Structural Macrokinetics of Biomimetic Processes in Artificial Cells

Gradov O.V., Gradova M.A.

Vernadsky Institute of Geochemistry and Analytical Chemistry RAS,
Moscow, 119991, Kosygin Str, 19, Russia,
e-mail: o.v.gradov@gmail.com

1. Introduction.

It is known that all cytophysiological processes occur on the cell ultrastructure, which is a heterogeneous (heterophase) medium. So the kinetics of metabolic processes should be considered as a structural macrokinetics of this partially ordered medium (soft matter). A macrokinetic approach is applied to a number of phenomena in which the reaction is synchronized with the diffusion, heat and mass transfer and charge transport, which include metabolism as a special case of processes in distributed active systems. However, the formation of non-equilibrium distribution of the reagents in the cell's ultrastructure is supported by the diffusion-limiting membranous structures, which are a special case of soft matter, together with the functionally similar colloidal systems. In this case, it is possible to simulate the structural macrokinetics of cytophysiological processes using heterogeneous distributed active medium (soft matter) as a carrier, reproducing the ultrastructural organization of the cytoplasm.

2. Materials and methods

The basis of the formation of stationary spatially inhomogeneous cytoplasmic distribution of reagents is the process of ultrastructural self-organization in distributed systems. Therefore, in cytophysiological modeling we used the method of photoinduced self-organization in a heterogeneous active medium (nanodispersed system) instead of the common methods of assembly, based on the forced association. The advantage of this method is that in the active medium under irradiation the formation of biomorphic dissipative structures and initiation of photoinduced metabolic processes on them occur simultaneously.

The structures obtained were investigated by the analytical SEM, TOF MS, X-ray phase microanalysis and the methods of chemical kinetics and mathematical morphology.

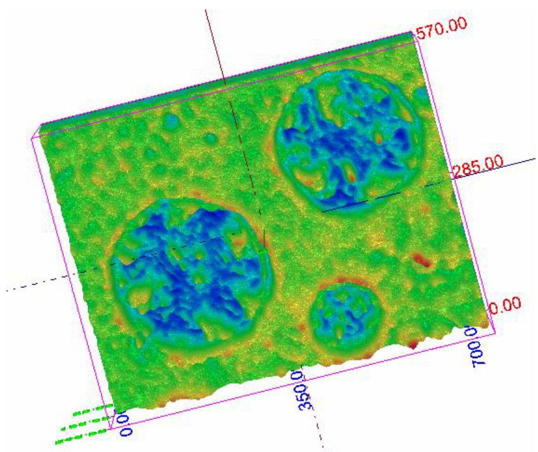

Fig. 1: Artificial Cells. 3D-view.

3. Results

From the data obtained it was found that the microstructures formed have a non-equilibrium distribution of concentrations, evolving in time and space, show oscillatory modes of reactions, possess distinct dynamics (pacemakers, standing waves) and reactivity to the external physical and chemical factors. Finally they are similar to the biological cells at the ultrastructural level due to the same physico-chemical mechanisms of an abiogenic origin. In other words, the self-organized biomimetic structures reveal structural macrokinetic behavior close to the biophysical one.

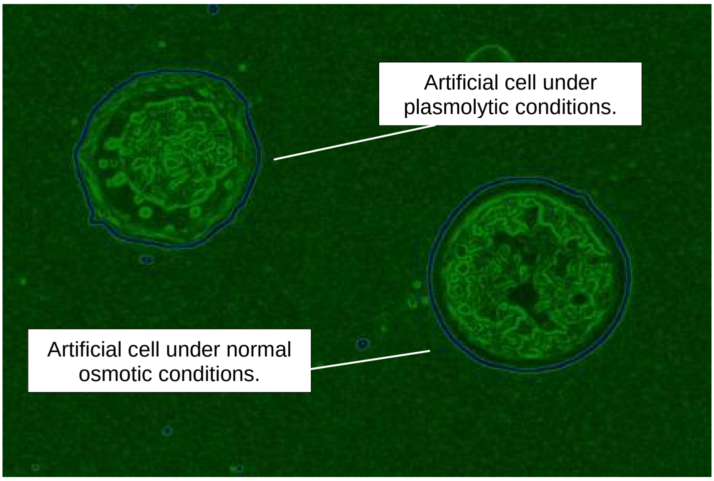

Fig. 2: Osmotic conditions model, based on the structural-kinetics cell's model.

4. Conclusion

Our model reproduces the structural-macrokinetic aspect of a number of metabolic phenomena, based on the physico-chemical analogies with the biological cell. Thus, the semi-permeability of bioorganic membranes is simulated by semiconductive polymer inorganic dynamic membranes, exergonic chemoosmotic redox processes are equivalent to cellular respiration, biomimetic self-oscillating reactions are analogues of oscillatory metabolic processes and finally the structure formation in these models is also provided by reaction-diffusion mechanisms.

References

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