NANOSTRUCTURES IN PROTEIN FILMS

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It has recently been theoretically and experimentally argued that some new chemical order appears at condensation of self-assembled cluster films of different materials, which were formed by weak bonds and depended on the sample size (Zhang, 1997). In particular a similar formation of polydispersed nanostructures was observed in polymers generated in colloidal solutions. Alike properties have been revealed on the functioning macroscopic level (Dai Hongile et al, 1996). There are theoretical predictions of analogous structures in proteins (Stupp et al, 1997).

In the present communication, some experimental results are described, which show that protein films, exhibiting non-linear dynamics, are formed in a non-equilibrium open protein-water system in vitro at rapid enough condensation. Non-identified earlier, highly regular nanostructures have been observed, which generated supramolecular aggregates (Rapis, 1997). The films generally exhibit a similar shape (though with minor difference in size), being separated on nanometric scale (scanning electron microscopy) and demonstrating some periodicity and layer orientations (Fig. 1).

Blocks of self-assembled thin films (multilayer stacks) have been morphologically identified. These films are really cut, with some symmetry features, which mainly appeared on the edges. The films were firmly adhered to the substrate (glass, plastic, wood, stone or metal). Such a supramolecular material gave a vividly green spontaneous fluorescence under an appropriate laser. Three-dimensional tree-like, terrace-like, tube-, funnel- and cone-like structures have been also revealed. Among this diversity of nano-structures, those with straight anisotropic rods connected (probably, covalently) to spiral blocks are most common (Stupp et al, 1997 for polymers).

In general the observations under discussion have shown non-linear chaotic (turbulent) dynamics for self-assembling dissipative nano-structures in non-equilibrium systems. Features of nematic liquid-crystal films (Joanny, 1997) and elastic films (Aggell et al, 1997) are also characteristic of the systems under discussion.

The non-equilibrium mechanism in question is associated with formation of charged solid aggregates of a dispersed anisotropic phase and with its separation from an isotropic dispersed medium, e.g., at a rapid evaporation of water far from thermal equilibrium (see Poulin et al, 1997), When protein molecules are aggregated from a colloidal suspension, different kinds of electric, magnetic and related forces manifest. Weak chemical bonding also become characteristic of such aggregates and related nano-structures.

Moreover, recent results have shown that such structural forms of protein were separated non-only in vitro but also in biological systems. Besides, a method of producing nano-structures in vitro has been developed. It can be supposed that polydispersed polymer

tree-blocks are formed from protein colloid suspensions as basic simplest units on nano-metric scale.

Our observations have also shown that more complex polymer blocs have been formed in protein differing from the other polymers mainly because of the role of tree-block systems, each chemically connected to a rod, unlike the situation for other polymers (Stupp, Bonheur et al, 1997). Often these blocks are situated one inside another, forming "families" resembling matreshka's fitted into one another

It is worthy of note that the experimental results obtained have to large extent supported recent theoretical predictions related to protein dynamics and published in recent months (e.g., Stupp et al, 1997). This concerns the data on the role of nano-structures, their size-dependent chemistry and mediator role in macroscopic organization of functioning material (Aggell et al, 1997. Stupp et al, 1997).

The meaning of the results may become clear in light of searching the protein folding mechanism. Additional investigations (nuclear magnetic resonance, x-ray structural analysis, etc,), concerning the chemistry of the material in question, are necessary to be accomplished for revealing more accurately the protein nano-structure compositions.