

Hyperspectral topography of the twisted, cholesteric patterns of an insect cuticle in the context of biomimicry

Aurélie Jullien¹, Maxim Neradovskiy¹, Adriana Scarangella², Michel Mitov²

1. Institut de Physique de Nice, UCA, CNRS, 06560 Valbonne, France. 2. CEMES, Université de Toulouse, CNRS, France

Biological systems inspire the design of multifunctional materials and devices. However, current synthetic replicas rarely capture the range of structural complexity observed in natural materials. Prior to the definition of a biomimetic design, a dual investigation with a common set of criteria for comparing the biological material and the replica is required. Here, we deal with this issue by addressing the non-trivial case of insect cuticles tessellated with polygonal microcells with iridescent colours due to the twisted cholesteric organization of chitin fibres.

Cholesteric patterns exhibit spatial variation in the helical pitch and in the orientation of the helix axis, as in the two-band, green and silver cuticle of the scarab beetle, *Chrysina gloriosa*, which is the focus of the present study. The silver bands are pattern-free, whereas the green bands exhibit an array of microcells. By hyperspectral microscopy with 6 nm spectral resolution in the range of 400 nm-1000 nm [1,2], we investigated the topography of twisted cuticular structures under various orientations of the helical axis, from an orientation close to the normal to the cuticle surface in the silver bands to a spatially varying orientation in the microcells. We deal with two aspects of the topography: the shape of the surface at the interface between the transparent wax layer, which is a challenging task since the cuticle is covered by the wax layer preventing direct topographic measurements by standard techniques, and the chitin-protein matrix, and the features of the deep layers in the cuticle, by addressing the distribution of the helical pitch of the twisted structure at a variable depth. We demonstrate that both types of topographic information are embedded in the hyperspectral data. Specifically, we show that the spatial distribution of the spectral center of mass portrays the axiconic geometrical shape of the hexagonal microcells [3,4]. This topographic study enables to compare, at several length scales, the textural, structural and spectral properties of the microcells of the green band of the scarab beetle with those of the polygonal texture formed in flat films of cholesteric liquid crystal oligomers. The hyperspectral imaging technique offers a unique opportunity to reveal the common features and differences in the spectral-spatial signatures of biological and synthetic samples [5].

To provide an overview of the type of available data and cartographies, Figure 1 illustrates the salient outcomes of the hyperspectral analysis for the green and silver stripes of the scarab beetle and for the synthetic bio-inspired sample. The three-dimensional graphic enables visualization of the interdependence between the spatial modulation of the light reflected by the sample and the gradual spectral changes.

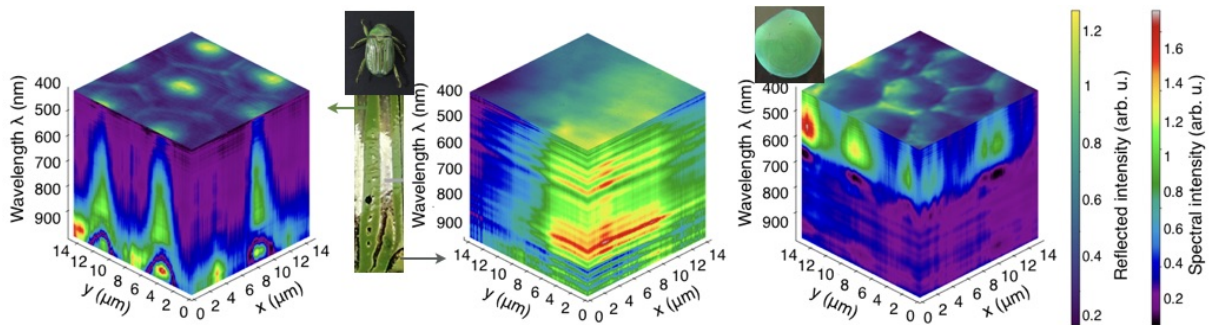


Figure 1: From left to right : hyperspectral datacubes of the green and silver bands of the scarab beetle *Chrysina gloriosa* and the synthetic, bio-inspired sample. Two different sets of color bars are associated with each cube. The black-to-yellow color bar indicates the overall reflected intensity (i.e., not spectrally resolved), as plotted on the top (y vs x). The second color bar (black-to-red) indicates the reflected spectral intensity, as plotted on the sides (wavelength vs x , wavelength vs y).

References

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