Structural and optical analysis of the photonic crystal in *Parides sesostris* wing scales

Shinya YOSHIOKA[1]

[1] *Graduate School of Frontier Biosciences, Osaka University*

Contact email: syoshi@fbs.osaka-u.ac.jp

It is known that the wing scales of several butterfly species contain photonic crystals that produce brilliant structural colors. The Emerald-patched Cattleheart butterfly, *Parides sesostris*, is such an example. The bottom part of the green wing scale consists of the gyroid-type photonic crystal with a lattice constant that is comparable with the wavelength of light [1]. The photonic crystals found in the butterfly wing scales are not usually observed as a single crystal that spreads over the entire scale, but they are separated into many small domains with different crystal orientations. Thus, it is expected that the color becomes different from domain to domain, because a photonic crystal generally has band gaps at different frequencies depending on the direction of light propagation. In fact, the matte green scales of *Cyanophrys remus* butterfly, which are also known to possess the gyroid-type photonic crystals, have been observed as gleaming patches with different colours and intensities under an optical microscope [2]. On the other hand, the wing scale of *P. sesostris* is observed to be uniformly green in spite of the multi domain structure. The domain structure becomes noticeable only when the scale is observed under crossed polarizers: the first polarizer makes the illuminating light linearly polarized and the scale is observed through the second polarizer that has the perpendicular polarization to the first one.

In this study, we carefully investigated the structure of the wing scale of *P. sesostris* to clarify how the multidomain photonic crystal produces the uniform color. The photonic crystal was carefully observed by using scanning and transmission electron microscopes. In particular, the upper part of the scale structure was removed so that the top surface of the photonic crystal could be directly observed. These observations revealed that the crystal orientations of different domains are not perfectly random, but there is a preferred crystal orientation that is aligned along the surface normal of the scale [3]. In addition, we calculated the polarization dependent reflectance from the gyroid-type photonic crystal in the case that light is incident from the preferred crystal orientation. It was found that the calculation moderately reproduce experimentally observed reflectance spectra.

[1] K. Michielsen and D. G. Stavenga, J. R. Soc. Interface, 2008, 5, 85-94.
[2] K. Kertész et al., Phys. Rev. E, 2006, 74, 021922.
[3] S. Yoshioka et al., J. R. Soc. Interface, 2014, 11, 20131029.