Title: Application of the electric and magnetic fields in sensors and biosensors

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Abstract

For over two centuries electric and magnetic fields remain among the most important effects used for controlled movement of objects, molecules and ions. Their utilization revolutionized myriads of branches of science and industry and technologies based on them are commonly used in various aspects of our everyday life. Main goal of this thesis is to make a contribution in this field and create important solutions that aid various sensing and biosensing technologies. Presented research concerns three practical applications complemented with basic research of unusual electrokinetic phenomena.

First part of my thesis consists of basic research focused on analysis of interaction upon application of alternating electric field. As a result, novel electrokinetic phenomenon of non-trivial characteristics was analyzed. Namely, long-range repulsion between oppositely charged surface was described. Created system was in fact a capacitor filled with electrolyte consisting of ions of unequal mobilities. Strength, range and time scale of the observed effect exceeded all previously reported electrokinetic phenomena.

Next part is focused on utilization of the electric field for improvement of various detection methods. First improved technology was surface enhanced Raman spectroscopy (SERS). Application of the alternating electric field allowed for deposition of wide range of tested analytes, from small organic molecules, through dyes and drugs, to biomolecules, such as DNA and proteins, on SERS substrates. Moreover, practical dependency between electrophoretic mobilities of deposited analytes and frequency of applied voltage was described.

Second application of the electric field concerned phage-based method of bacteria detection. Layers of phages oriented in the electric fields were utilized for fast and sensitive detection of bacteria. Proper orientation of bacteriophages allowed to overcome the problem of sterical hindrances of virions. Combination of developed solution with chemical modification of the surface allowed for creation of densely packed layers of properly ordered phages. This resulted in 64-fold increase of sensitivity of prepared sensing layers. Detection step took only 15 min and obtained limit of detection was less than 100 CFU/ml.

As the last part of performed research I used magnetic field for improvement of another phage-based method for bacteria detection. Bioconjugates prepared for this purpose were composed of sub-micron fluorescent-magnetic particles covered with bacteriophages. For preparation of bioconjugates only simple and accessible components were used. Moreover, created detection technology was based on flow cytometer – equipment common in hospitals and diagnostic laboratories. All of this resulted in technology that can be easily adapted and implemented, not only in highly-equipped research facilities.

Finally, I summarized all described achievements and proposed paths of further development of designed technologies and described effects.