Understanding adsorption/deposition mechanisms of particles and macromolecules at solid/liquid interfaces is of major significance for a number of scientific disciplines such as: material and food sciences, pharmaceutical and cosmetic industries, medical sciences, electrophoresis, chromatography, filtration, and catalysis. Especially important are macromolecule (protein, peptide, and polyelectrolyte) adsorption processes responsible for artificial organ failure, plaque formation, fouling of contact lenses etc. On the other hand, controlled macromolecule adsorption on various surfaces is a prerequisite of their efficient separation and purification, ultra filtration, and membrane filtration units, biocompatibility of implants or drug delivery. Due to a number of potential applications, the most important issue is to understand mechanisms that govern this phenomenon.
Although there are many reports available in the literature describing formation of multilayers by layer-by-layer technique; knowledge of effective formation of nanoparticle multilayers and their stability under various environmental conditions remains still rather fragmentary. Therefore the aim of this project is to carry out novel investigations on the mechanisms of nanoparticle multilayer formation on flat solid surfaces under in situ conditions. The proposed research project is focused on gaining an intense look and broadening the knowledge on the correlation between various physicochemical properties of nanoparticles and the structure and stability of their multilayers obtained in the self-assembly process. The major goal of this research project is developing a complete and quantitative description of nanoaprticle and nanoaprticle/biomolecule multilayer formation based on experimental methods working in situ, especially using the streaming potential method. Additionally, extensive modeling of these processes in terms of the MC-RSA methods is envisaged. The experiments planned within the scope of this project are focused on determining the influence of the electrokinetic properties of nanoparticles and macromolecules on the mechanisms of their deposition on solid surfaces and the coverage, porosity, thickness, structure and stability of obtained multilayers. The release of nanoparticles from their monolayers is especially important for further application of obtained nanostructures thus, the release aspect will be examined thoroughly in order to determine the rate of nanoparticle release depending on the composition and coverage of the monolayers. Moreover, controlling the structure and density of obtained multilayers, composed of nanoparticles and biomolecules characerized by multiple attractive properties for industrial applications, is of major challenge in designing novel and efficient drug delivery systems, antibacterial coatings, or ensuring artificial organ compatibility. The proposed studies are of particular importance for basic science because they will provide crucial information on the mechanisms and deposition (adsorption) kinetics of nanoaprticle multilayer formation. Such studies address the gap between quantitative description and understanding of fundamental adsorption phenomena responsible for the formation of novel multilayered structures and their stability.
Moreover, the research works included in the research project cover a wide spectrum of issues, which combines elements of colloid chemistry, surface chemistry and transport and adsorption of particles at solid/liquid interfaces, the results will have a significant impact on the development of sciences. The use of precisely characterized nanoparticles as well as macromolecules of defined size and surface properties, and the control of the parameters including temperature, ionic strength, pH in order to obtain colloidal multilayers will contribute to preparation of functional films and coatings of well-defined structure and topology. In this way, one can determine the validity of theoretical approaches in the nanoscale. The experimental data gathered for various colloid systems can be treated as useful references for the interpretation of protein adsorption phenomena. Additionally, an important aim of the research is to understand and describe the mechanisms of nanoparticle release from their films of precisely defined degree of heterogeneity. In this way one can precisely define the behaviour of obtained nanostructures in accordance with their destination. Besides the essential aspects of cognition in identifying the mechanisms of binding and release of nanoparticles from precisely characterized multilayers, the subject of proposed research project and selected prticles are essential for the development of industry and technology. The obtained knowledge will allow to construct new materials of desirable properties e.g. biocidal coatings or efficient and stable sensors. The element of novelty of the proposed project is also application of the streaming potential method for direct characterization of particle multilayers. It is worth underlying that this kind of studies have not been systematically investigated and described in the literature. The research objectives included in this project are significant both for basic colloid science and for developing a robust procedure for preparing nanofilms of controlled composition and density. Controlling the density and structure of such multilayer systems is an essential requirement for the development of biosensors, microcapsules, novel biocompatibile materials etc.