ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Role of photonic crystals in Red Palm Weevil, Rhynchophorus ferrugineus Olivier coloration.

Mohamed Ragaei, and Al-kazafy H Sabry*.

Pests and Plant Protection Dep. National Research Centre, Cairo, Egypt.

ABSTRACT

Under scan electron microscope the red palm weevil (RPW) adult body (head, wings and abdomen) containing a nanostructure called photonic crystals. The photonic crystals absorb the white light in different wavelength to reflect the color of adult. These colors are due to arrays of nanoscale structures that scatter light only at specific wavelengths and at certain angles. So, it can say that the color of RPW adults was due to the photonic crystals structure reflection not due to melanic pigments. The function of photonic crystals not only produces the color in adult of RPW but also to guide, store and amplify light to use it in vital function in this insect. The results showed that the photonic crystals are spreads on the upper wings, the head and abdomen. This photonic structure can be also used in insect taxonomy. Some insects use this nanostructure in camouflage, mimicry and signalling. The results showed also, the scales of the upper wing not straight of the wing membrane. It made an angle (20 - 30°). This angle allows the white light to reflect and make the color wing. EDX was carried out to the upper wings of RPW. The results showed that the upper wings contain semiconductor materials such as Carbon (65.81%) and Silicon (0.57%).

Keywords: Photonic crystals, red palm weevil, coloration, nanoscales

**Corresponding author*

INTRODUCTION

It was known that color; resulting from the light reflected by an object and the ptical system of the organism see it. If the organism reflects all wavelengths of light, white color only was produced. On the other hand, if the organisms absorb all wavelengths, the black color only was appears. However, if organisms absorb all wavelengths apart from one region of the spectrum, it has a color of this region (the length of visible light from 380 to 760 nm). The reflected color which is producing colors depends on the viewing angle of light, which in turn involved of the apparent spacing of the structures [1]. Producing coloration also is responsible for some other organism's coloration such as the blues and greens of the feathers of many birds, as well as many butterfly wings and beetle wing-cases (elytra) [2].

In nature the colors are produced by two mechanisms due to physical interaction of light with nanostructure called photonic crystals [3].

Historically, in the late 1980s the modern field of photonic crystals was born, by John and Yablonovitch [4] [5]. The use of photonic crystals made of semiconductor materials, like silicon (Si), enable the integration to microelectronics. The optical properties of a photonic crystals can be tuned by changing external conditions of the PC, e.g. by alteration of the refractive index contrast by infiltration of the PC structures with liquids or other materials [6].

Chitin; a principal component in insect cuticle which consists of very complex forms and three dimensions photonic crystal have been shown to occur in many insects such as butterflies [7]. These photonic crystals also found in weevils (Brazilian diamond weevil) and beetles [8]. The same authors also found that the weevil bears scales, dispersed in hemispheric cavities aligned on the elytra. These scales reflect and overlapping variety of colors.

Photonic crystals structures PCs are formed as nanostructure size in the chitin of the some insects wing scales. The sizes of these structures approximately are 150 nanometers and about the same distance apart. These nanostructures crystals also are arranged with regular manner in small patches; all neighboring patches contain arrays with differing orientations. This result clears that these emerald-patched scales reflect green light evenly at different angles instead of being iridescent [9].

The main aim of this work is demonstrate the role of photonic crystals in red palm weevil coloration

MATERIALS AND METHODS

Insect test

The adults of red palm weevil were obtained from the Plant Protection Research Institute, Giza, Egypt.

Electronic microscope

This work carried out in the electronic microscope unite, central laboratory, National Research Centre. The adults of red palm weevil were killed by chloroform solvent, cleaning manually and freezing. Freezing of the sample very quickly was instead of fixing it. This technique providing the sample stays cold enough, this 'locks up' the water and prevents it from evaporating inside the microscope. After that the wings, head and abdomen of red palm weevil adults were separated and coated by gold. Coating of samples with gold is required in the field of electron microscopy to enable or improve the imaging of samples. Creating a conductive layer of metal on the sample inhibits charging, reduces thermal damage and improves the secondary electron signal required for topographic examination in the SEM. All images were taken under low vacuum scanning electron microscope.

Refractive index (n) is equal to the velocity of light (*c*) of a given wavelength in empty space divided by its velocity (v) in a substance.

$$N = \frac{C}{v}$$

ISSN: 0975-8585

The device used was V-700 Series UV-Visible/NIR Spectrophotometers, JASCO, made in Japan. This work was achieved in Laser technology Unit, Spectroscopy department, Physics division, National Research Centre, Egypt.

EDX (Energy Dispersive X- ray) was conducted to the upper wings to know the main component of wings elements.

RESULTS AND DISCUSSION

The upper wings, head and abdomen of red palm weevil (RPW), *Rhynchophorus ferrugineus* adults are investigated under scan electronic microscope.

The abdomen of adults

The figure 1 shows that the scale of the abdomen not flat but it's diagonal. This situation allows to the white light to reflect and gives more than color to the abdomen. Each part of the scale can gives color different of other. This variation and overlapping of colors can be gives the abdomen color of the red palm weevil in figure 1. The reflective angle is different in the top part of scale from the bottom (Fig. 2). The reflective angle is the main factor affecting on refractive index. This result was obtained also by Pantelić *et al*. (2011)[10] with the wing scales of butterfly. The authors studied that the butterfly wings spectroscopically and its relation to the illumination and observation angles. The male structural color of butterfly was visible in flight only within a certain range of angles**.** The iridescence of *Apatura iris* was appeared in angle at18 degrees [11]. The authors found that UV reflectivity makes the butterfly male was very visible to its own species and less visible to all other organisms, especially the predators of this insect. By this way the insect can be protect it self from any natural enemies. This means that the insect uses this strategy in camouflage. Starkey and Vukusic (2013)[12] recorded that a reflectance maximum will shift to shorter wavelength at larger angles.

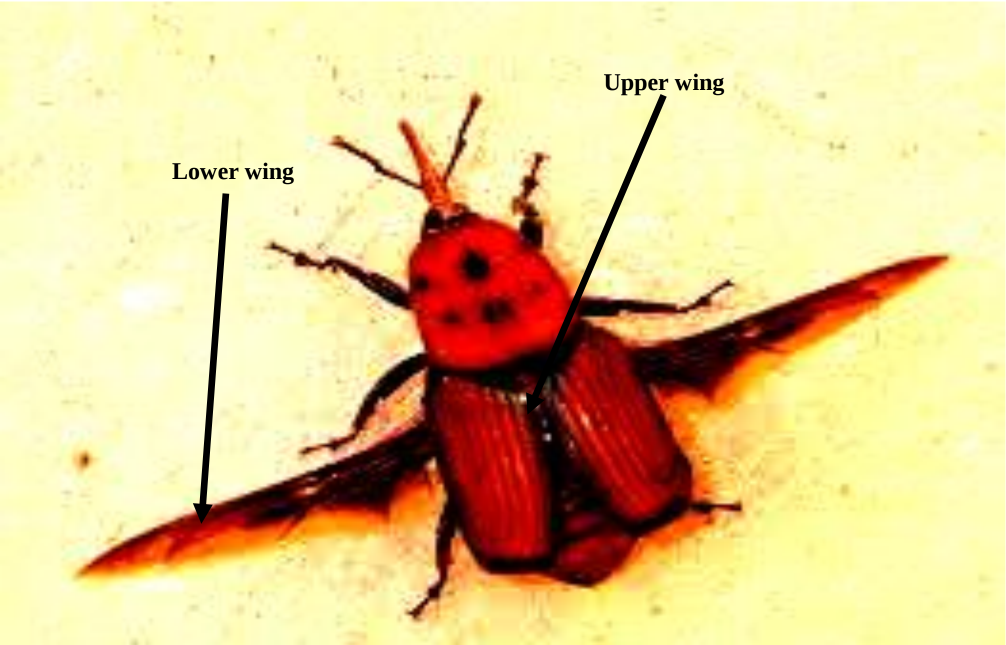

Fig. 1. Adult of Red Palm Weevil

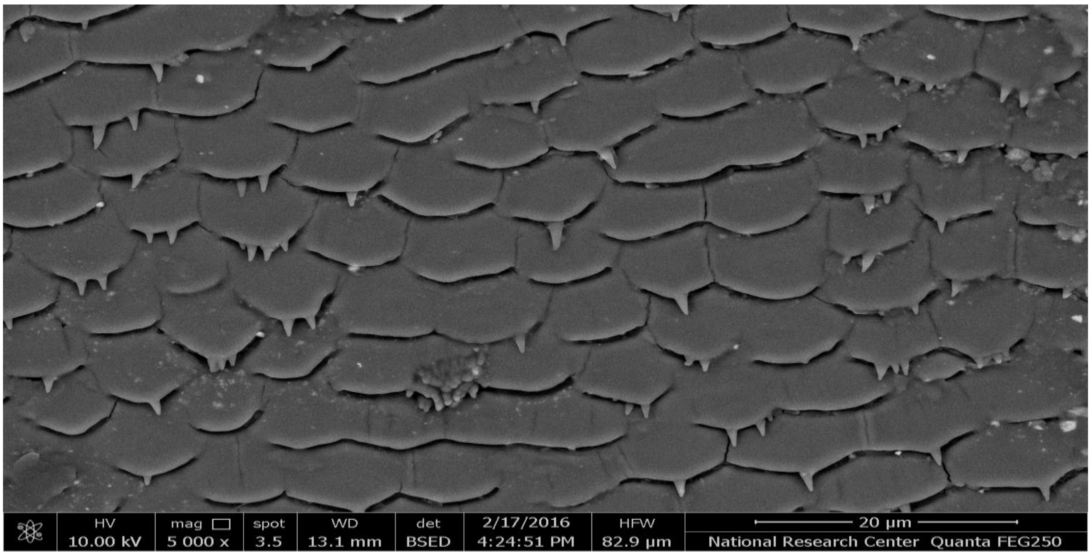

Fig. 2. SEM of the abdomen scales of RPW. All scales are diagonal not flat

The upper wing of adult

As shows in Figure 3 the upper wing of RPW consists of many layers. Each layer can be reflects the light in specific wavelength and each layer has a specific refractive index. This

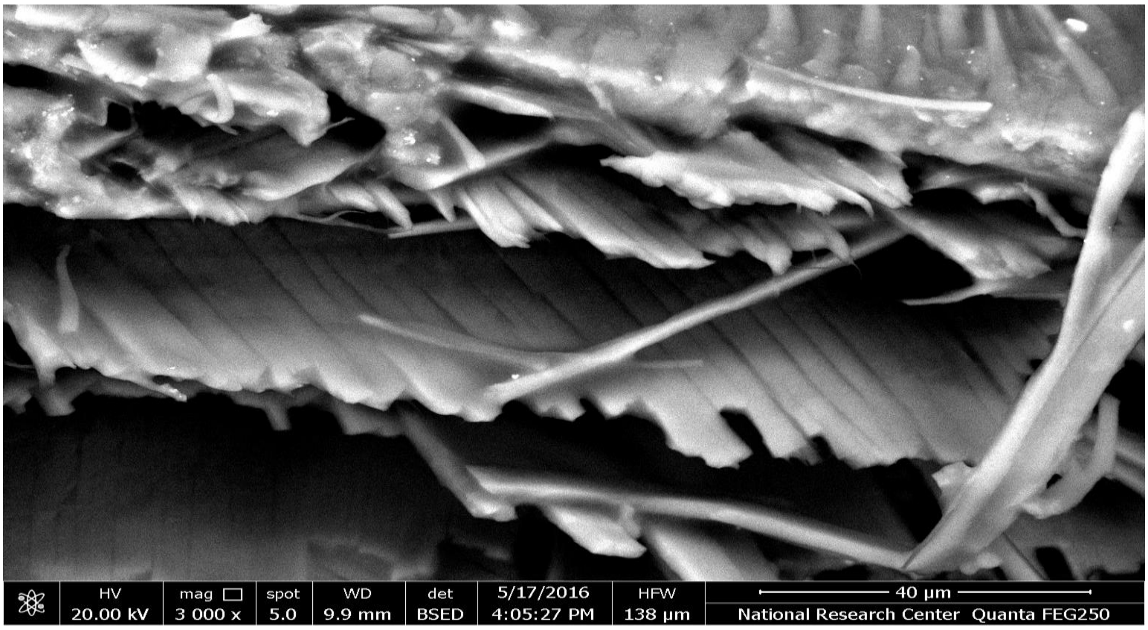

Fig. 3. Multi layers in the upper wings of the Red Palm Weevil

reflection makes overlapping in wing colors. This result shows that multi layer play an important role in insect coloration. By using EDX (Energy Dispersive X-Ray Analysis) the upper wing contains many elements as shown in Figure 4 and Table (1). The most important element is silicon (0.57%) which considered the main element in photonic crystals and solar cells.

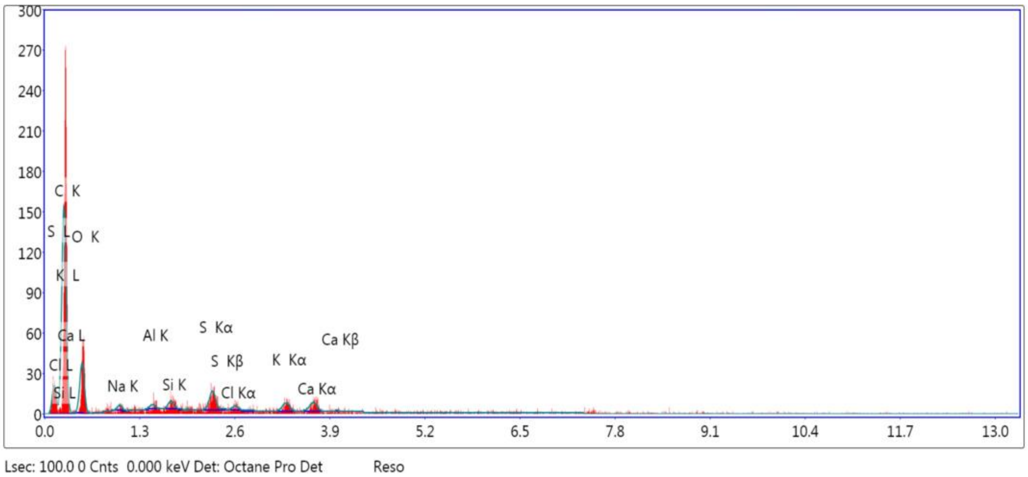

Fig. 4. The EDX of the upper wings

Table 1. Elements in upper wing

Element	Weight %	Atomic %	Net Int	Error %
C K	65.81	73.86	22.17	8.28
O K	27.96	23.56	5.84	15.83
NaK	0.76	0.45	0.61	71.77
AlK	0.34	0.17	0.62	69.58
SiK	0.57	0.28	1.2	55.68
S K	1.59	0.67	3.05	17.6
ClK	0.45	0.17	0.77	62.99
K K	1.09	0.38	1.59	31.71

Shin *et al*. (2003)[13] cleared that silicon element has a high transparency in the infra-red region, and the well-established processing technologies, would be a standard material for realization of photonic crystal-based on integrated optics. In this way, by increasing of ultra compact optical or integrated circuits, photonic crystals promise to play a good role in near future with high density optical integrated circuits. This result may be clears that some insect imitate this phenomenon. Yun *et al*. (2014) [14]cleared that silicon has been a major component in photonic crystal structures because it has a high refractive index and the Si-based fabrication process is well established. Ragaei and Sabry (2013)[15] found that silicon in the upper wing of sphingid moth adult and play an important role in solar cells.

Carbon also, is existed in the upper wing (65.81%). Carbon is a main element in photonic crystals fabrication. Photonic crystals (FCs) based on carbon nanofibers (CNFs) are considered a promising system for the development of tunable photonic crystals in the visible range [16]

Refractive index of the outer layer of the upper wing is determined in figure (5). The refractive index is determined through the wavelengths ranged from 250 - 2500 nm. The wavelength of visible light (approx. 380–760 nm), so the refractive index in this range is only determined. Figure (5) shows that the refractive index of outer layer are ranged from 1.06 to 1.11. The Maximum reflective index value (1.11) is observed in the UV part of the spectrum (500 nm) as shown in Figure (5). On the other hand, McNamara *et al*. (2014)[17] found that the maximum refractive index value for the extant weevil scales was 1.37, corresponding to a respective chitin volume fraction of 0.44 and 0.65. Land (1972)[18] stated that the reflection of color obtained

ISSN: 0975-8585

from a multilayer structure depends on the refractive index of each layer and its periodicity. The result was confirmed that the layers with a high optical thickness reflect longer wavelengths than thinner one. Arwin *et al*. (2013)[19] found that the main constituents of insects cuticle in general are protein and chitin, so the values of refractive index are range from 1.4 to 1.8 in visiblespectral region. In this work the exoskeleton was chosen because the bottom (inner) part is the endocuticle which is softer than the exocuticle. But the exocuticle have many layered structure. Arwin *et al*. (2013)[19] cleared that the exocuticle is around 6-8 µm thick if the effect of an oblique cut is taken into account. Tamanis *et al*. (2012)[20] investigated that the nanostructures built of chitin in *Phyllobius maculicornis* weevil by electron microscopy and reflectance spectroscopy. The multiple layers forming which are composed from micro- and nanostructures were observed on the surface of scale as well as on three-dimensional nanostructural lattice inside the scale. The authors believed that the interaction among of these three structures may be forming the coloration of the beetle.

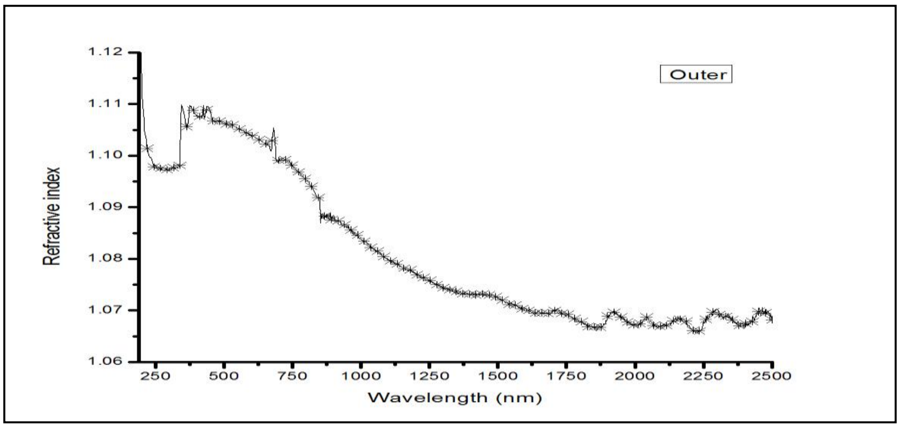

Fig. 5. Refractive index of the outer layer of the upper wing of the Red Palm Weevil adult

The head of adult

The scales in the head of RPW adult are also diagonal (Fig. 6) as the scales in the abdomen. These diagonal scales reflect the white light in different angle and make variation in reflection and overlapping in color. This may be responsible to the color of head.

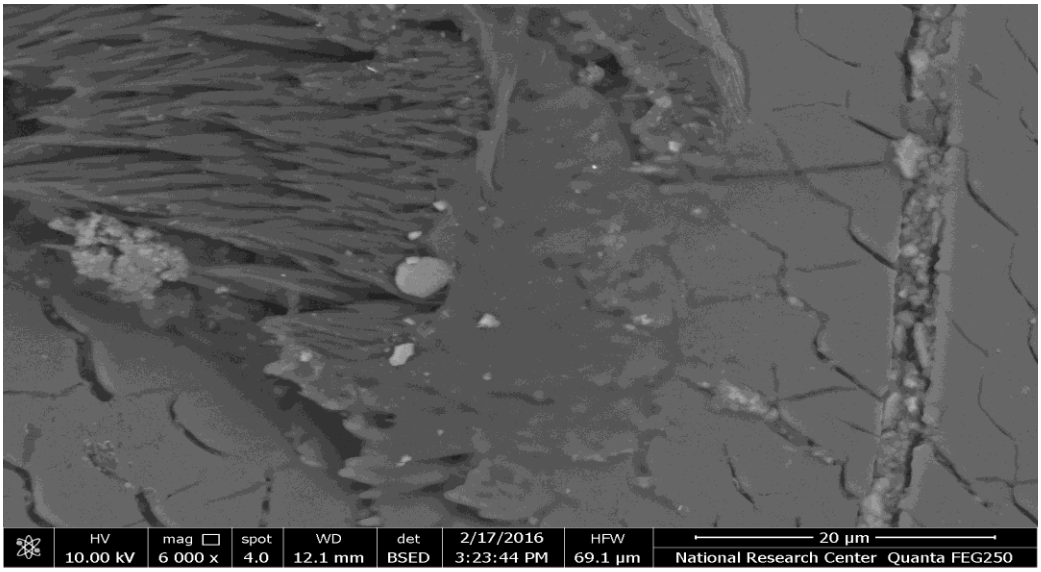

Fig. 6. SEM in the scales of RPW Adult head

Finally, this work cleared that the color of red palm weevil adult not due to pigmented color but photonic crystals action. The color of wings may be due to the multilayer effects and the color of body due to the diagonal scales. The upper wings consist of many elements as silicon and carbon (semiconductor elements). The weevil can be using this photonic crystal in camouflage from its natural enemies.

ACKNOWLEDGMENTS

We are grateful to Dr. Ayman M. Mostafa, Laser Technology Unit, Spectroscopy Department, Physics Division, National Research Centre, Egypt for his helping in determining of refractive index of some specimens. This work was financially supported by National Research Centre, Cairo, Egypt, Project NO. **100715P**

REFERENCES

[1] Margareta W 2002; 1 (2): 1–12.
[2] Philip B 2012; 306 (5): 74–79.
[3] Shawkey MD, Saranathan V, Palsdottir H, Crum J, Ellisman MH, Auer M, Prum RO 2009; 6: S213-S220.
[4] Yablonovitch E 1987; 58:2059–62.
[5] John S 1987;58:2486–9.
[6] Hall N 2003; 2639-2643
[7] Berthier S 2006; 1st edn. Springer.
[8] Vigneron JP, Simonis P 2010; 181–218.
[9] Vukusic P 2004; 17 (2): 35–39.
[10] Pantelić D, Ćurčić S, Savić-Šević S, Korać A, Kovačević A, Ćurčić B, Bokić B 2011; 19(7): 5817-5826
[11] Giraldo MA, Yoshioka S, Stavenga DG 2008; 194(3), 201–207
[12] Starkey T, Vukusic P 2013; 2(4): 289–3 07
[13] Shin JH, Han HS Seo SY 2003; Kluwer Academic Publishers, Trento, Italy, pp 482.
[14] Yun JG, Jung DH, Kim HJ, Choi WS, Hong BY, Noda S, Song BS 2014; 126: 99–102
[15] Ragaei M, Sabry KH 2013; 1(3):10-26
[16] Rehammar R, Kinaret JM 2008; 16(26):21682–21691
[17] McNamara ME, Saranathan V, Locatelli ER, Noh H, Briggs DEG, Orr PJ, Cao H 2014; 11: 20140736.
[18] Land MF 1972; 24, 75–106.
[19] Arwin H, Berlind T, Johs B, Järrendahl K 2013; 21(9): 22645- 22656
[20] Tamanis E, Mihailova I, Valainis U, Gerbreders V 2012; 12 (3): 58 – 64.