Fractal Motives At The Molecular Structure Of Objects Living And Non-Living Nature

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***Abstract*—Fractal motives in physical and natural structures are applied to the skin of Gurza, Natrix and other well-known snakes. In this paper presents the results of studies morphology of surface structures of snakes and crystal surfaces nanorelief using atomic force microscope. In the analysis of morphology snake scaly surface and morphology of the crystal surface revealed multifractality of surface structures: nanoislands, pores and patterns.**

***Keywords*—patterns of snakes, microrelief, scaly surface, fractals, crystal surface, physical and natural structures, percolation strips, nanoislands.**

Introduction

Currently, the basic science and natural phenomena are finding the successful application of percolation and fractal concepts. That approach has changed description of disordered objects and processes of nature. For example, in [1-4], the researchers are interested in the skin of snakes in order to develop of high strength materials that provide friction reduction. Biologists have long been studying the surface of skin of snakes and fish. Physicists are interested in fractal surface of solids [5-7]. Many problems in biological physics associated with the behavior of complicated systems has profound analogies or with a percolation phenomena or fractal growth on various models. The research of fractal structure of living beings has been based on a number of fundamental theoretical provisions set out in [8-10]. So in [10] the study of biological fractals is gradually cover all levels of organization of living from molecules to ecosystems. Biological structures has cell in the basis. These objects on the surface of serpent in his vital functions are formed as a result of physical - chemical reactions and energy flows, on the other hand form the necessary structures for skin to ensure reducing friction during movement on the ground and in the water. [1,11-18]. Examples of snakes having complex relief of the skin are: ordinary copperhead snake, natrix, catsnakes - telescopus, common malpolon monspessulanus, false natrix, Indian striker, nose-horned viper, Indian cobra, gurza and many others. Some snakes (for example, the pit viper family of snakes) strips have a light color, and saw-scaled viper has two white longitudinal stripes.

The study of morphology surface skin of fish, snakes, birds, is not only scientific interest, but also relates to the capabilities of detection and creating structures for provide low friction at their contact with other surfaces. As it was mentioned, about this shows results of a number researchers [1-4], creating a super slippery surface on the steel sheet, identical the texture of snake skin. Patterns formed on steel sheets of 7.5 mm in diameter imitation oval flakes snakes (called "reptile skins") [1]. In dry conditions (without oil and other lubricants) during conducting on the sapphire surface with some pressing, the created "reptile skin" showed much less friction than smooth steel surface. "Snakeskin" will be used in the manufacture of highly sensitive scientific equipment, where the engineering challenge is to further miniaturization of moving parts [1]. The authors of [1] made some progress when used polymers, which better imitate snakeskin than steel, however this work is not yet completed. More real structure similar surfaces of reptiles and fish can be found in [16-17]. Natural fractal surface was studied in [17,20], however, are not revealed similar elements and communication nodes in them, both living and nonliving objects.

The purpose of this work was an experimental description of fractal structures of the skin surface Natrix, Caucasian viper and the surface of layered crystals, confirming the unity of fractality of living and non-living systems that might become a morphological basis for creation of materials with low friction.

Experimental results and discussion.

The surface morphology of layered crystals and skin surface of Natrix and Caucasian viper were studied by atomic force microscope (AFM) brand

«Solver NEXT» [19]. Skin samples viper and natrix were dried with air blowing at a temperature not exceeding 50 ° C for 10-12 hours. Crystals $A_2^VB_3^{VI}$ <impurity> (Bi_2Te_3, Sb_2Te_3) were produced by vertical directed crystallization.

Freshly cleaved surface (0001) obtained without etching and studied their characteristics under the microscope in 5-10 minutes at different scales.

The atomic force microscope (AFM) was used as device is probing sample surface with a sharp needle in length of 1-2 microns and in diameter not more than 10 nm. The needle is mounted on the free end of the measuring console. We used non-contact mode of operation of microscope. The magnitude and sign (repulsive and attractive) of "console" force depends on deviation of console, its elastic constants. The force exerted by the contact AFM a measuring console, unlike capillary is variable.

The snakes surface and the surface of $A_2^VB_3^{VI}$ layered crystals were studied by AFM method. In Figs. 1-4 present various parts of snake skin. Natrix and viper body is covered with dry parallel flakes (flakes cutaneous origin), which partially cover each other. The flakes on the anterior abdominal wall is many times longer and wider than on the top surface(Fig.1).

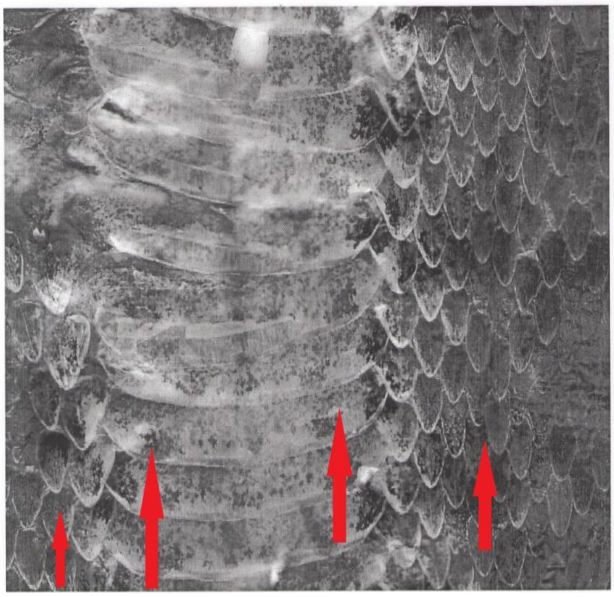
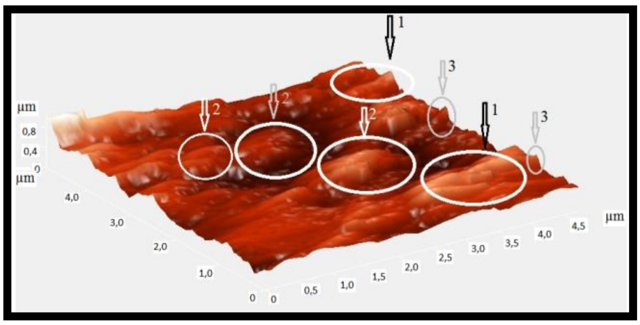
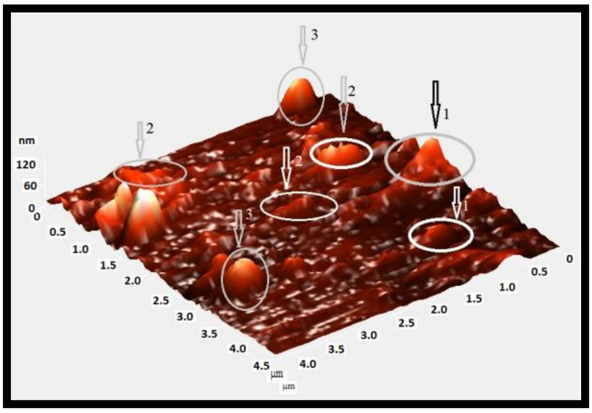


Fig.1. *The area belly of Caucasian viper – Gurza (in the middle marked wide and long strip, and on the sides visible small flakes).*



a)



b)

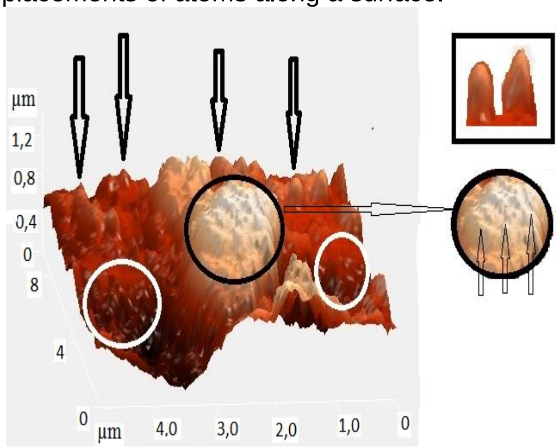
Fig.2. *Fractal surface of the skin of Caucasian viper -a), fractal surface of semiconductor structure - b). Legend: in both figures (a,b) marked by white circles (1,3) separate nanoislands, coalesced nano-objects (2).*

The belly region fragment shown in Fig.1 was obtained by skin scanning. In the belly they usually have a separate series of broad flakes, which act as adhesion to the earth surface at movement. These viper flakes marked with red arrows below. In the belly of a viper (see Fig.1), we have a fractal relief, leading to a significant increase in the total area and allowing to reduce friction on the earth, that has been noted in [1]. Fractal surface of snakes is a surface with a low coefficient of friction and the best receiver of various radiations. These photos AFM - images of body surface viper (see Fig.2a) and nanoislands aggregated on the (0001) surface of $A_2^VB_3^{VI}$<impurity> crystals (see Fig.2b), considered on the basis of fractal concepts of physical objects.

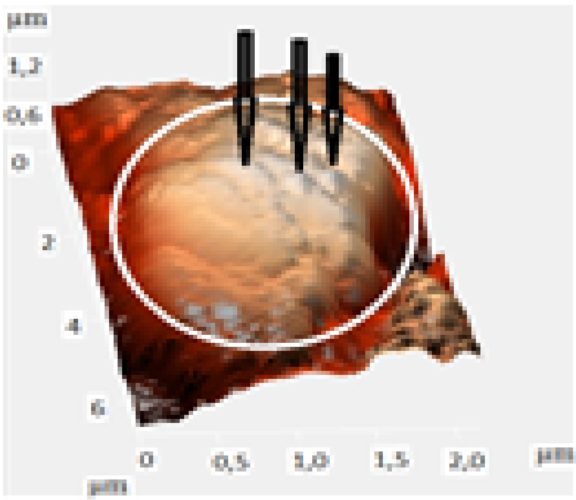
Fractal approach allowed to reveal on the surface of these living and non-living objects similar macrostructure coalesced into larger formations. The peculiarity of the structures presented on the surface (see Fig. 3g-5b) certainly related to the fact that the $A_2^VB_3^{VI}$<impurity> based layered crystal refers to systems in which a base surface (0001) may be considered as a medium with nanoislands different sizes. In the AFM-image in a 3D-scale upper arrow marked separate nanostructures. White circles marked small size nano-objects which formed localized patterns (marked with a black circle and allocated on the right Fig.3). On the right at the top of the square two nanoislands highlighted. In Fig.3b is given a separate such localized structure - marked by vertical arrows. In Fig.3c are given localized patterns on Bi_2Te_3 surface and a similar structure of natural zeolite mineral (see Fig.3d).

Presented in Fig.4a photos of Natrix surface patterns and compared with the surface (0001) of Bi_2Te_3 (see. Fig.4b) revealed the presence of pores in biological structures and solid crystals. Similar pores and other nano-objects (nanoislands) were found on the surface of the fish [16-17].

In Fig.5a are given AFM-images of the surface viper: by circles marked the nanostructures (percolation transitions) more clearly these transitions is fixed in Fig.5b: vertical arrows indicate the nanoislands (herein percolation communications is marked by rectangles). There are a number of areas of localized nanoislands on the entire viper skin. This "localization" of nano-objects as is typical for many surfaces of semiconductor thin films and surface edges of the crystals [20]. Fractal coating aggregates, clusters, nanoparticles are formed by coalescence of small nanoislands (see Fig.2b), marked by white circles small nanostructures allocated on the right at the top and indicated by vertical arrows (Fig.3a). Here, we compared the morphology of fractal aggregates with nano-objects formed on the (0001) surface $A_2^VB_3^{VI}$ crystals. The similarity of identical formed structures suggests that the mechanisms of growth of free fractal systems and localized structures on the surface have identical mechanisms of self-organization associated with the diffusion displacements of atoms along a surface.



a)



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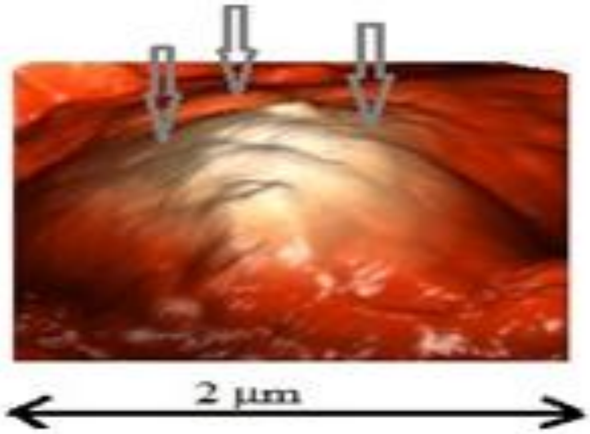
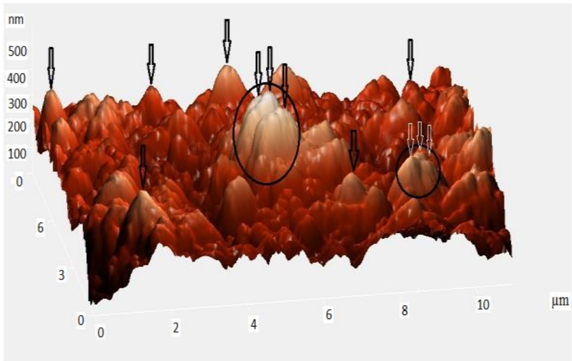


c)



d)

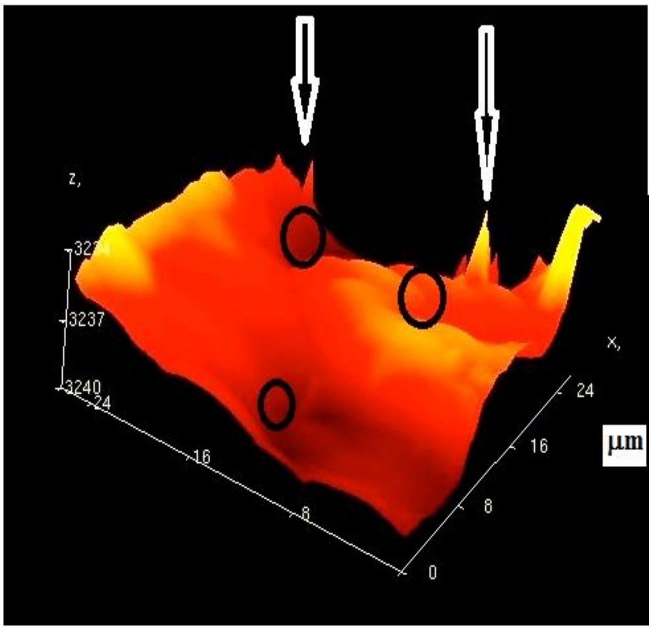
Fig.3. *Fragments of integument viper (a, b), surface localized nanoislands - patterns of solid crystal (c, d).*

By analyzing the signals received from the flakes sensors, central nervous system sends commands for the flow channel (channels highlighted ellipses on Fig.5a) throughout the body, what gives impetus to the dynamics of the snake movement. Upper formations tightly connected to each other and form a strip of flakes extending from head to tail serving as transmission channels various signals. However, need to study the chemical composition of strips - the so-called percolation structures. By the way, they may consist of materials that pose a mixture of dielectrics, metals and organic substances which represent local accumulations of fractals Based on percolation theory [5-6], can explore problems of snakes motion dynamics and disseminating signals at their surface.

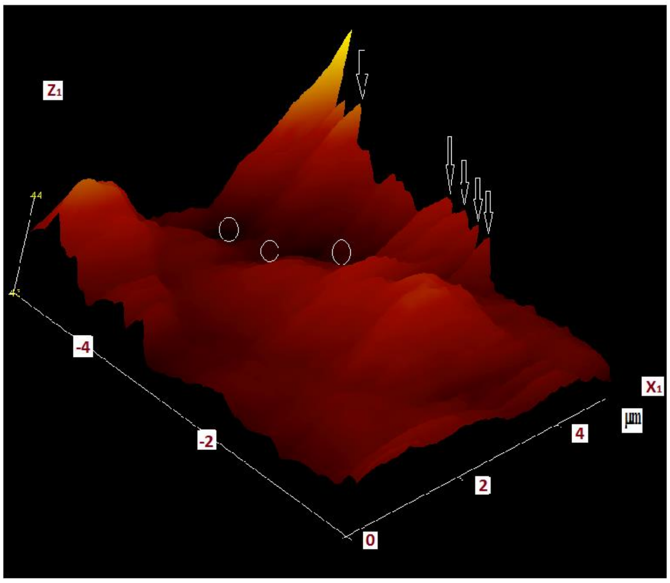
Presented at the Fig.4a and Fig.5a a height of nanostructures in AFM-images 3D-scale snakes surface are indicate a nano dimensions of surface structures: nanoislands and pores.

Preliminary analysis of surface a number of natural objects and our represented structures have allowed to reveal in them signs of percolation fractals.

Visible snake skin surface strictly fractally, and flakes are placed tightly and some areas has its regions of condensations (Fig.3a, 5a). Description of fractal objects on surface of biological objects (snakes) requires the introduction of a not single fractal dimension. It is necessary to use set of parameters similar the fractal dimension. In this case, we can talk about the multifractal properties of the surface of the skin unusual living object [13-15].



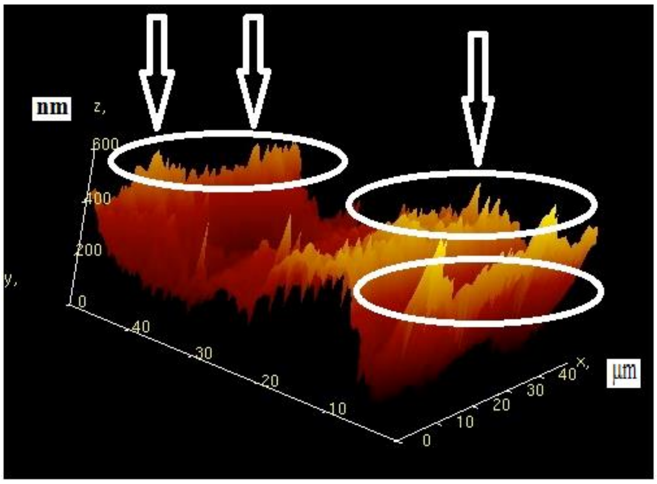
a)



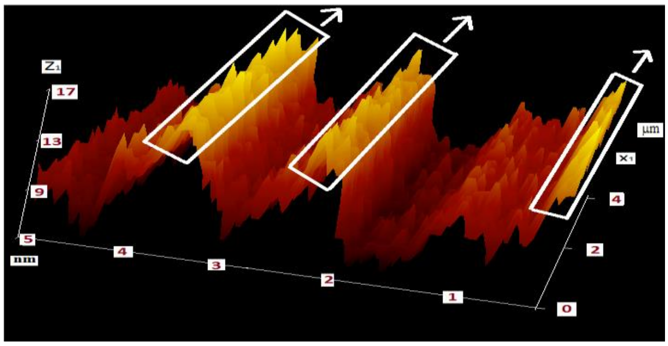
b)

Fig.4. *Natrix surfaces with pores (area scans 40x40 µm; $\grave{n}_{min}$=200nm, $\grave{n}_{max}$=600nm) - a), the fractal surface of a semiconductor structure with pores also marked by circles, nano-islands highlighted by vertical arrows -b).*

Using the concepts of multifractals associated with the determination of the fractal dimension of real end systems. When determining the fractal dimension are facing with the natural difficulties associated with the fact that these ratios correspond to the ideal case of mathematical fractal objects. For real systems (such as ours) has limit values of size, limiting the scope of manifestation of the fractal properties, which we evaluated: the fractal dimension of the surface is in the range 2 <D_f <3.



a)



b)

Fig.5. *AFM- image in 3D-scale of Caucasian viper surface (scan 24x24μm) -The upper part of surface skin viper -a); Noticeable nanoislands and nano protrusions of depressions on crystal surface -b).*

Aggregated structures on the surface (0001) of Bi_2Te_3 marked with white rectangles (Fig.5b).

Highlighted areas (circles on surface viper, and the area of the rectangles on the surface of the crystal) are similar; nanoislands coalesced to form a single chain, in which current can flow, or transmitted different signals.

CONCLUSIONS:

By analysis of the structure of crystals and surface of the skin surface biological objects, in particular the structure of the skin of snakes and nanocrystalline fractals on the surface of the (0001) crystal systems $A^V{}_2B^{VI}{}_3$, is revealed multifractality skin of snakes and their identity with the surface structures of layered crystals.

In the above AFM-images are shown fractal motives in the structures of living and nonliving objects associated with multifractality and the local concentration of surface patterns. The obtained structures will serve as a basis for the creation of materials with low friction.

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