Chirality of gyroid-type photonic crystals in the scale of *Teinopalpus Imeperialis*

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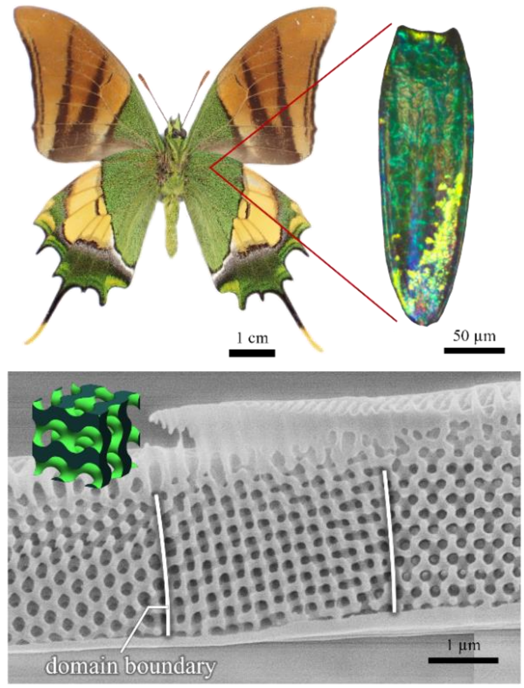
The intricate nanostructures responsible for vivid structural colors in certain insects have attracted attention. The wing scales of butterflies and the scales of beetles are known to possess photonic crystals based on mathematically defined minimal surfaces. While many weevils have diamond-type minimal-surface-based photonic crystals within their scales, some butterflies, such as *Callophrys rubi*, have gyroid-type minimal-surface-based photonic crystals. These nanostructures exhibit vivid colors known as structural colors due to their periodicity, and research on their optical properties and applications in materials science has been intensively conducted.

However, how organisms form such complex structures remains a challenging question. Gyroid-type photonic crystals are chiral, and thus have left-handed (LH) or right-handed (RH) helical structures, depending on which of the two spaces separated by the minimal surface is filled with cuticle. It has been reported that LH gyroid-type photonic crystals in the scales of *Callophrys rubi* are found to be more frequent than RH gyroid-type photonic crystals[1]. Another butterfly (*Thecla opisena*) with gyroid-type photonic crystals inside its scales is similarly indicated to have more LH gyroid-type photonic crystals than RH ones[2]. This suggests that when the butterfly forms gyroid-type photonic crystals, the direction in which the cuticle is filled is unbalanced. The chiral imbalance provides valuable insights into the formation mechanism of the gyroid structure.

In this study, we investigate the chirality of the gyroid-type photonic crystal in another butterfly (*Teinopalpus Imeperialis*), which possesses gyroid-type photonic crystals. The distinctive green coloration of *Teinopalpus Imeperialis*, as shown in Figure 1(a), originates from the periodic network structure inside the scales, which are known to be gyroid-type photonic crystals (Figure 1(b)). The crystals inside the scales are polycrystalline and are composed of microcrystals that are called domains, which are assembled without gaps between them. A recent previous study using small-angle X-ray scattering has revealed that the scales on the dorsal side have the [111] direction of the gyroid structure facing the scale surface [3]. The [111] direction of the gyroid structure has through holes and is comparatively easy to distinguish the orientation of the helix. Thus, we prepared the frontal section of the scale and observed the section of the nanostructure. We report the results of our investigation of the chirality of the gyroid structures.

(a)



(b)

Figure 1: (a) Photograph of *Teinopalpus Imeperialis* and micrograph of a green scale. (b) Electron micrograph of a cross-section of the scale. The inset shows a schematic diagram of a gyroid-type photonic crystal.

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[2] B. D. Wilts, *et al.*, *Sci. Adv.*, **3**, e1603119, (2017).
[3] A. Singer *et al.*, *Sci. Adv.*, **2**, e1600149, (2016).