently, a very broad PA band with a peak centered at 570 nm has been observed for the living matter tissue obtained from a sea creature [11].

The aim of this work is to study a sea urchin tissue using the PAS method at room temperature. It will be proposed that the photoacoustic effect in the yellow/green radiation could play a very important role in the ignition mechanism operating in higher-level living systems.

## 2. EXPERIMENTAL

PA spectra were measured using a thin film sample of a sea urchin at room temperature before dehydration on conventional equipment comprising a light source of a 1 kW power xenon arc lamp with a ¼ m ORIEL monochromator of a bandpass width of 5 nm at 500 nm. The signal bandwidth narrowing to reduce the low frequency noise was accomplished with the use of lock-in detection. Namely, the light output from the monochromator was mechanically chopped at a frequency of 10 Hz. The acoustic signal was detected by a very sensitive TREVIE M27 microphone attached to the PA cell. The amplitude and phase of the microphone signal relative to the input excitation were recorded on a dual Stanford Research SR830 lock-in amplifier. For an averaging of 20 modulation periods, the signal-to-noise ratio was at least 50 for a particular incident light wavelength, representing an approximately five-fold improvement over the unmodulated case. All the data was very good at reproducibility. The raw amplitude and phase of the sample signal were normalized for the PA spectrum of a graphite blackbody reference in order to correct the modulation frequency dependence of the thermal diffusion length [12].

## 3. RESULTS AND DISCUSSION

Fig. 1 presents the PA spectra of four samples of a sea urchin tissue taken from the surface of earwig. Four samples with different surface colors: green, orange, brown and gray were measured by PAS to obtain the PA response in different regions of electromagnetic radiations. An intense and broad absorption band in the visible region was recorded for all four samples with peak at 570 nm. Several times more intense PA spectrum, arising from charge transfer transitions ($\pi \rightarrow \pi^*$, $n \rightarrow \pi^*$) was observed below 350 nm. After dehydration processes a similar behavior of PA spectrum was recorded as in [8]. Some differences between green sample and other samples lay in the fact that the pigments of the earwig surface could pass the absorption charge transition band. The PA spectra in the visible region depended strongly on water deficiency in the tissue and the dehydration process made the broad absorption band disappear and the observed differences appeared.

The heat generated through the nonradiative transitions in the sample after absorption of the periodically varying incident light generates the PA spectra. The intensity ($I$) of PA spectra is expressed by the relation: $I = \gamma k A_{abs}$ where $\gamma$ is a coefficient related to the sample's thermal properties and the spectrometer's characteristic, $k$ is the probability of nonradiative transition from an exited state, and $A_{abs}$ is the sample's absorbance [14]. Two kinds of relaxation processes should be considered: radiative and nonradiative after excitation of electrons by electromagnetic radiation. The observed PA spectra are due to the nonradiative processes which could involve directly the localized levels of ions or indirectly the molecular levels.

Copper(II) and iron(III) complexes are very important in living systems and their d-d electron transitions are actively involved in different physical/chemical processes. The intensity peak observed in PA spectrum appears in the visible region at about the green/yellow region (Table 1). The spermidine copper(II) complexes, one of the main polyamine components in protein, take part in the processes of transferring information to DNA and the electron transitions between atomic levels (ground state and excited states) of copper(II) could play the role of a very sensitive "channel selector", especially for ions of transition metals with extended wave functions [5]. PAS in association with electron paramagnetic resonance method could provide more detailed information about the electronic structure of investigated complexes affected by the crystal field interaction, intermolecular transfer energy and dynamical radiative/nonradiative phenomena involving different relaxation processes. The Trunculariopsis Trunculus and Asterias Rubens tissues PA absorption spectra are similar as for the sea urchin tissue from the earwig surface [11]. The fact that very similar PA spectra are obtained for different see living systems (very ancient) suggests that that particular electromagnetic radiation could play a special role in the dynamical bioactive processes in the living matter.

Even a small amount of energy carried by photons could produce an igniting effect, releasing very intense reactions in an irradiated system [11]. A symbolic radiation model has been proposed where the photoacoustic response by yellow/green and red electromagnetic radiation via non-radiation transition could be a very important reaction during evolution of the living matter. The value of energy difference between implicated energy levels estimated from the relation $\Delta E=(h\nu_{yellow/green}-h\nu_{red})$ is about $10^{-3}$ J for copper(II) complexes contained in an average human being [11]. This mechanism could provide a lot of energy over a prolonged period of time. If iron(III) complexes are considered the heating effect could be even more intense. Thus in this work we propose an ignition mechanism operating in the living matter with the radiation of electromagnetic waves playing a similar role as the sparking plug in a car engine.

## 4. CONCLUSIONS

PA study of sea urchin tissue revealed that the most intense photoacoustic response in the visible region of electromagnetic radiation is at about yellow/green color. The intensity of PA spectrum strongly depended on the dehydration process. It is suggested that an ignition mechanism could exist in the living matter involving radiation processes operating most effectively in the visible region of electromagnetic waves.

## REFERENCES

[1] A. Rosencwaig and A. Gersho // *J. Appl. Phys.* **47** (1976) 64.

[2] A. Rosencwaig, *Photoacoustic and Photoacoustic Spectroscopy* (Wiley, New York, 1980).

[3] *Progress in Photothermal and Photoacoustic Science and Technology*, ed. by A. Mandelis (Elsevier, New York,1992).

[4] R. Wu and Q. Su // *J. Mol. Struc.* **559** (2001) 195.

[5] N. Guskos, G.P. Papadopoulos, V. Likodimos, G.L.R. Mair, J. Majszczyk, J. Typek, M. Wabia, E. Grech, T. Dziembowska and T.A. Perkowska // *J. Phys. D: Appl. Phys.* **33** (2000) 2664; *J. Appl. Phys.* **90** (2001) 1436; *NATO Science Series: II: Mathematics, Physics and Chemistry* **76** (2002) 519; *Rev. Adv. Mat. Sci.* **14** (2007) 97.

[6] Y. Yang and S. Zhang // *Spectrochim. Acta A* **59** (2003) 1205; *J. Phys. Chem.* **64** (2003) 1333.

[7] Y. Yu and Q. Su // *J. Photochemistry and Photobiology A* **155** (2003) 73.

[8] N. Guskos, G. Papadopoulos, J. Majszczyk, J. Typek, M. Wabia, V. Likodimos, D.G. Paschalidis, I.A. Tossidis and K. Aidinis // *Acta Phys. Pol. A* **103** (2003) 301; *Spectroscopy Letters* **39** (2006) 21; *Rev. Adv. Mater. Sci.* **11** (2006) 59.

[9] L. Lomozik and A. Gasowska // *J. Inorg. Biochem.* **62** (1996) 103; *J. Inorg. Biochem.* **63** (1996) 191; **72** (1998) 37.

[10] N. Guskos, S. Glenis, V. Likodimos, J. Typek, H. Fuks, M. Wabia, R. Szymczak, C. L. Lin and T. A. Perkowska // *J. Appl. Phys.* **93** (2003) 9834.

[11] N. Guskos, K. Aidnis, G. J. Papadopoulos, J. Majszczyk, J. Typek, J. Rybicki, and M. Majszczyk // *Optical Materials* **30** (2008) 814*; International Workshop on Advanced Spectroscopy and Optical Materials, 13-17 July 2008, Gdańsk, Poland*.

[12] G. J. Papadopoulos and G. L. R. Mair // *J. Phys. D: Appl. Phys.* **25** (1992) 722.

[13] N. Guskos, G.P. Papadopoulos, V. Likodimos, S. Patapis, D. Yarmis, A. Przepiera, K. Przepiera, J. Majszczyk, J. Typek, M. Wabia, K. Aidinis and Z. Drazek // *Mat. Research Bull.* **37** (2002) 1051.

[14] M. J. Adams, J. G. Highfield and G. F. Kirkbright // *Anal. Chem.* **52** (1980) 1260.