Diffraction-based optical diffuser inspired by *Morpho* butterfly's nanostructure

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Morpho butterfly's metallic blue is a typical example of structural colors, whereas its properties are exceptional. Although this color is produced by interference from an ordered nanostructure, the single color in wide angular range contradicts the interference. This mystery is attributed to a specific nanostructure having both order and disorder (Fig.1). After proof of this mechanism by artificial reproduction, we have found its wide applicability, and continued engineering investigations in various directions [1]. Recently, converting this reflective principle to transmission, we realized a possibility of new daylight window with high transmittance, wide angular spread, low color dispersion, and controllability of light shape which have been impossible to meet simultaneously [2] (Figs.2, 3). Although our originally proposed nanostructure was difficult to fabricate, we have designed a feasible nanostructure to solve the problem using the principles obtained from the reflection studies [3]. Finally, a novel *Morpho*-type optical transmission device was successfully fabricated using nanoimprint technique, which was verified [4] in comparison with the present articles on the market [5,6] (Fig. 4).
Although the exploration of the transmission-type *Morpho*-device is still under progress, our various experiences for the reflection technology [1] can effectively profit the researches of transmission-devices, either for fabrication, estimation, and/or simulation-aided design. Indeed, the concept of 2D–3D conversion [3] had an essential role to realize the novel transmission device. Since the realized device has the controllable diffusion properties (spread angle, shape, etc.) with low light loss, it has various potential applications such as displays, LED lighting, and daylight windows. Optical diffusers are extensively used in various light sources to create homogeneous lighting over a wide field of view [7].

References:

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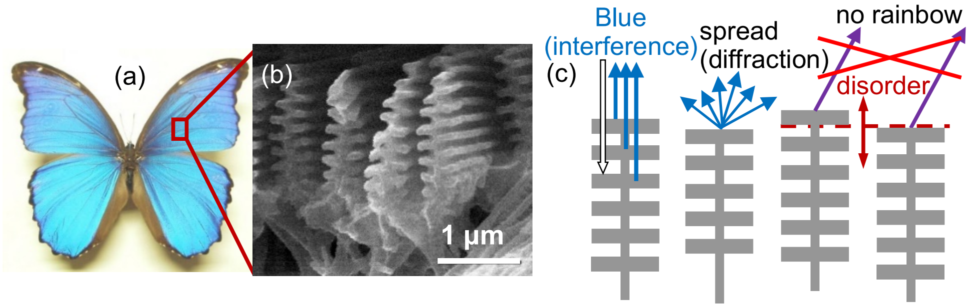

Fig. 1 (**a**) Photograph of a male *Morpho Didius* (**b**) cross-sectional SEM image of its wing scale's nanostructure. (**c**) Schematic of the principles of the *Morpho*-color that produce a single color in a wide-angular range in spite of the interference. [1]

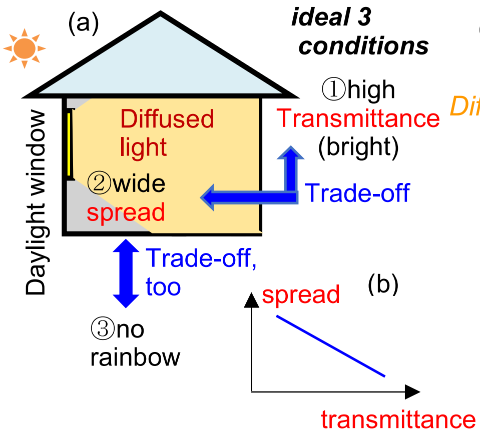

Fig. 2 (**a**) Conditions for ideal daylight window, which contain trade-off relationship in between. (**b**) Trade-off between transmittance and angular spread.

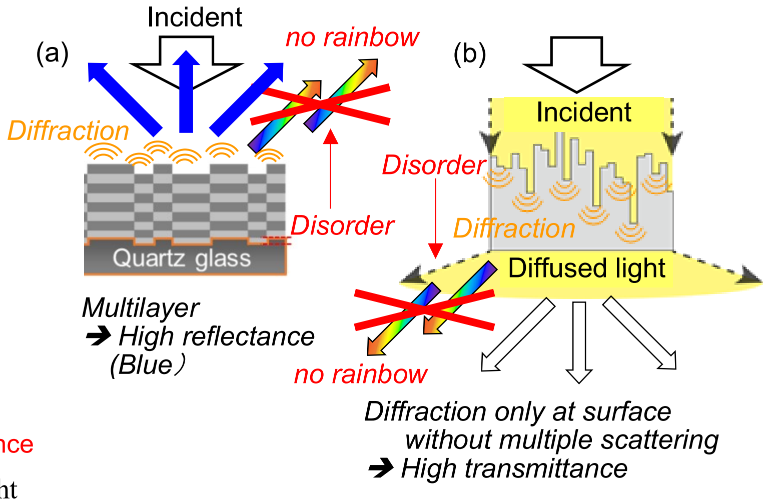

Fig. 3 Schematic of the concept of transfer from reflection (**a**) to transmission (**b**). Common principles between them are diffraction spread, disorder to prevent the multicolor [7].

Fig. 4 Plots of diffusion factors vs. transmittance for different types of diffusers. Red circles and green squares represent the results for the market articles from a company [5] and another one [6], respectively. Other plots indicate our results, blue triangle for the simulation on the original 3D design, yellow rhombus for the simulation on the 2D-conversion design, and violet rhombus for the measurement on the fabricated diffuser [7].