Structural Colours through Photonic Crystals

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Summary:

It is becoming increasingly evident that Nature has developed a panoply of sophisticated optical systems which enable living creatures to control the way they reflect light. In most circumstances, chemical means (pigments) are used, but sometimes organisms need to use light efficiently, or particular pigments are difficult to make, or expensive in terms of energy. They then resort to structural means, creating composite materials in which interference and diffraction are used to create striking or camouflaging colour effects.

We discuss here the structures present in a marine creature, the sea mouse (Aphrodita sp., Polychaeta:Aphroditidae), and a butterfly (Teinopalpus imperialis). We show both exploit partial photonic band gaps to achieve colour effects. In the former case, the sea mouse achieves a striking iridescence of its spines and felt, with a strong peak reflectance which tunes with angle. We show the microstructure responsible for this and the iridescent effects in the figure below.

We compare the results of laser microreflectometer measurements of sea mouse hairs with calculations treating the microstructure as a stack of gratings, and with band structure calculations.

In the case of Teinopalpus imperialis, it achieves a structural and non-iridescent green through the use of a mosaic structure, consisting of a distorted silicon structure. It can also achieve a remarkable structural black by adapting this structure. We comment on the determination of the wing scale structure, and aspects of the resulting optical properties.

We comment on what we may learn from these and other natural systems, and possible applications for the designs they have evolved, and the methods they have developed to achieve their optical microstructures.

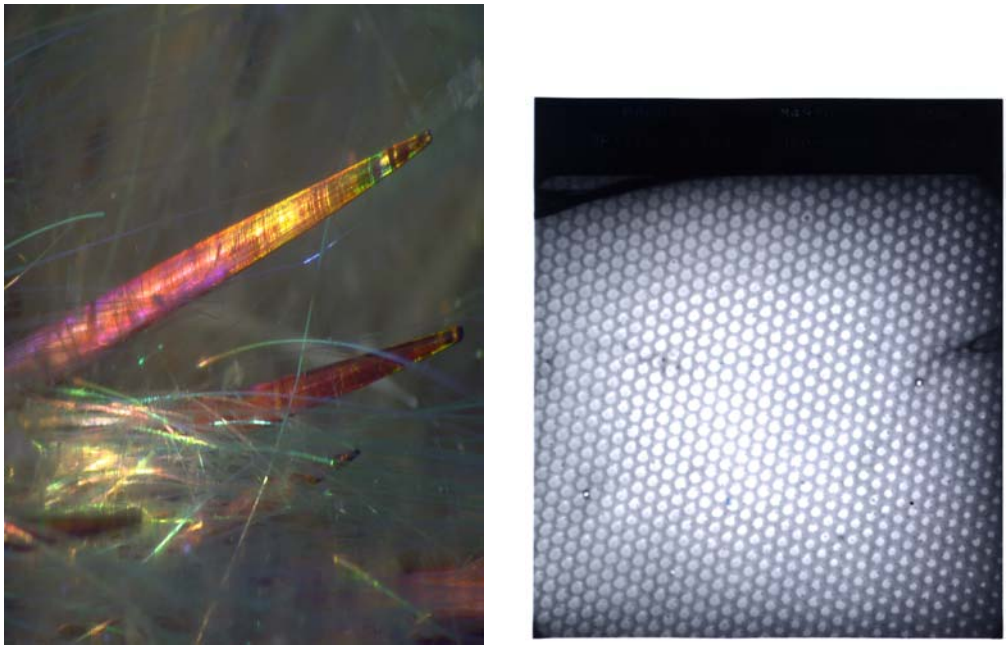

Figure 1: Fig 1 (left panel): Reflectance of light by a sea mouse spine, showing strong colouration in the red.. (right panel) A micrograph of the wall of a spine, showing hexagonally-packed voids in a chitin matrix, with a spacing of 0.51 μm.