Journal of the Serbian Chemical Society
JSCS-info@shd.org.rs • www.shd.org.rs/JSCS
J. Serb. Chem. Soc. *88* (11) 1119–1123 (2023) *Note*
JSCS–5684 Published 11 November 2023

NOTE

Thermal investigation of material derived from the species *Apatura iris*

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(Received 27 March, revised 20 April, accepted 21 July 2023)

Abstract: The material's size and shape influence its physical, chemical and mechanical properties. This study describes an investigation of natural photonic structure of the butterfly's wing, mainly composed of chitin. The effect of corrugations at the nanoscale on material's optical response is unambiguously revealed in the presented thermal measurements. Furthermore, the presented study shows the possibility of exploiting holography to monitor dynamics *in situ*.

Keywords: *Apatura iris* butterfly; biopolymer chitin; sensing dynamics *in situ*.

INTRODUCTION

Apatura iris butterfly's wing used for this study is shown in Fig. 1.[1–3] Butterfly wings are made of the biopolymer chitin,[4] with general formula $(C_8H_{13}O_5N)_n$. The chitin composition of different parts of the butterfly's body is described elsewhere.[5] The paper revealed that chitins from different parts are chemically very similar, but with significant differences in their surface morphologies.

In this study the surface morphology is characterized by JEOL JSM 6610 LV (Japan), scanning electron microscope (SEM) in conjunction with the energy dispersive spectroscopy (EDS) detector model X-Max large area analytical silicon drift connected with INCA Energy 350 Microanalysis (detection of elements $Z \geq 5$, detection limit: ~ 0.1 mas. %, resolution, 126 eV).

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https://doi.org/10.2298/JSC230327042P

Micro-elemental (EDS) analysis of *A. iris* butterfly's wing in two selected points, scale cell and the wing membrane, given in Fig. 2, showed the presence of carbon (C), oxygen (O) and nitrogen (N) originated from chitin. As it can be seen, the content of C, N and O slightly differs in scale cell and the wing membrane, indicating different chitin compositions in different surface structures. The presence of gold (Au) originates from the sample preparation for SEM/EDS analysis.

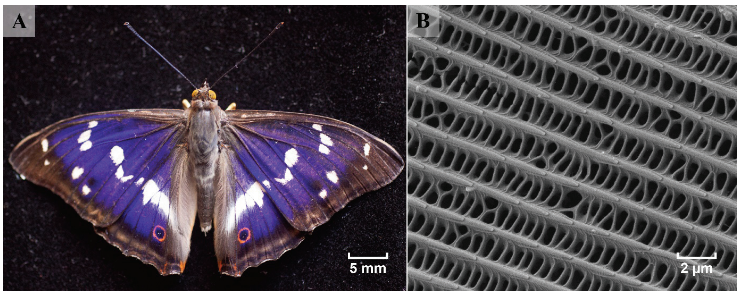

Fig. 1. *Apatura iris* butterfly: A) an optical image of the whole butterfly; B) SEM image of a ground scale of the wing.

Thermal camera "FLIR A65" (640×512 pixel, thermal resolution 50 mK, focal length 13 mm, field of view angle 45°×37°) is used to measure the temperature of the sample after the irradiation with laser. Later, holographic method will be used to characterize the interaction of the photonic structure with light.[6,7] A scheme of the holographic setup that is going to be used in the experiment is described elsewhere.[8] The setup will allow the simultaneous recording of deformation and temperature.

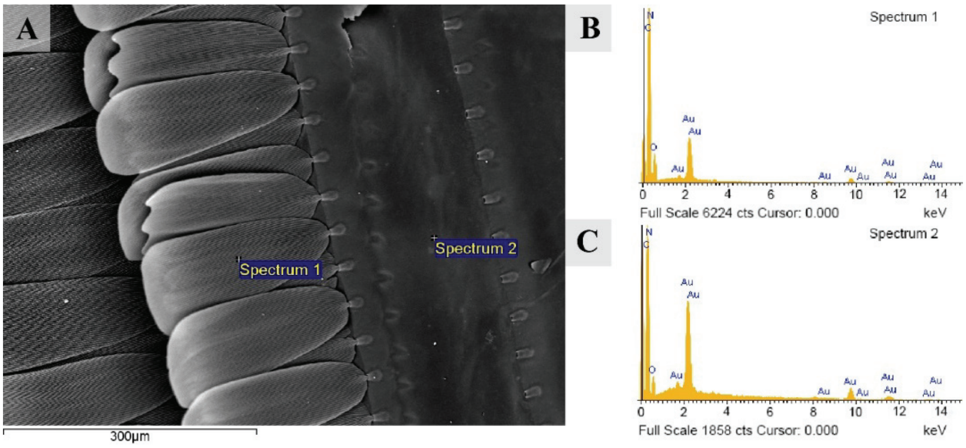

Fig. 2. A) SEM image of the scale cells and the wing membrane of *Apatura iris* butterfly's wing; B) EDS analysis of the wing at the scale cell (Spectrum 1); C) EDS analysis of the wing at the wing membrane (Spectrum 2).

RESULTS AND DISCUSSION

Six samples are individually irradiated by external lasers operating at four different wavelengths (450, 532, 660 and 980 nm) keeping the power and illuminated spot diameter constant at 1 mW and 1 mm, respectively. The thermal measurement is made over the period that includes the time before the start of heating (interaction with laser), during the heating itself, and after the irradiation stopped, more precisely the cooling of the sample.

The difference in temperature due to heating by laser at various wavelengths has been observed. The highest temperature is caused by the interaction with 450 nm light, while the lowest is recorded for the wavelength of 532 nm. However, the complete reversible cooling (reaching the initial state) has not been observed for the wavelengths of 450 and 980 nm. A complete return to the initial state is observed for the wavelengths of 532 and 660 nm.

Analyzing data in depth is vital to link thermal measurement with the reflectance spectrum[9] (Fig. 3A) and the heating/cooling process as a function of time. Fig. 3B is showing the change in temperature over time, as a function of wavelengths.

Finally, the thermal measurements match the reflectance pattern and the heating/cooling dynamics as a function of time. It is evident that the temperature maximum in Fig. 3B at 450 nm corresponds to the reflectance maximum. The maximum value recorded at 450 nm is followed by 660 nm, while the reflectance is at minimum around 532 nm.

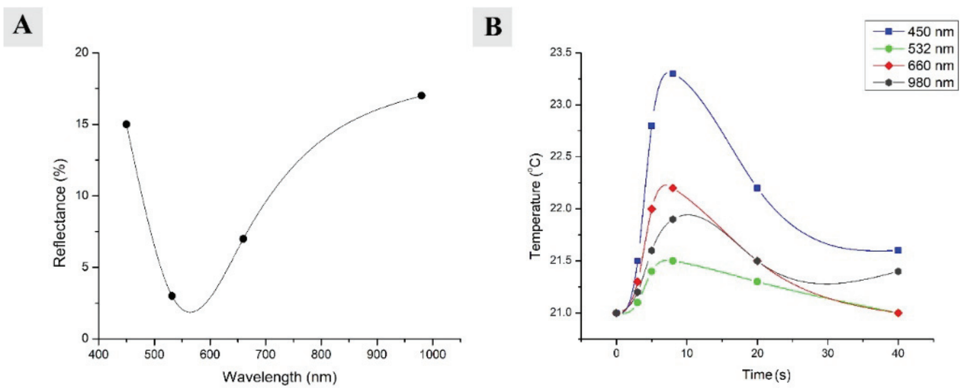

Fig. 3. A) *Apatura iris* reflectance spectrum; B) cooling dynamics as a function of time after the irradiation with four different wavelengths. The lasers have been switched on at 2nd s and switched off at 9th s in order to record heating/cooling dynamics. (Reflectance spectrum is taken from the reference 9).

The only observed discrepancy refers to the wavelength which does not belong to the visible part of the spectrum and for which completely different rules apply. The photon at 980 nm carries the energy that cannot cause any electronic transitions but can affect the vibrational one within the system as well as thermal management by vibrational relaxation.

The observed asymmetric heating/cooling response scales perfectly with the measured reflectance response.

CONCLUSION

This paper presents an investigation of *Apatura iris*'s natural photonic structures under the light irradiation at different wavelengths. The correlation between the reflectance at different wavelengths and thermal response is revealed.

Acknowledgements. B.K., D.V., and B.B. acknowledge funding provided by the Institute of Physics Belgrade, through the institutional funding by the Ministry of Education, Science and Technological Development of the Republic of Serbia. Additionally, B.K. acknowledges support from F.R.S.-FNRS. M.P. acknowledges support from the Ministry of Education, Science and Technological Development of the Republic of Serbia (Grant No. 451-03-47/2023-01/200026). D.M. and A.R. acknowledges support from Ministry of Science, Technological Development and Innovation of the Republic of Serbia Contract number: 451-03-47/2023-01/200051. All authors acknowledge the support of the Office of Naval Research Global through the Research Grant N62902-22-1-2024.

ИЗВОД

ТЕРМАЛНО ИСПИТИВАЊЕ МАТЕРИЈАЛА ИЗ ЛЕПТИРА *Apatura iris*

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Облик и величина материјала утичу на његове физичке, хемијске и механичке особине. Ова студија описује проучавање природних фотонских структура, крила лептира која се претежно састоје од полимера хитина. Ефекат нано коругације на оптички одговор материјала је презентован кроз термална мерења. Такође је представљена могућност примене холографске методе за праћење динамике *in situ*.

(Примљено 27. марта, ревидирано 20. априла, прихваћено 21. јула 2023)

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