МОЛЕКУЛЯРНА БІОФІЗИКА

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FRACTAL TEXTURES OF SERUM ALBUMIN AND Na-DNA FILMS FROM SOLUTIONS WITH METAL HALIDES

Glibitskiy G.M.
O. Ya. Usikov Institute for Radiophysics and Electronics of the National Academy of Sciences of Ukraine
12, Acad. Proskura St., 61085, Kharkov, Ukraine.
e-mail: glibit@ukr.net
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Fractal texture features of the albumin and Na-DNA films with fluoride, chloride and bromide of sodium analyzed. The films were obtained from bovine serum albumin and human serum albumin ("Sigma-Aldrich") solutions at a concentration of 0.5 mg/ml in the presence of sodium salts at a concentration of 20 mM, and from the solution of Na-DNA ("Serva") with a concentration of 0.25 mg/ml in the presence of a metal chloride at a concentration of 10 mM. The geometrical parameters of textures differ depending on location on the surface of the cuvette and the composition of the ions in solution. Periodic structures with characteristic repetition period of $L_2 \approx 4 \div 6$ microns are present in the individual structural elements. Factal textures on the surface of films with chlorides of sodium, potassium and rubidium have been analyzed.
KEYWORDS: albumin, solution, film, fractal, texture, chlorides.

ФРАКТАЛЬНІ ТЕКСТУРИ ПЛІВОК СИРОВАТКОВОГО АЛЬБУМИНУ І Na-ДНК З РОЗЧИНІВ З ГАЛОГЕНИДАМИ МЕТАЛІВ

Г. М. Глибицький
Національна академія наук України Інститут радіофізики та електроніки ім. О. Я. Усикова,
вул. Ак. Проскури 12, м. Харків, 61085, Україна

Аналізуються фрактальні особливості текстур плівок альбумінів і Na-ДНК з фторидом, хлоридом і бромідом натрію. Плівки були отримані з розчинів бичачого сироваткового альбуміну та сироваткового альбуміну людини ("Sigma-Aldrich») при концентрації 0,5 мг/мл в присутності солей натрію в концентрації 20 мМ, і з розчинів Na- ДНК ("Serva") з концентрацією 0,25 мг/мл в присутності хлоридів металів при концентрації 10 мМ. Геометричні параметри текстури розрізняються залежно від місця розташування на поверхні кювети і складу іонів в розчині. В окремих структурних елементах присутні періодичні структури з характерним періодом повторення $L_2 \approx 4 \div 6$ мкм. Проведено аналіз фрактальних текстур на поверхні плівок з хлоридами натрію, калію і рубідію.
КЛЮЧОВІ СЛОВА: розчин, плівка, альбумін, фрактал, текстура, галогеніди металів.

МАСШТАБНО ИНВАРИАНТНЫЕ ФРАКТАЛЬНЫЕ ТЕКСТУРЫ ПЛЕНОК СЫВОРОТОЧНОГО АЛЬБУМИНА И Na-ДНК ИЗ РАСТВОРОВ С ГАЛОГЕНИДАМИ МЕТАЛЛОВ

Г.М. Глибицкий
Национальная академия наук Украины Институт радиофизики и электроники им. А. Я. Усикова
ул. Ак. Проскуры 12, г. Харьков, 61085, Украина

Анализируются фрактальные особенности текстур пленок альбуминов и Na-ДНК с фторидом, хлоридом и бромидом натрия. Пленки были получены из растворов бычьего сывороточного альбумина и сывороточного альбумина человека ("Sigma-Aldrich») при концентрации 0,5 мг/мл в присутствии солей натрия в концентрации 20 мМ, и из растворов Na- ДНК ("Serva") с концентрацией 0,25 мг/мл в присутствии хлоридов металлов при концентрации 10 мМ. Геометрические параметры текстуры различаются в зависимости от местоположения на поверхности кюветы и состава ионов в растворе. В отдельных структурных элементах присутствуют периодические структуры с характерным периодом повторения $L_2 \approx 4 \div 6$ мкм. Проведен анализ фрактальных текстур на поверхности пленок с хлоридами натрия, калия и рубидия.
КЛЮЧЕВЫЕ СЛОВА: раствор, пленка, альбумин, фрактал, текстура, галогениды металлов

The method of structural analysing the drying film of biological fluids (BF) is used for diagnosis in medicine and biology [1, 2] due to the fact that the structure of the solid-phase drying fluid characterizes the relationship between the substances located in the BF. The ongoing researches in this area are devoted to the analysis of processes in drying drops, to the development of theoretical models of the processes occurring during drying solutions BF [3, 4], to the study of the influence of humidity on the formation of the film structure [5, 6]. Besides such biological fluids as blood and cerebrospinal fluid, the objects of study are films from solutions of proteins [7] and nucleic acids [8]. The dendritic structures are formed on the surface of these films from solutions of biopolymers. The analysis of these structures allows to determine the degree of influence of biologically active substances [9 -11]. Previously, it was shown that on the surface of bovine serum albumin (BSA) films from solutions with sodium chloride metal salts are the scale-invariant fractal textures (SIFT) formed [12]. The analysis of the effect of metal salts on the formation of scale invariant fractal textures is carried out in the article.

MATERIALS AND METHODS

The films were obtained from BSA and human serum albumin (HSA) ("Sigma-Aldrich") solutions, at a concentration of 0.5 mg/ml in the presence of sodium salts at a concentration of 20 mM, and from the solution of Na-DNA ("Serva") with a concentration of 0.25 mg/ml in the presence of a metal chloride at a concentration of 10 mM. The chemically pure reagents were used. The solutions of biopolymers of 0.5 ml are poured into a cuvette with an area of 20x20 mm^2, which is positioned in a container with inlets for air evacuation. The cuvette, the container with silica gel and a relative humidity (RH) sensor are placed in the water bath. The apparatus for producing films is shown in [10, 12] in more detail.

RESULTS AND DISCUSSION

Figures 1 and 2 show the photographs of the films obtained from the solutions of BSA at a concentration of 20 mM NaF and 20 mM NaBr. It can be seen that the fractal texture on the film surface are not formed. The structures in Figure 1 are similar to the structures on the surface of films from solutions of Na-DNA with lithium chloride and calcium chloride [13]. Crystal structures in Figure 2 may form due to self-organization processes. On the other hand, scale invariant fractal textures formed on the surface of films from BSA solutions with 20 mM NaCl [12] and occupy no more than 40% of all textures on film.

The geometrical parameters of textures differ depending on location on the surface of the cuvette. Thus, the total length SIFT per unit area in the central part of the cuvette exceeds the corresponding value in the peripheral portion of the cuvette more than 1.3 times.

The photos of SIFT (the film from BSA solution with 20 mM NaCl) from the central and peripheral parts of the cuvette are shown in Figures 3 and 4. Such structures are also formed on the surface of films from solutions of other proteins. SIFT on the film surface from the HSA solutions with 20 mM KCl are presented in Figures 5 and 6. Linear L and angular α parameters of the repeating structural elements can be identified (Fig. 7). Textures on the peripheral (Figs 4, 6) and in the central (Figs. 3, 5, 8) portions of the film have lowest and highest values of L respectively. So, linear and angular parameters of the elements (Fig. 8) are varied in the range of L = 80 μm ÷ 350 μm and α = 110° ÷ 140°.

As it is shown in [14], the salts move into the central part of the drying droplet of biological fluid, while the protein molecules move in the opposite direction due to the difference in osmotic pressure generated by the dissolved salts and protein.

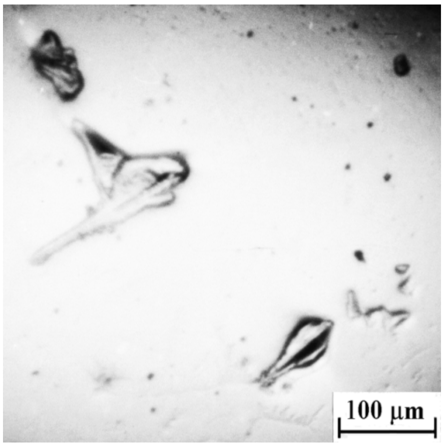

Fig. 1. Photo of the film obtained from solution containing BSA +20 mM NaF. T = 40°C, RH=0%.

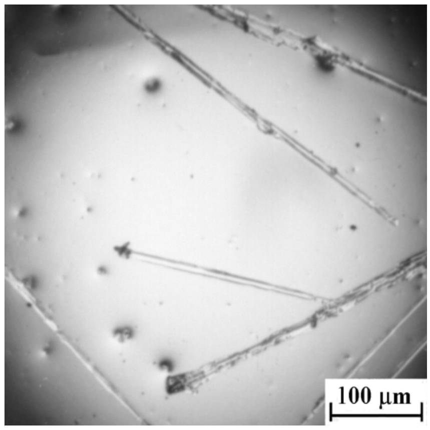

Fig. 2. Photo of the film obtained from solution containing BSA +20 mM NaBr; T = 40°C, RH=0%

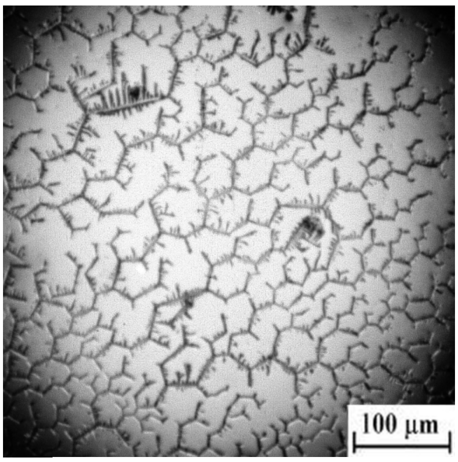

Fig. 3. Photo of the film obtained from solution containing BSA +20 mM NaCl; T = 40°C, RH=0%, central part of the cuvette.

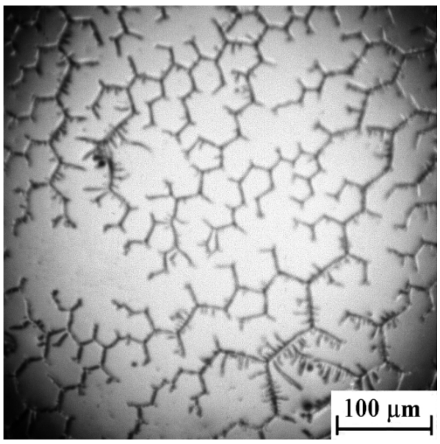

Fig. 4. Photo of the film obtained from solution containing BSA +20 mM NaCl; T = 40°C, RH=0%, peripheral part of the cuvette.

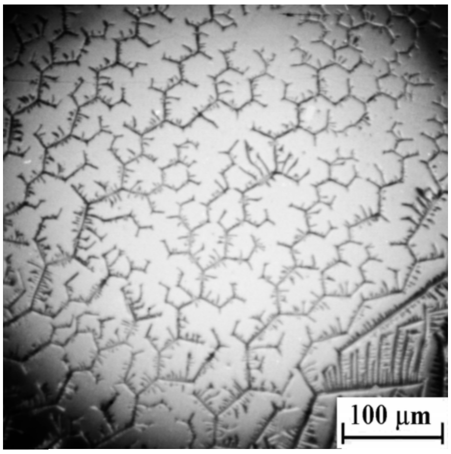

Fig. 5. Photo of the film obtained from solution containing HSA +20 mM KCl;
T = 40°C, RH=0%, central part of the cuvette.

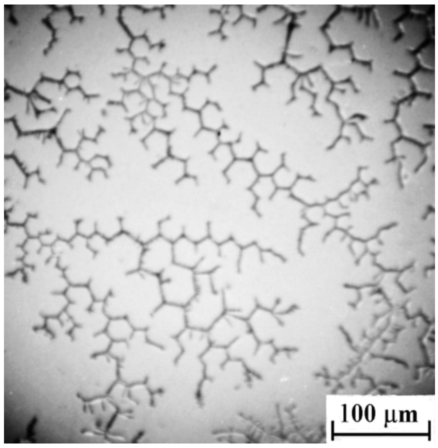

Fig. 6. Photo of the film obtained from solution containing HSA +20 mM KCl;
T = 40°C, RH=0%, peripheral part of the cuvette.

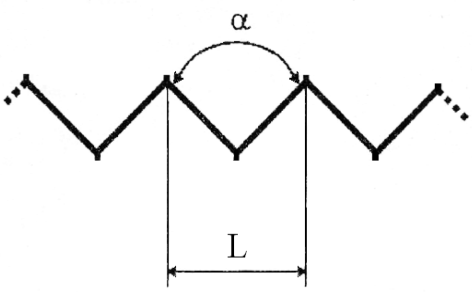

Fig. 7. Linear and angular parameters of the repeating structural elements

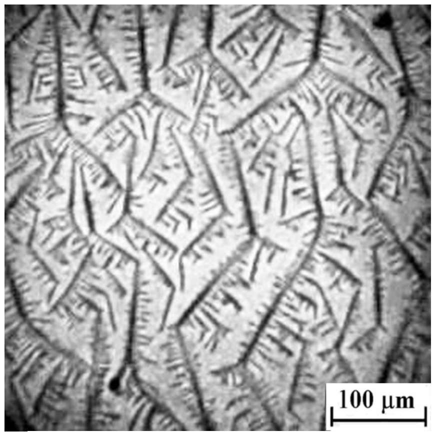

Fig.8. Photo of the film obtained from solution containing BSA +20 mM NaCl; T = 40°C, RH=0%, detail of the central part of the cell L = 80 μm ÷350 μm, α = 110° ÷ 140°

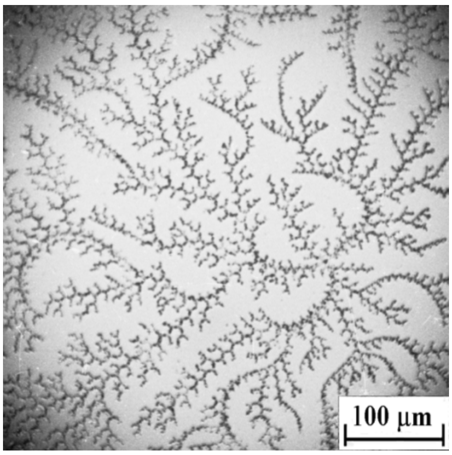

Fig. 9. Photo of the film obtained from solution containing Na-DNA + 10 mM NaCl; T = 40°C, RH=26%.

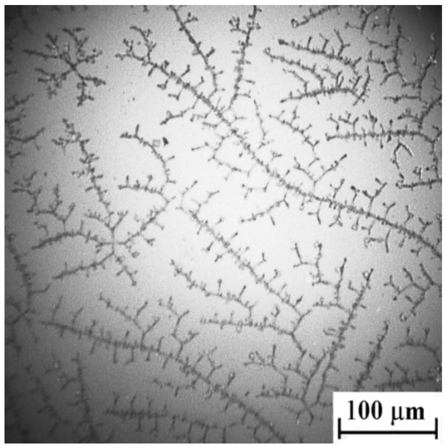

Fig. 10. Photo of the film obtained from solution containing Na-DNA + 10 mM RbCl; T = 40°C, RH=20%, central part of the cuvette

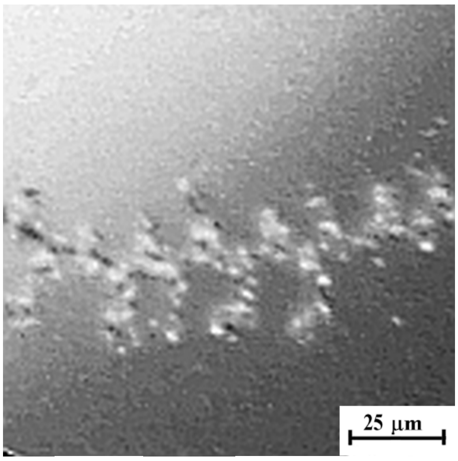

Fig. 11. Photo of the peripheral part of the film obtained from a solution containing Na-DNA + 10 mM RbCl;
T = 40°C, RH=20%.

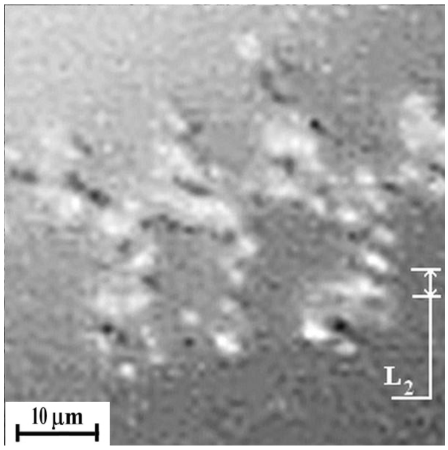

Fig. 12. Periodic structures with repetition period of L_2, enlarged scale photo of the Fig. 11.

Thus, the increased density of SIFT in the central part of the cuvette may be explained by the redistribution of salts and biopolymers on the surface of the cuvette during the solution drying.

The SIFT were formed on the surface of films from DNA solutions with chlorides of sodium, potassium, rubidium. Figures 9 and 10 present similar textures, obtained from DNA solutions with salts of sodium and rubidium. The values of the parameters of L and α depend on the composition of the ions in solution. Thus, the SIFT with values of $\alpha \approx 180°$ are fixed on the films of Na-DNA solutions with rubidium chloride (Fig. 10). As can be seen from Fig. 12, the periodic structures with characteristic repetition period of $L_2 \approx 4 \div 6$ microns are present in the individual structural elements.

In [15, 16] it is assumed that fractal textures on the surface of the substrate are crystal hydrates. Formation of the solvent structure and the number of binding sites with protein are important properties of salts presented in the solution [17]; the organization of ordered structures is based on a combination of various non-covalent interactions [18].

The obtained data show that the key factor in the formation of SIFT on the biopolymer film surface is the presence of such metal chlorides in the solution as sodium, potassium and rubidium.

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