# The "surface - particles" interaction can be evaluated by changes in the fractal dimension of this surface

**Golikova O. S.[1], Marynchenko L.V.[1], Nizhelska O.I.[2]**

*1 Department of Biotechnology and Biotechnic, Igor Sikorsky Kyiv Polytechnic Institute, 37, Prospect Beresteiskyi, Kyiv-03056, Ukraine.*

*E-mail: golikova.oleksandra@lll.kpi.ua*

*2 Laboratory 36 Composite Materials for Nuclear-Hydrogen Energy, Institute of Applied Physics of NASU (Sumy), Prospect Nauki, 46, Kyiv - 03028, Ukraine.*

## Introduction

Fractal / domain / cellular structures can be formed in crystals, powders, liquids, gases, plasma as a manifestation of self-organization under the condition of application of external fields – temperature, electromagnetic, mechanical oscillations, etc. The formation of textured films on various surfaces is studied considering the wide range of applications. For example: gettering of materials for integrated circuits, coating of "biosolar panels" by modified *E. coli* cells with lycopene capable of converting sunlight into electric current, immobilization of biotechnological producers or diagnostic biosensors based on porous silicon. The formation of biofilms has a negative impact for implants in regenerative medicine.

The analysis of film textures is used in diagnostics, to assess the quality of products, and can be the basis for the development of express tests. In addition to differences in the shape of cells, fractal behavior can be influenced by other factors, for example, the distribution of adhesion forces on the surface, physicochemical interactions between charged particles, as a result of changes caused by any effects.

***The aim of our work*** was study of the influence of solvents or a static magnetic field on the texture of suspensions of microorganisms dried on the surface of silicon, namely, a numerical assessment of the dimensions of the formed structures and the relationship with the biological characteristics of these microorganisms.

## Methods

Research was carried out with a washed culture of yeast *Saccharomyces cerevisiae*, with probiotic strains of bacteria *Lactobacillus bulgaricus*, *Streptococcus thermophilus*, and with freshwater unicellular green microalgae *Chlamydomonas* ACKU 751, 759, 761.

The orderliness of yeast, microalgae and probiotic bacteria has been detected, which corresponds to the microscopic or grain-heterophase level of distribution of structural elements (5 nm - 100 μm). In order to carry out the detection a drop of a suspension of microorganisms (in distilled water, physiological saline, and ethanol) was applied to a plate of degreased polished silicon or glass, left to dry completely spontaneously [1].

Then the surface texture was photographed in reflected light at various magnifications (**Fig 1-3)**. The same was conducted under the influence of a static magnetic field (MF) with an induction of 0.15 to 0.17 T, directed perpendicular to the surface of the sample. Magnetic treatment changes the physical and chemical properties of the silicon surface [2]. The resulting microimages were processed in the ImageJ program: the images were converted to black and white, brightness and contrast were changed, and the size scale was removed. Then, with the help of the FracLac plugin, using the "Box counting" method, using standard settings, the indicator of fractal dimension F was calculated, as an indicator of the density axis of self-similarity, which shows the completeness of filling the space with a fractal in case of its increase, and lacunarity L, as a measure of heterogeneity.

## Results of optical microscopy

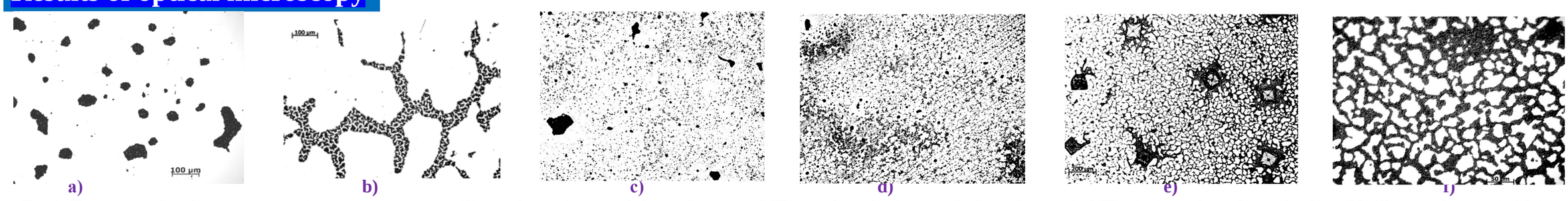


**Fig 1. Texture of dried yeast suspensions: in water on a silicon plate: a) control, b) under static MF; in ethanol: c) control, d) under static MF; e), f) in physiological saline (NaCl crystals are visible)**

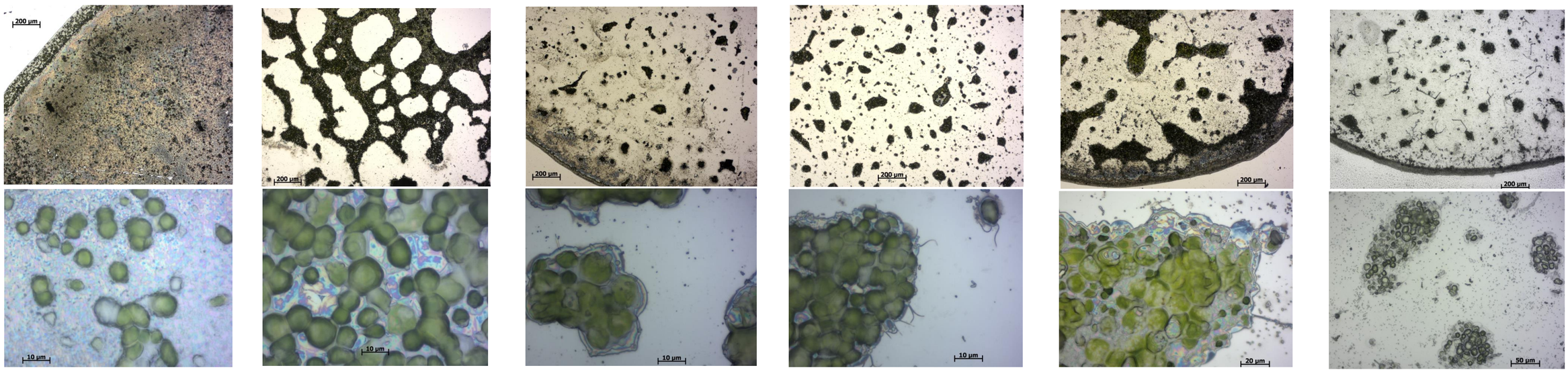


**Fig 2. Texture of dried suspensions of *Chlamydomonas* algae in water on a silicon or glass plate: a) strain 751, control, b) strain 751, under static MF; c) strain 759, control, d) strain 759, under static MF; e) strain 761, control, f) strain 761, exposed to MF**

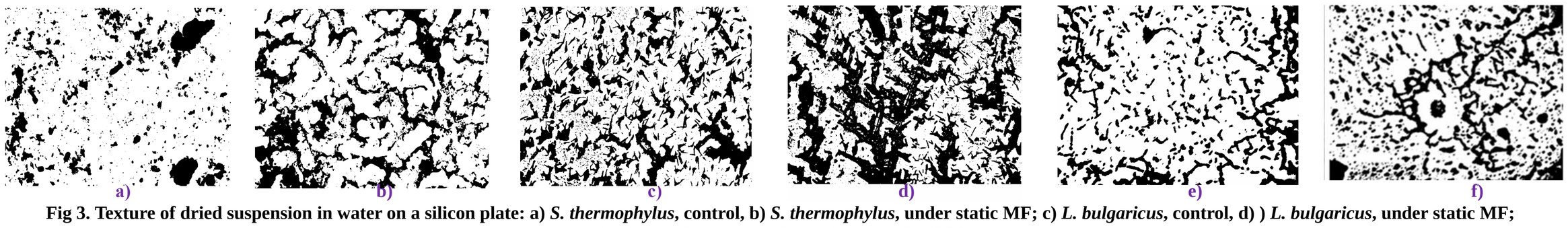


**Fig 3. Texture of dried suspension in water on a silicon plate: a) *S. thermophylus*, control, b) *S. thermophylus*, under static MF; c) *L. bulgaricus*, control, d) ) *L. bulgaricus*, under static MF; e) mixed culture, control, and f) exposed to MF**

## Conclusions

1) Visually, there were found significant differences both in the preservation of the shape of dried cells (under the influence of MF, the structure of cells has not been collapsed within 2 years of observation) [1], and in the self-organization of cells during drying on the silicon surface.
2) The trend for different types of microorganisms was an increase in average fractal dimension *D* (formation of figures):for example, for yeast cells, D was observed on x100 images from 1.288±0.017 for control samples to 1.497±0.032; for *Chlamydomonas* strain 751 x50, the fractal dimension increased from 1.6489±0.068 to 1.7349±0.029; for a mixed culture of *S. thermophylus* and *L. bulgaricus* on x200 images – from 1.703±0.008 to 1.832±0.005. It should be noted that the value of D depended on the magnification of the image, since both clusters and single cells fell into the field of view.
3) Simultaneously with an increase in fractal dimension *D*, a decrease in lacunarity *L* was observed, which indicated a decrease in voids in the pattern of cell distribution on the surface or an increase in certain orderliness. For example, for *Chlamydomonas* strain 751 x50 *L* decreased from 0.7524 ± 0.1138 to 0.3966 ± 0.0848.
4) The authors attribute cell distribution to the interaction of the predominantly negative ζ-potential of microorganisms with positively charged silicon impurities that getter the surface under MF exposure, that is, with the interaction of cell surface charges with the silicon surface.
5) In the presence of large aggregates of cells surrounded by mucus, as, for example, in the algae strains *Chlamydomonas* 759 and 761, there was no free movement of cells in the direction of the available positive charge when the suspension droplet dried, so the formation of a pseudofractal texture was not observed.

[1] O.I. Nizhelska, L.V. Marynchenko, V.A. Makara, S.M. Naumenko, A.M. Kurylyuk The stabilizing effect of magnetic field for the shape of yeast *Saccharomyces cerevisiae* on silicon surface // Innovative Biosystems and Bioengineering, 2018, vol. 2, no. 4, 278–286 doi: 10.20535/ibb.2018.2.4.151881

[2] *Makara V. A.*, Steblenko LP, Korotchenkov OA, et al. The Features of Magneto-stimulating Change of Surface Electric Potential in Silicon Crystals Used for the Needs of the Solar Energetics and Microelectronics. Nanosistemyi, nanomaterialyi, nanotehnologii. 2014;12(2):247-258.