International Journal of Engineering, Mathematical and Physical Sciences
ISSN: 2517-9934
Vol:8, No:7, 2014

Transformations of Spatial Distributions of Bio-Polymers and Nanoparticles in Water Suspensions Induced by Resonance-Like Low Frequency Electrical Fields

A. A. Vasin, N. V. Klassen, A. M. Likhter

***Abstract*—**Water suspensions of in-organic (metals and oxides) and organic nano-objects (chitozan and collagen) were subjected to the treatment of direct and alternative electrical fields. In addition to quasi-periodical spatial patterning resonance-like performance of spatial distributions of these suspensions has been found at low frequencies of alternating electrical field. These resonances are explained as the result of creation of equilibrium states of groups of charged nano-objects with opposite signs of charges at the inter-particle distances where the forces of Coulomb attraction are compensated by the repulsion forces induced by relatively negative polarization of hydrated regions surrounding the nanoparticles with respect to pure water. The low frequencies of these resonances are explained by comparatively big distances between the particles and their big masses with t\respect to masses of atoms constituting molecules with high resonance frequencies. These new resonances open a new approach to detailed modeling and understanding of mechanisms of the influence of electrical fields on the functioning of internal organs of living organisms at the level of cells and neurons.

***Keywords*—**Bio-polymers, chitosan, collagen, nanoparticles, coulomb attraction, polarization repulsion, periodical patterning, electrical low frequency resonances, transformations.

I. Introduction

APPLICATION of diagnostics of human organisms by means of electrical signals and therapy by direct and alternative electrical fields and currents are well known and applied rather widely [1], [2]. On the other hand the micro-molecular mechanisms of the role of electrical fields and currents in the functioning of living systems up to now is not understood in details. This paper contains an attempt to use the last our results presented at this Conference for development of a new approach to modeling and understanding of the mechanisms of influence of electrical treatments on the performance of internal organs. This approach is based on especial properties of systems of bio-polymers and nanoparticles with opposite electrical charges immersed in liquid water. Due to anomalously high dielectric permittivity of water and essential decrease of this permittivity in the regions surrounding charged nanoparticles and bio-polymers additional interaction appears between the objects with opposite charges. This interaction is repulsive on the contrary to usual Coulomb attraction. The spatial dependence of the repulsion is sharper in comparison with the attraction (inverse proportionality to the third power of the distance instead of the second power in the Coulomb case, because the repulsion results from the fields of dipoles). So at longer distances the attraction is stronger whereas during the approaching of the particles the repulsion becomes higher. So the equilibrium point appears like the equilibrium point in diatomic molecules where these two forces compensate each other. Our analytical estimations and experimental observations show that for nanoparticles and big bio-molecules this equilibrium inter-particles distance is in the range from shares of micrometer to tens of micrometer depending on dimensions and charges of the particles [3]. Due to relatively big distances between the particles and their big masses in comparison with diatomic molecules the resonant frequencies of these systems should be expected in the range from shares of Hertz to tens of Hertz. These values are in good correspondence with the frequencies of electromagnetic treatments found to be effective for living organisms. In this paper we present several experimental results obtained on models of resonance systems which can exists in living organisms. These results are in satisfactory correspondence with the analytical estimations and data from medical experience.

II. Experimental Setup

Distilled water suspensions with chitozan or collagen as bio-polymers and with non-organic nanoparticles (silicon dioxide, copper, nickel, barium titanate, lanthanum bromide, etc.) were mixed in various proportion by means of ultra-sound mixer. The typical dimensions of the nanoparticles were in the range 30 – 60 nm. The layers of these suspensions with the thickness 0,01 – 0.05 cm were poured out onto a glass substrate supplied with two parallel copper plates forming a sort of electrical condenser with 0.03 cm thickness. The distance between the contacts in various experiments was from 0.3 to 0.6 cm. The plates were isolated from the suspension with thin polymer film. The condenser was covered with a thin glass fixed on the condenser plates. The electrical fields were applied by means of direct electrical

N.V. Klassen is with Institute of Solid State Physics, Chernogolovka, 142432, Russia (phone: +7(496)522-46-94, fax: +7(496)524-97-01, e-mail: klassen@issp.ac.ru).
A.A. Vasin and A.M. Likhter are with Astrakhan State University, Astrakhan, 414056, Russia (e-mail: alexcampeones@yandex.ru, likhter@bk.ru).

source or electric generator of acoustic frequencies. The amplitude of the direct electric field applied to the condenser could be increased up to 400 v whereas the amplitude of the alternative electric field – up to 60 v.

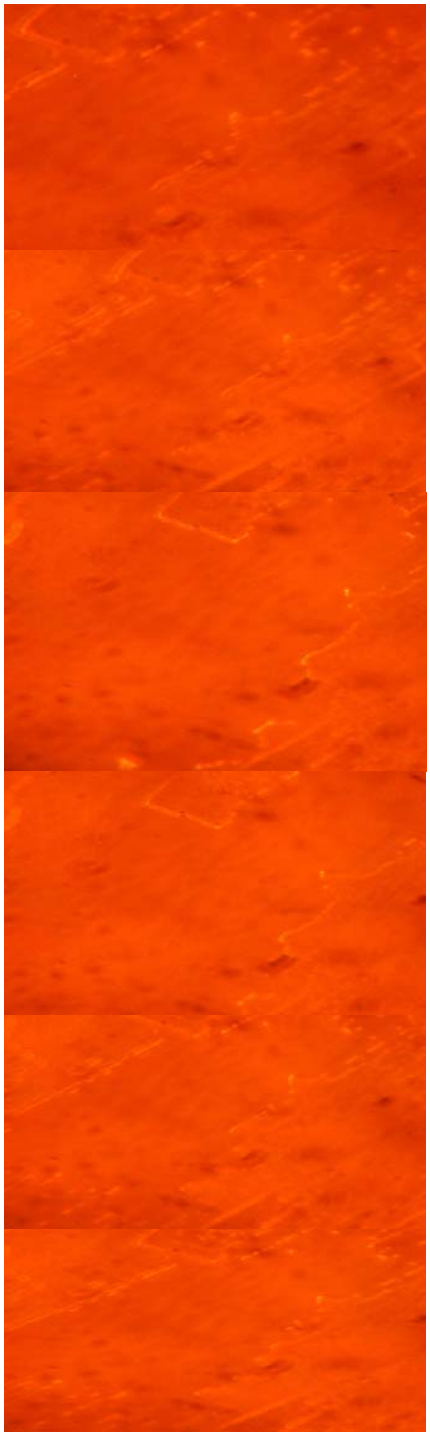

Fig.1 Resonant transformations of lines

The transformations of the suspension morphology were observed via the optical microscope "Amplival" supplied with video cameras and the images were registered by a computer including continuous recording of their variations in real time.

III. Experimental Results

We have found that several patterns created by application of direct electrical field to the water suspensions of bio-polymers and nanoparticles demonstrate resonance oscillations of images when subjected to low frequency alternating electrical fields.

Fig. 1 presents one of these situations where variations of the images of the water suspension with chitozan and silicon dioxide nanoparticles are shown. A set of 6 micro-pictures demonstrates temporal variations of the images of one and the same place of the suspension traces created at the cover glass. Two lines which are parallel to the electrodes of the condenser reveal oscillations rather clearly (their mean directions are inclined to the horizontal line by an angle of about 45°. The first line is close to the center, the second one is seen at the left half of the pictures). Taking into consideration the fact that the interval between the photos is about one second the resonance frequency inducing oscillations of these two line is about 1 Hertz. It is worth noting that the inclined line at the left part of the pictures besides disturbances of its form varies its position rather strongly (at pictures 3 and 4 it is not seen at all due to transfer out from the image area).

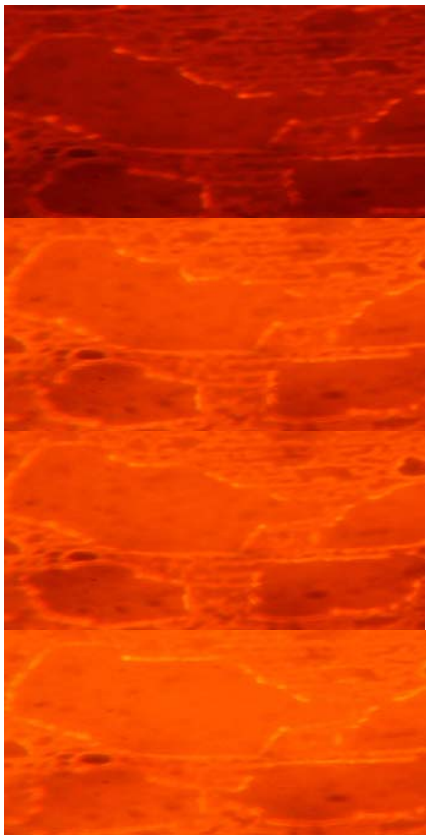

Fig. 2 Resonant regular transformation

Fig. 1 shows rather irregular disturbances of several lines of the suspension.

At Fig. 2 we demonstrate different situation when the low frequency (about 1 Hertz) of the external electrical field transforms rather irregular boundary of the suspension film (composed from water and SiO_2 nanoparticles) to the boundary with much better geometry (i.e. from “indefinite” geometry to the figure with three pairs of mutually parallel boundaries close to hexagon form). In some cases application of alternating electrical fields with such low frequencies resulted in displacements of separate micro-particles. One of these situations is presented at Fig. 3 where three pictures demonstrate the sequence of positions of several particles formed in the suspension with silicon dioxide nanoparticles. It should be noted that the fields of other frequencies including direct field did not induced noticeable variations of the pictures presented at Figs. 1-3.

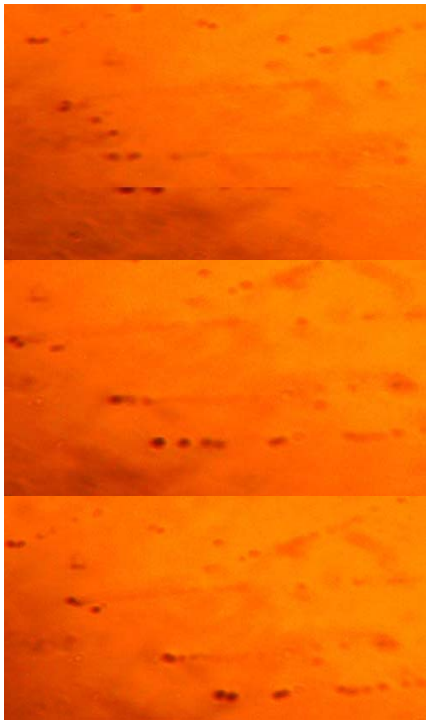

Fig. 3 Resonant displacement of points

IV. Discussion of the Results

The model of creating the quasi-periodical patterns of the suspensions is described in [3]:

It is well known that as a result of chemical interaction with components of water molecules (first of all - with a positive hydrogen ions and negative hydroxyl ions) and metallic and dielectric nanoparticles acquire an electric charge, and in border layer between the particle and the mass of water there is the electrical potential difference (the so - called hydrogen potential, the magnitude and sign of which are determined by the chemical composition of the particles and water which is characterized by a decimal logarithm of the hydrogen ion concentration, called pH) [4]. Our experimental observations and theoretical analysis showed that the interaction between particles and biopolymers is not described only by the attraction and repulsion in accordance with the Coulomb law. Important role in this interaction plays a dielectric constant of water. As is well known, one of the parties to the uniqueness of water is that its dielectric constant field is unusually high (e=81).The reason for this anomaly is asymmetrical arrangement of hydrogen ions (H+ in the water molecule H2O in relation to ions of oxygen O_2^- [5] (Fig. 3). The nature of this asymmetry is explained by the large share of covalent bonds between the hydrogen ions and oxygen in the water molecule. The minimum energy of these relations is achieved when the angle between their electronic "bridges" in 104.5^0. As the centers of gravity of positive and negative charges in the water molecule are not the same, it has a large dipole moment. The orientation of this dipole moment in an external electric field defines an anomalously large permittivity of water.

On the other hand, charged particles, once in the water, attract the dipole molecules, forming hydrates (Fig. 4). Molecules that are included in the hydrate region have a fixed orientation and their reorientation in an external electric field is quite difficult. Therefore, local dielectric permeability of the hydrate regions formed around the charged particles should be significantly lower than that of pure water. In addition, the nanoparticles have significantly reduced relative to clean water permittivity. Therefore, when applying for aqueous suspension with charged nanoparticles external electric field on the borders of hydrated areas there is a negative electric polarization. Effect of inhomogeneous field on the resulting polarization charges should push hydrate region in the direction of the field weakening because of its relatively negative polarization. On the other hand, the same nanoparticles out of the water environment have a positive polarizability and should, on the contrary, to get involved in a region of strong field.

The above considerations are confirmed by our observations of the influence of electric field on water suspension, when pushing out of the water drops onto the cover glass was observed after application of the electric field. Because the field on top of the glass above the electrodes was much less than the field directly between them, the bottom surface of the glass cover was a region with the reduced value of the field, where the particles with the surrounding water droplets were pushed out and accumulated.

The facts of the patterning described above can be explained by the fact that the both types of charged particles with opposite charges in water in addition to the Coulomb attraction are subjected to the repulsion forces pushing them out to the regions of decreased field. This process results from the fact that the dielectric permittivity around the charged particles is much lower in comparison with pure water. The minimum of electrostatic energy in this case will be achieved when the aggregate of these particles with hydrated water will be push out from the stronger field region (for the example to the cover glass).

The formation of quasiperiodic structures can be explained due to the same reasons, which treated the formation of a periodic lattice of a crystal from individual atoms, i.e. the balance between the forces of interatomic attraction and repulsion. Attraction is a result of interaction of particles with opposite electrical charges. Repulsive forces between the particles arise from reduced polarizability areas around the nanoparticles. As repulsive forces are caused by inhomogeneities of the electric polarization, their spatial dependence is similar to the spatial dependence of the dipole field - i.e. decreases inversely proportional to the cube of the distance. Coulomb forces depending on whether the source of the field is point or line, fall is inversely proportional to the second or first degree of the distance. Therefore at large distances from the particle to the source of the field the force of attraction is stronger, and on small distances the repulsive force is dominating. Consequently there is a point, where these forces compensate each other. This is the equilibrium distance between the two oppositely charged particles in water suspension. If the particles with one sign of the charge are identical to each other, the teams of the two groups of the particles with opposite charges can form quasi-periodic structure like those that are observed in the experiments described above. The spatial ranges of these structures correspond to balance of repulsion and attraction and are determined by the values of the charges of the particles, their size and the difference in the dielectric constant between pure water and scope that includes the particle and its hydrating water molecules. According to our estimates typical distances of these two-dimensional quasi-crystals for particles used in our experiments are in the range from a fraction of a micron to tens of microns, which is observed indeed in our experiments.

It is important to stress that the availability of the equilibrium distance between charged particles in the water environment, in which the Coulomb attraction is compensated with polarization repulsion, as in the case of diatomic molecules is immediately followed by the conclusion of vibrational resonance of this system. Because the masses of the particles that make up this type of resonators are much more the atomic masses and the distance between them is much more that the interatomic one, the resonance frequencies of these systems must be many orders of magnitude lower than molecular frequencies, making value from shares of Hertz up to tens or hundreds of Hertz.

In scientific publications there are a large number of experimental data on the effective impact of electromagnetic fields of low frequencies on living systems. We emphasize that effective mechanism of influence of low-frequency fields are not known yet. The experiments presented here and subsequent discussion (which in final variant will be supported by analytical calculations) indicate the possible existence in living systems of low-frequency resonance systems composed of electrically active non-organic and Bioorganic particles. This type of resonance oscillations arising in the low-frequency electric or magnetic field, is capable of significantly changing the permeability of cells or neuron membranes, modifying intracellular metabolism and the passage of the receptor and control signals through neuron structures. Thus the conscious management of these processes by using optimized from the point of addressed localization and frequency electromagnetic treatments has great potential for regulation and correction of the organisms.

V. Resume

Resonance-like performance of spatial distributions of water suspensions with bio-polymers (chitozan and collagen) has been found at low frequencies of alternating electrical field. These resonances are explained as the result of creation of equilibrium states of groups of charged nano-objects with opposite signs of charges at the inter-particle distances where the forces of Coulomb attraction are compensated by the repulsion forces induced by relatively negative polarization of hydrated regions surrounding the nanoparticles with respect to pure water. The low frequencies of these resonances are explained by comparatively big distances between the particles and their big masses with t\respect to masses of atoms constituting molecules with high resonance frequencies. These new resonances open a new approach to detailed modeling and understanding of mechanisms of the influence of electrical fields on the functioning of internal organs of living organisms at the level of cells and neurons.

References

[1] Matthew J. Snyder, BS*, Joel A. Wilensky, PhD*, and Joseph D. Fortin, DO, Review Article Current Applications of Electrotherapeutics in Collagen Healing, *Pain Physician*, Volume 5, Number 2, pp 172-181, 2002, American Society of Interventional Pain Physicians®.

[2] L. C. Kloth, Electrical Stimulation for Wound Healing: A Review of Evidence from in vitro Studies, Lower Extremity Wounds 4(1); 2005 pp. 23–44.

[3] Klassen N.V., Vasin A.V., Likchter A.M., Voronin K.A., Mariasevskaya A.V., Shmit'ko I.M., Electrical interactions and patterning of bio-polymers and nanoparticles in water suspensions, paper at this Conference.

[4] John L. Finney "Water? What's so special about it?", *Phil. Trans. R. Soc. Lond.* B (2004) 359, 1145–1165.

[5] P.Kumar, S.Han, H.E. Stanley, Anomalies of water and hydrogen bond dynamics in hydrophobic nanoconfinement, J. Phys.: Condens. Matter 21 (2009) 504108 (9pp) doi:10.1088/0953-8984/21/50/504108.