Physical & Electromagnetic Optics: Color due to Diffraction in Nature

Optical Engineering

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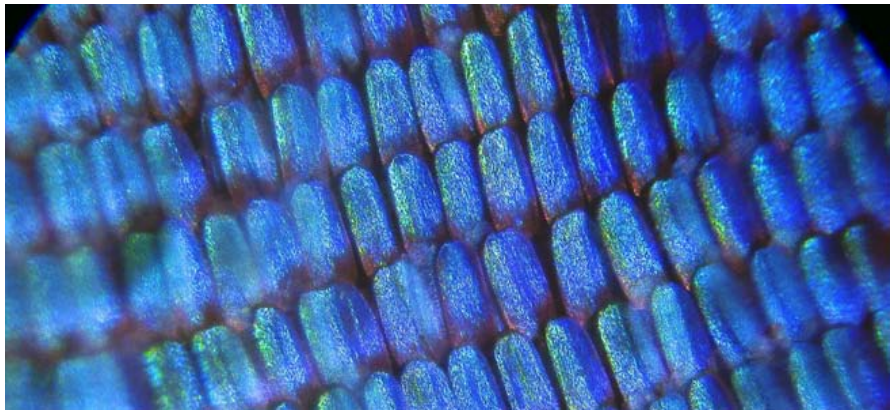
Color due to Diffraction in Nature

Morpho Butterfly

Morpho Butterfly wing scales



Blue light has a wavelength range from 400 to 480 nm. The slits in the scales of the Morpho are 200 nm apart. Because the distance between slits corresponds to half of the wavelength of blue light, this is the wavelength that undergoes constructive interference. The slits are attached to a base of melanin, a material that absorbs light, further strengthening the blue image.

Color due to Diffraction in Nature

Beetles

The dung beetle Geotrupes vernalis

Leaf beetle Chrysolina fastuosa (Scopoli)

Beetles are almost as popular among insect collectors as butterflies, partly because of their bright diffraction colors.

Color due to Diffraction in Nature

The colors of the peacock feather and of the mallard's green head and blue speculum are not caused by pigments of the respective color, but result from the microstructure of the feathers, see below.

A peacock's feather in natural size

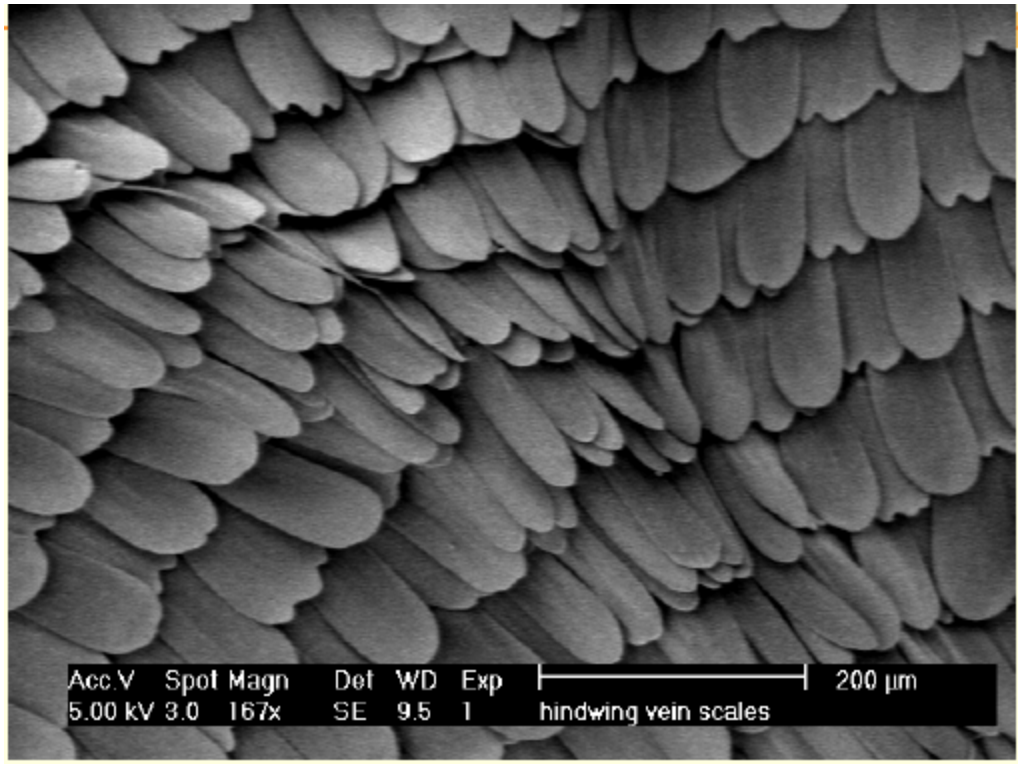
A mallard drake (Anas platyrhynchos L.)

Color due to Diffraction in Nature

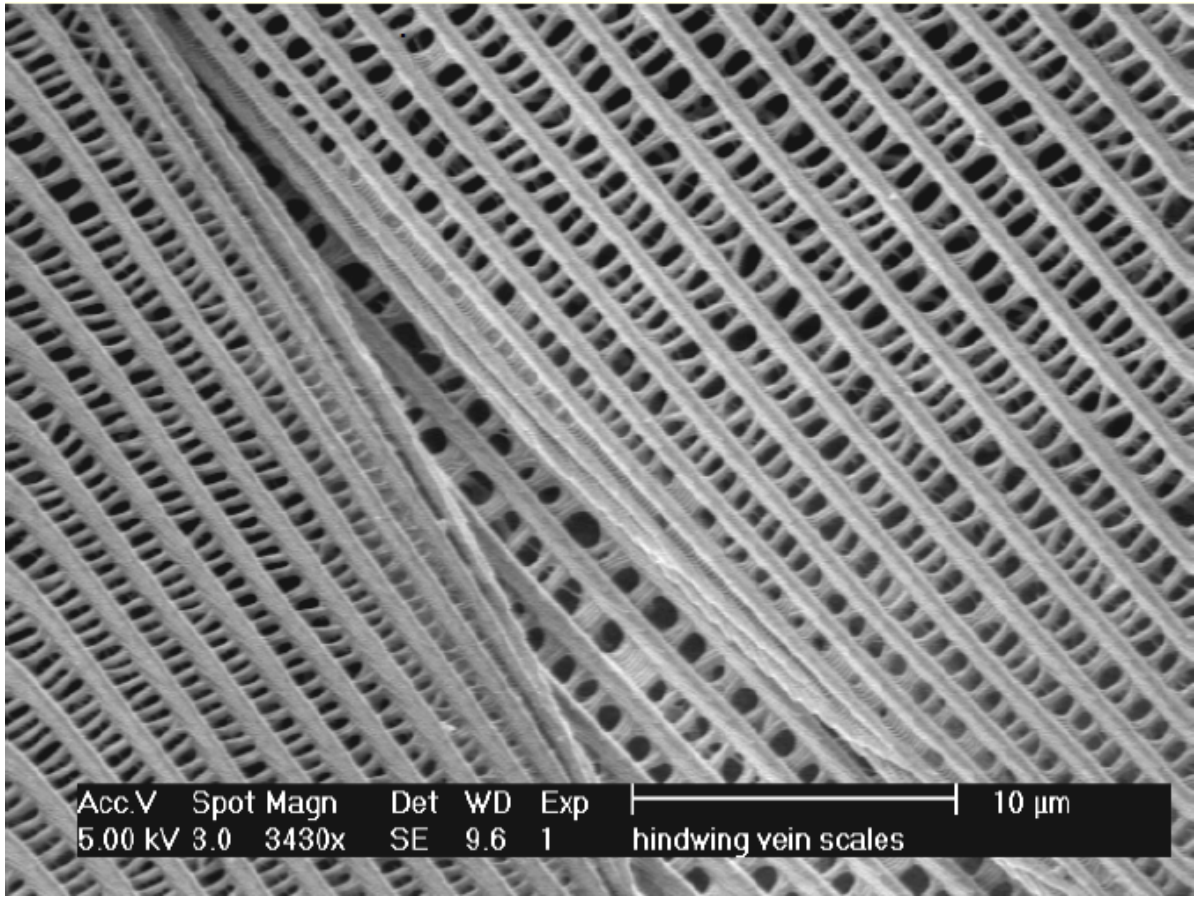
The play of color in opal is also due to diffraction of a most amazing sort.

Technically, opal is not a mineral, but a mineraloid, a non-crystalline mixture of silica and water. On the microscopic scale, opal is made of tiny colloidal silica spheres. When they are regular in size and stacking, they produce the colors of precious opal.

Monarch Butterfly Scales

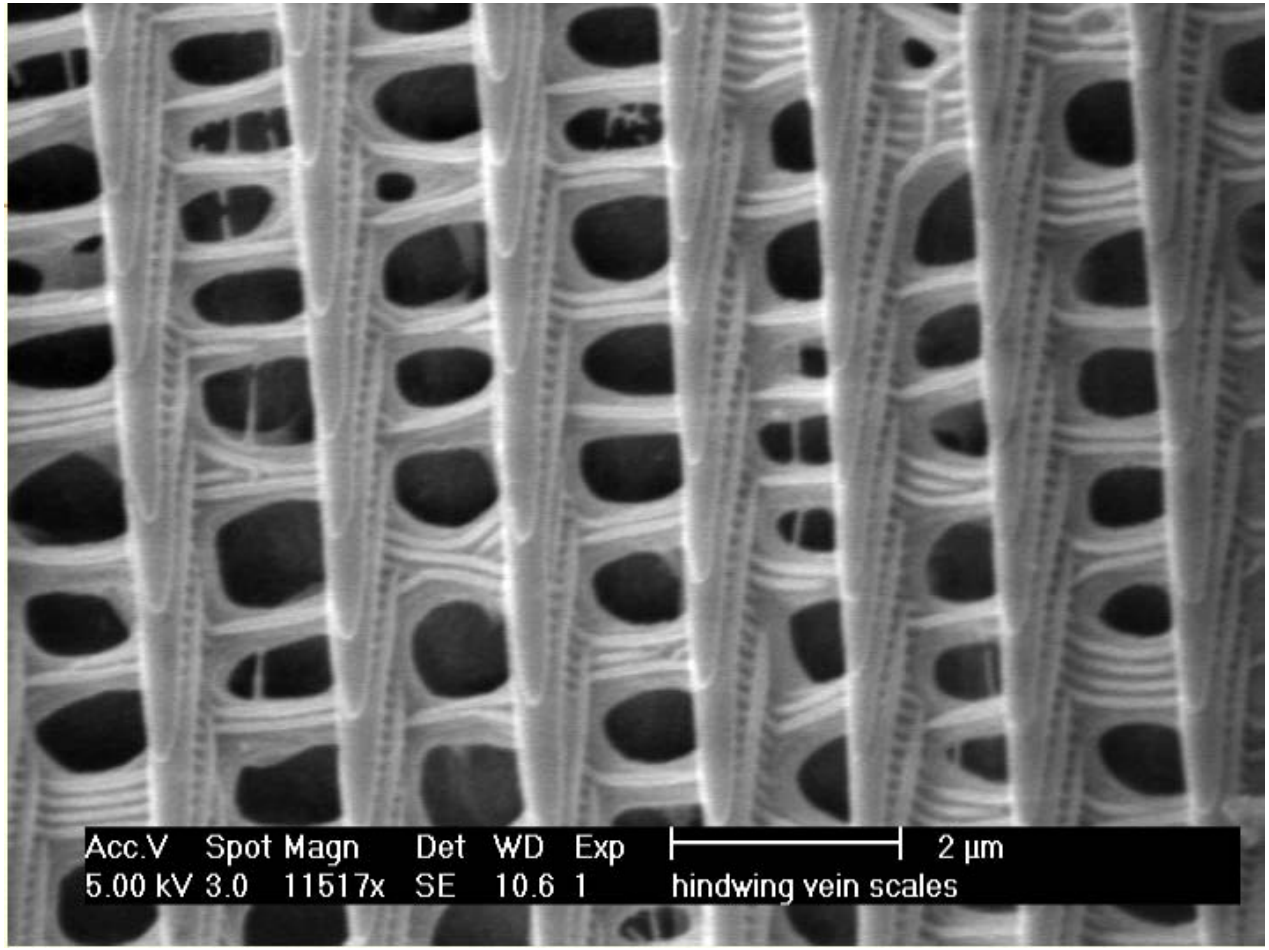


Scanning Electron Microscope Image of Monarch Butterfly Scales



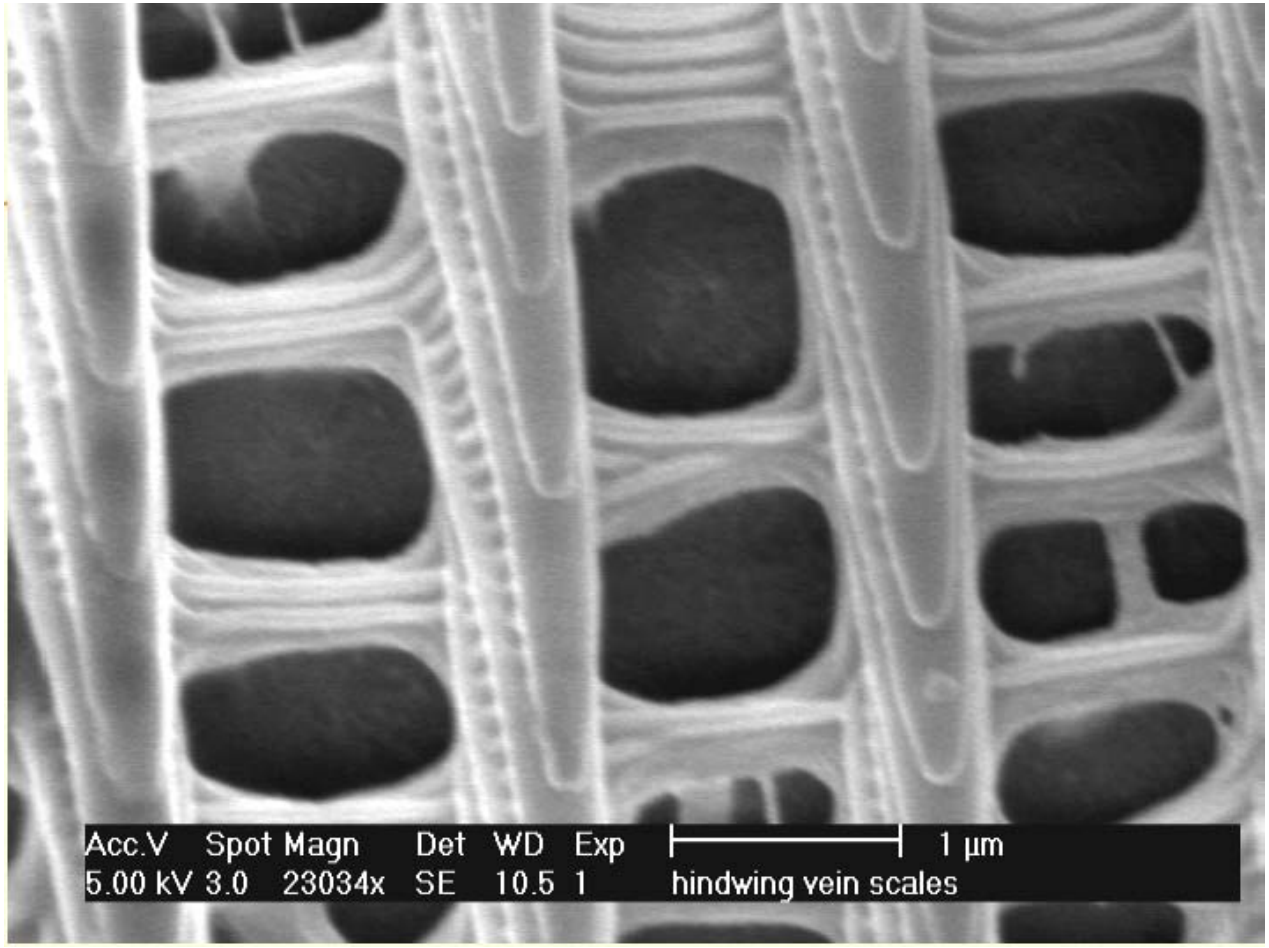
Using a scanning electron microscope, one can see that within each scale, there is an amazing array of tiny structures. These are scales on the hindwing of a monarch magnified about 3500 times.

Scanning Electron Microscope Image of Monarch Butterfly Scales



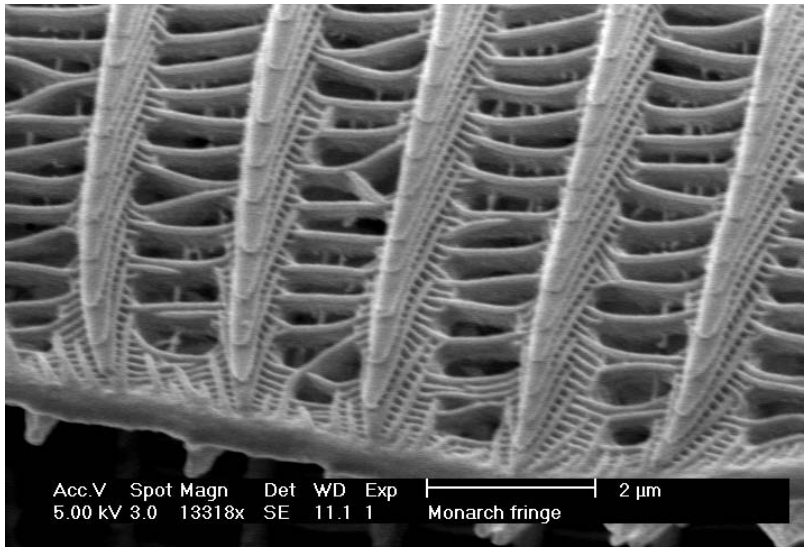
This scale is magnified about 11500 times. Look at all the structure!

Scanning Electron Microscope Image of Monarch Butterfly Scales

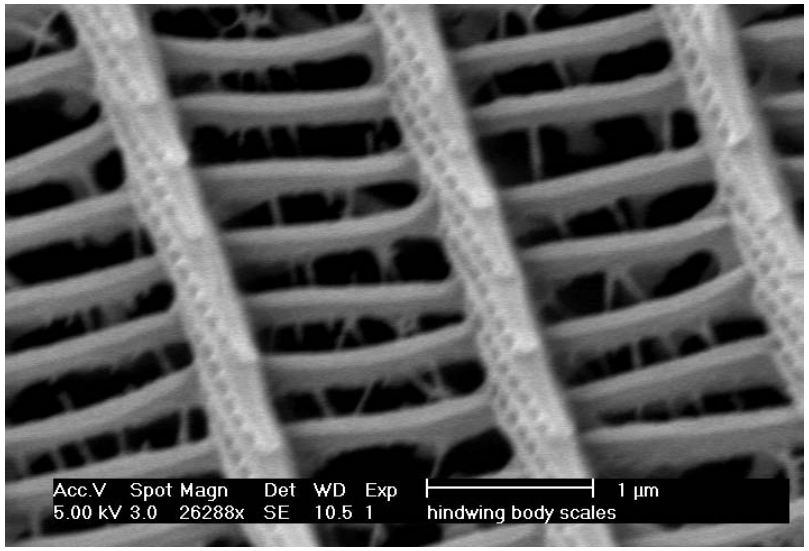


Here is a the same scale magnified 23000 times!

Scanning Electron Microscope Image of Monarch Butterfly Scales



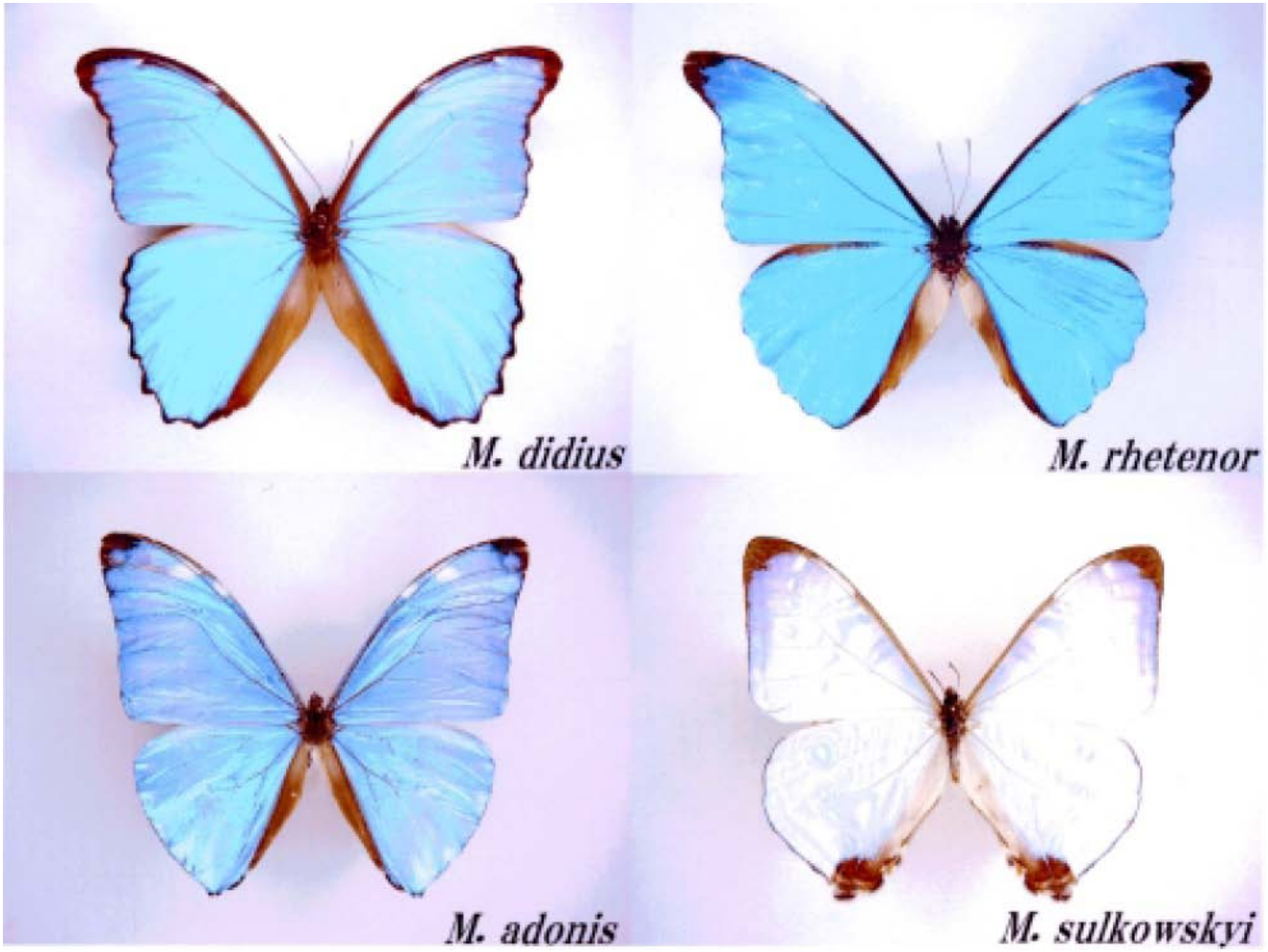
This scale on the left is from an area of the wing that is black in color.



This scale on the left is from an area that is orange/yellow. Although there are small differences in size, the shape is obviously the same.

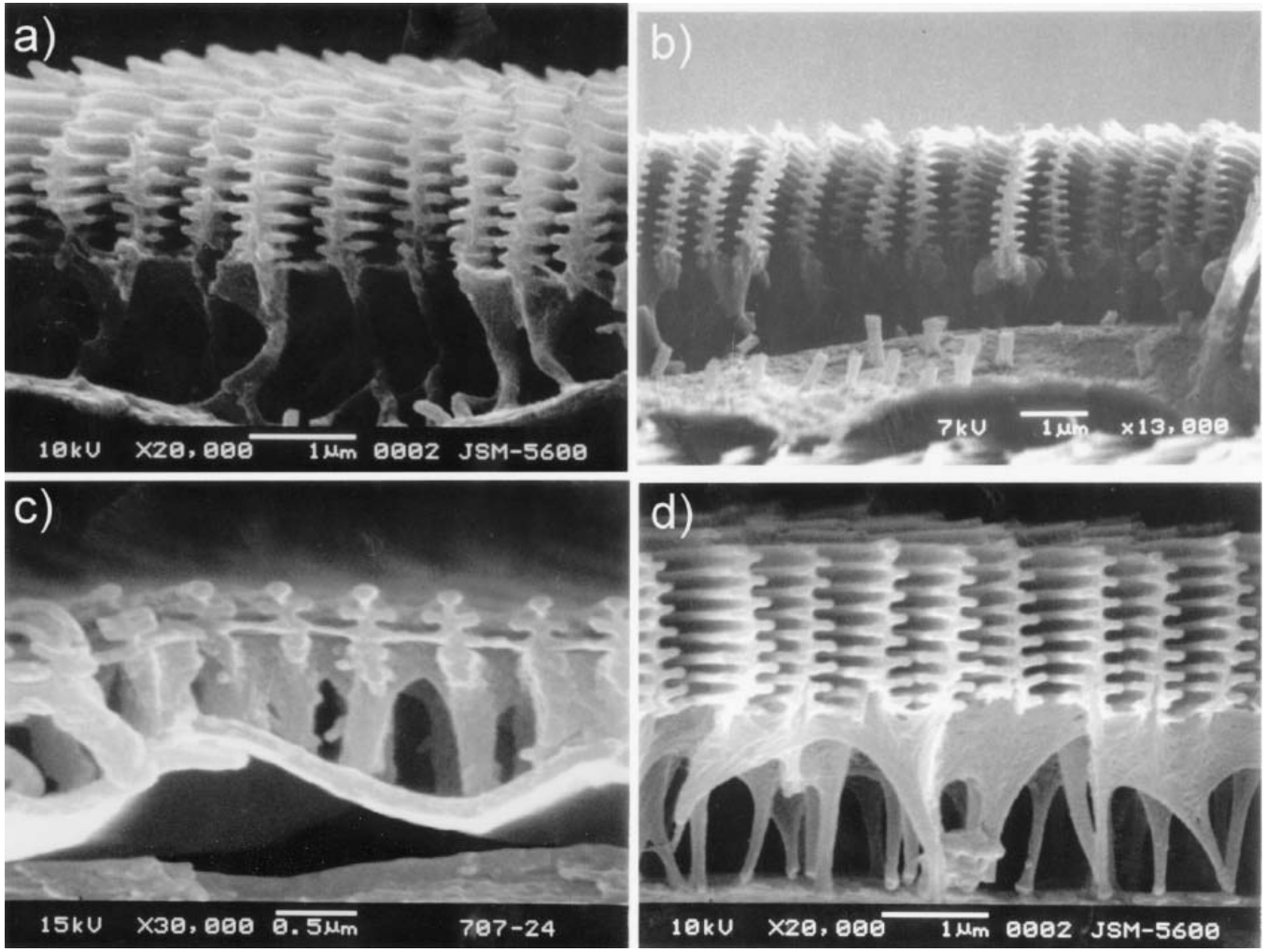
Photographs of the male *Morpho butterflies*

M. didius, M. rhetenor, M. adonis, and M. sulkowskyi



S. Kinoshita et al., *Forma*, ***17, 103–121, 2002***

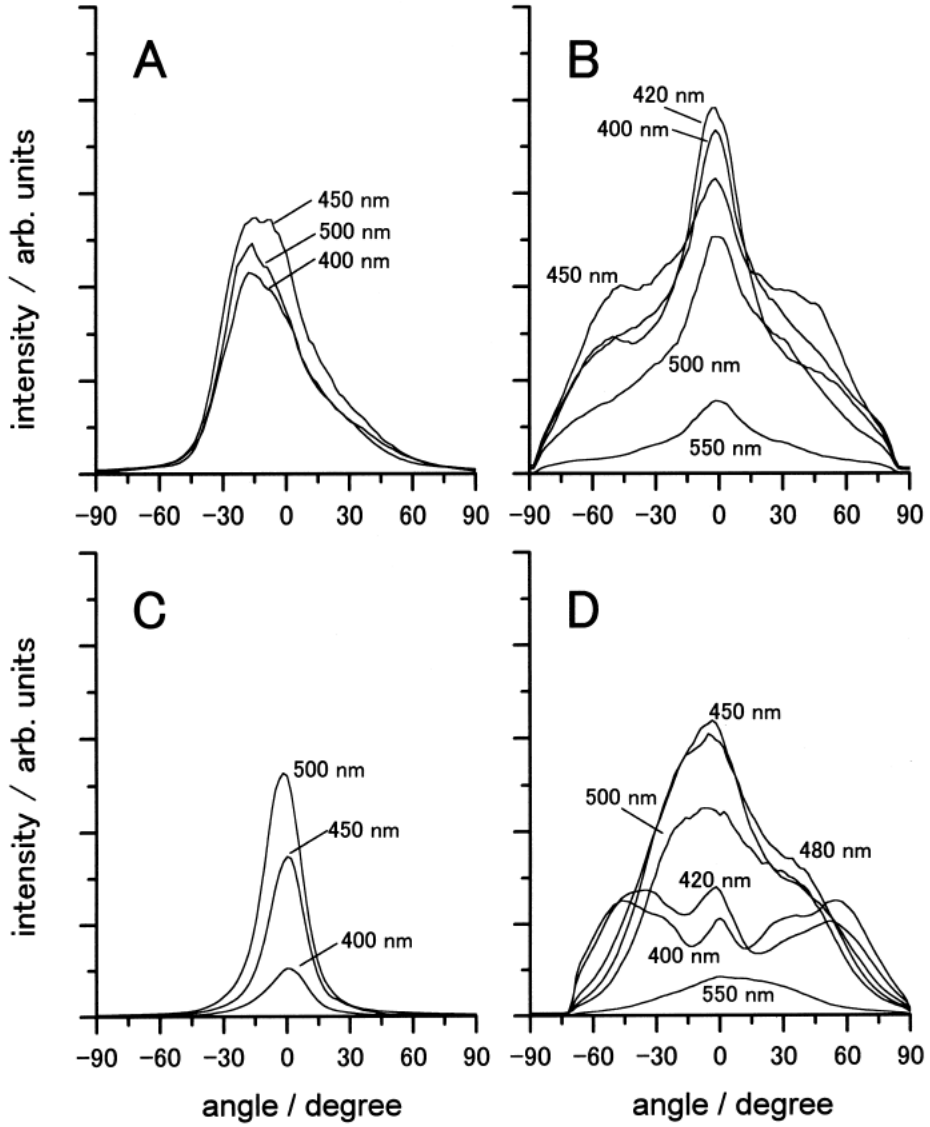
Scanning electron microscope images of the cross sections of the iridescent scales of *Morpho butterflies*



(a) a ground scale of *M. didius, (b) a scale of M. rhetenor, (c) a cover scale of M. adonis and (d) a scale of M. sulkowskyi.*

S. Kinoshita et al., *Forma*, ***17, 103–121, 2002***

Angular Dependence of Reflected Light of Morpho butterfly M. didius



Angular dependence of reflected light intensity in a plane perpendicular to the ridges for various wavelengths from B) an intact wing and D) a wing without cover scales of the male *M. didius under normal* incidence. Also shown is the angular dependence of reflected light intensity in a plane parallel to the ridges for A) an intact wing and C) a wing without cover scales.

S. Kinoshita et al., *Forma*, ***17, 103–121, 2002***