Role of Surface Features of Butterfly Wings in Optical Properties Characterization

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This study describes atomic force microscopy of butterfly wing sample which represents a natural optical structure. The color strongly depends on the structure and surface appearance of the wing scales. Morpho Didius scales were chosen as specimen for microscopy measurements.

1 Introduction

Nowadays, scanning probe microscopy (SPM) is a very popular method to study microscopic structure of a material surface. SPM has better resolution then traditional instruments, such as a profilometer or optical microscope [1] and can be adapted to bare and untreated surfaces without complicated sample preparations. Another advantage is that the sample will not be damaged by exposure to a high energy beam, as could be happen in scanning electron or ion methods. There are many classes and modifications of SPM, as many scanning modes and methods have been invented. Nevertheless, there is still a large unstudied potential for the use of SPM for investigation of defects. Most importantly, atomic force microscopy (AFM) measurements allow the evaluation of surface roughness parameters with a high degree of precision.

Last century was noted that the role of structure for the color of the biological materials could be described by using microscopy techniques [2]. Probe microscopy allows a study of the surface without its preliminary processing. Structural coloration could be observed at some species of birds, insects, plants, clams, etc. The layered structure of the wing scales was studied by TEM [3]. A study of textured morphologies is also stimulated by interest to improve the self-cleaning and hydrophobic properties, reduce the influence of weather agents, and simultaneously absorb the maximum range of spectrum [4, 5].

These micro- and nanostructures are related to the modern field of optics (optic sensors, photonic crystals, solar cells) and photophysics [6] (optical bandgap, near-field optical interaction, scattering on nanoscale objects).

The feature with nanometer scale could be considered as scattering centers [7]. These structures could be responsible for the coloration since it defines the reflection, interference, diffraction, scattering and combination of these optical phenomena.

2 Experimental

The AFM modes could be distinguished by their dependence on distance between the probe and surface. The mode should be chosen considering sample properties (hardness, stability to local influence of probe) and the probe (parameters given in product specification). Intermittent (semicontact or tapping) was chosen for the measurements. This mode uses probe oscillations and detect shift of oscillation parameters (amplitude, phase, frequency) to detect morphology features (Fig.1).

We used AFM NTEGRA (NT-MDT production) which like most types of these tools is accompanied by user-friendly software providing measurement and further processing of results, with appropriate algorithm for image processing.

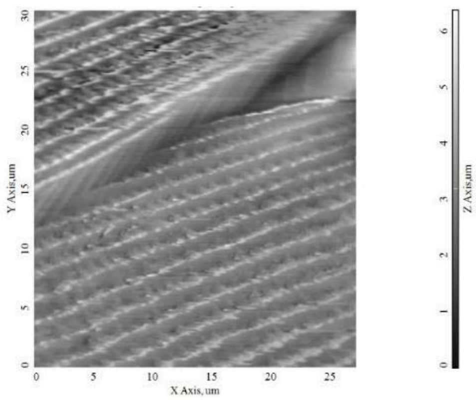

Fig. 1 *The area of butterfly wings where it is possible to observe the interface between two scales.*

The color strongly depends on the angle of view since surface of the wing is a diffraction grating with complicated shape of ridges (Fig.2).

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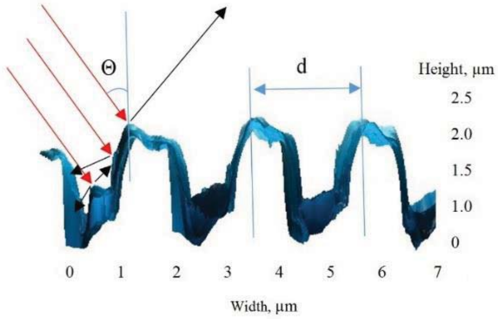

Fig. 2 *The diffraction grating of scales plays an important role. The observed reflection depends on incident angle (Θ) and lattice parameter (d).*

The wing could include quite different scales in different parts. On the backside of the wing, the scales also differ (Fig. 3). Some irregularities of the surface features suppose to reduce appearance of undesired phenomena between neighbour features.

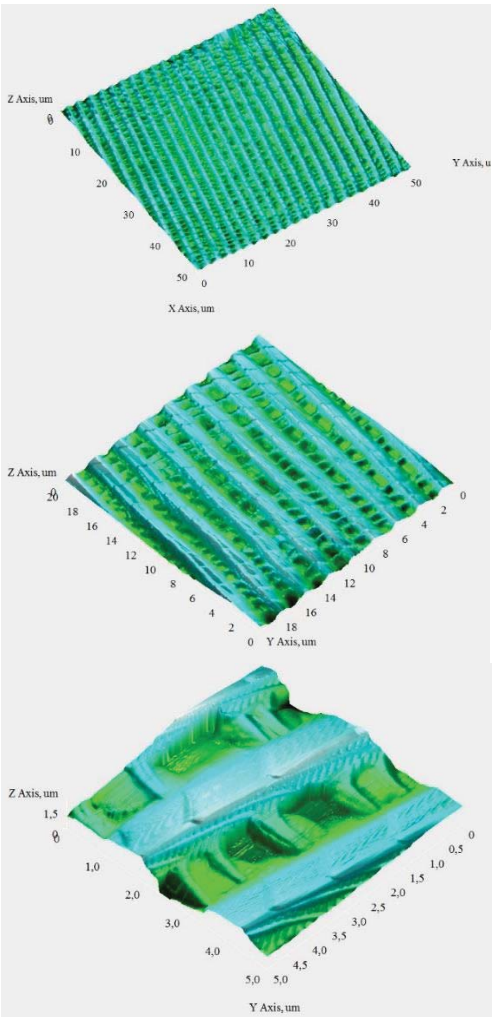

Fig. 3 *Scale structure from inner side of the wing*

The sizes of ridges and crossribs are comparable to the wavelength of light. AFM provides real 3D images of the scale surface and also information about feature sizes and shape.

3 Conclusion

The result contributes to morphological description of the wing scale and establishes scale surface texture. AFM measurements demonstrate diffraction effect on the wing ventral scale. This reflective diffraction grating takes a part in the light reflection. These surface ridges control further light propagation to the nanoscale optical structure of the scale.

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