Photonic crystal structure of wing scales in Thai butterflies, *Euploea mulciber* and *Troides aeacus*

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Abstract

We investigated the microstructure of wing scales of male butterflies (*Euploea mulciber* and *Troides aeacus*) collected in Thailand as photonic crystal in nature. Stereo microscope observation indicated that the blue background of *E. mulciber*'s forewing is blue and dark blue iridescence (B1and B2). In contrast, the background of *E. mulciber*'s hindwing is area without iridescence. Field emission scanning electron microscope (FE-SEM) observation revealed that bule background (B1 and B2) and white spots (W) are almost the same in structure and they have scales with highly tilted, triple-layered arrangement of the cutitles, which causes iridescence due to multiple interference between the layers. The *E. mulciber*'s hindwing has pale, brown and dark brown areas without iridescence. We found that B3 is covered with strange long scales. For male *T. aeacus*, stereo microscope observation showed that the yellow area Y1 on the hindwing is covered with yellow transparent scales. FE-SEM disclosed that they have cuticles standing perpendicularly to substrate frame. The hues of yellow may be caused by scattering of the incident light from substances with pigment.

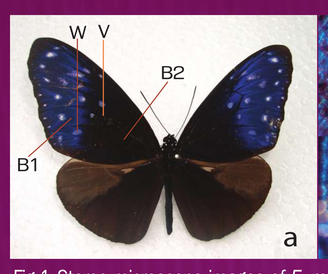
Inroduction

Photonic crystals are periodic optical nanostructures which occur in nature and in various form,the wing scales of butterflies have lately attracted considerable attention as photonic crystals for an excellent tool to manipulate light. The wing scales of butterflies are elaborated and repeated structures that related to producing the colour and light. Matějková-Plšková, *et al.* (2009) found characteristic the purple-blue of the male wing scales of *Sasakia charonda* butterflies are ascribed to the combination of the structural and chemical colouration with melanin[1]. Therefore, we are interested investigation the microstructure of wing scales of male butterflies collected in Thailand as photonic crystal in nature, encouraged by the recent studies on wing scales in Japanese butterflies of *Sasakia charonda*[1,2].

Materials and Methods

Two species of male butterflies (*E. mulciber* and *T. aeacus*) were used in this experiment which bred in Environmentol Entomology Research and Development Centre, Kasetsart University, Kamphaengsaen Campus, Nakhonpathom, Thailand. We observed the scales colour of the butterflies by stereo microscope and investigated the microstructure of wing scales by field emission scanning electron microscope (FE-SEM; JEOL JSM-6335F). The microscope was operated with the working distance about 15 mm using the incident probe accelerated at 5.0 kV. They were dried at 40^{o}C for few minutes and were coated with gold particles about 20 nm thick to avoid charging effects. All FE-SEM images were recorded in secondary electron (SE) mode detection.

Results and Discussion



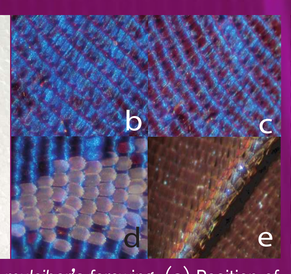


Fig.1 Stereo microscope images of *E. mulciber*'s forewing. (a) Position of observation in the wing scales. (b) B1 area is blue iridescence. (c) B2 area is dark blue iridescence (d) W area is white transpaent scales and (e) V area is the vein of the wing.

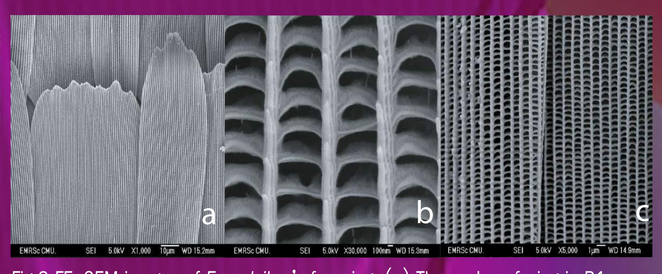


Fig.2 FE-SEM images of *E. mulciber*'s forewing. (a) The scales of wing in B1 area. (b) Top view of the blue scales. (c) White scales in white spot of the wing.

The forewing of male *E. mulciber* is dark brown strongly suffused with iridescent blue and numerous white spots (Fig.1a). Stereo microscope revealed that B1 area is almost blue iridescent and B2 area is almost dark blue iridescent (Fig.1b-e). The iridescent caused light reflection of the wing scales. Nevertheless, in B1 and B2 area are brown scales when do not light reflection on the wings. The microstructure of the wing scales by FE-SEM indicated that blue background (B1 and B2), white spots (W) and Vein (V) are almost the same in structure (Fig.2a-c). Moreover, they have scales with highly tilted, triple-layered arrangement of the cuticle, which causes iridescence due to multiple interference between the layers. Vukusic *et al.* (2001)investigated the colouration of a Costa Rica male *Ancyluris meliboeus* butterfly. They found that highly tilted, multilayerd arrangement in the scales produces a bright iridescence of broad wavelength range and generates a strong flicker contrast from minimal wing movement[4]. Stereo microscope observation ravealed that the hindwing of *E. mulciber* has pale area (P) (Fig.3a), brown area which is covered with strange long scales (B3)(Fig.3b) and dark brown areas (B4)(Fig.3c), all area without iridescence.

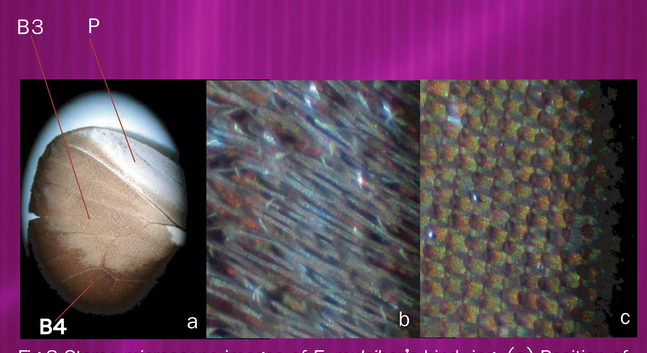


Fig.3 Stereo microscope images of *E. mulciber's* hindwing. (a) Position of observation in the wing scales. (b) Brown area is covered with strange long scales (B3) (c) Dark brown areas (B4)

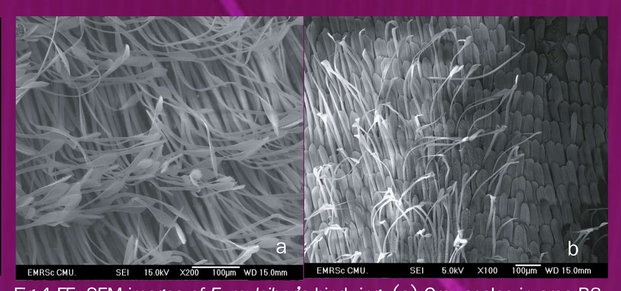


Fig.4 FE-SEM images of *E. mulciber's* hindwing. (a) Grey scales in area B3 and (b) Strange long scales covered the grey scales

The hindwing of male *T. aeacus* is the yellow area which observed by stereo microscope found that it is covered with yellow transparent scales (Y1), black marking in the edge and black dusting on the inner edge of marginal spots (Y2) (Fig.5b and 5c). For FE-SEM observation disclosed that they have cuticles standing perpendicularly to the substrate frame (Fig.6a and 6b). The yellow of wings may be caused by scattering of the incident light from substance with pigment. For instance, Prum *et al.* (2006) reported that the physical mechanisms of structural colour production in twelve *Lepidopteran* species were investigated, indicating that only the blue of *P. Zalmoxis* is a fluorescent pigmentary colour[3]. However, all of the species are appropriately nanostrucured to produce visible colours by coherent scattering.

Fig.5 Stereo microscope images of *T. aeacus's* hindwing. (a) Position of observation in the wing scales. (b) The yellow transparent scales (Y1) (c) The black dusting on the inner edge of marginal spots (Y2)

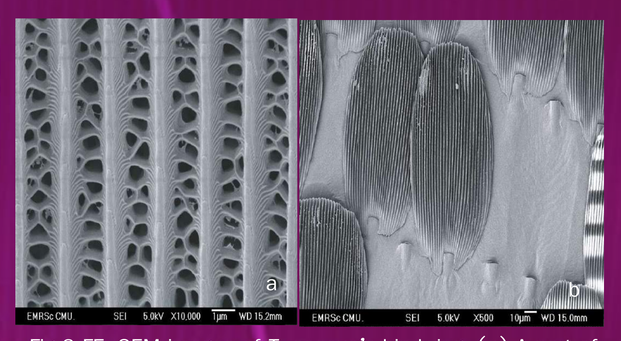


Fig.6 FE-SEM images of *T. aeacus's* hindwing. (a) A part of the black scale and (b) Yellow scales in area Y1.

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