3D visualization of the boundaries of the dielectrophoretic trapping volume

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Project Type: Semester or Master project

Context: Dielectrophoresis (DEP) is the effect representing the movement of a polarizable particulate caused by the force originating from the interaction with a non-uniform low-frequency electromagnetic field. DEP is utilized for long-range manipulation (trapping, focusing, separation) of various objects, with microscale precision and has acquired wide attention in a variety of applications, including biosensing, cellular analysis, water purification, and nanotechnology. However, the limiting factor for routine analytical operations with DEP is the absence of a reliable experimental approach for the quantitative estimation of the DEP force experienced by the particle ensemble. One technique that can effectively address this issue is to image the boundaries between two distinct regions where the DEP force becomes weaker than the thermal randomizing force (defining the Brownian motion) acting on a particle in a liquid medium. The distance from the point of the strongest electric field gradient (trapping region) to this boundary is thus the quantitative estimate of not only the DEP force but also the particle polarizability.

Project overview: At the NAM, there are ongoing research projects that involve the investigation of different fundamental DEP aspects coupled with the development of novel DEP platforms for application in analytical chemistry. The present project proposes to visualize the boundaries between two competing forces acting on particles: DEP and thermal randomizing. This visualization will be made in 3D similar to what is commonly called tomography, i.e., acquiring a sequence of images in the x-y plane along the z-direction. The experimental platform for that will include an array of metallic microelectrodes fabricated on a glass substrate. To facilitate the boundary visualization, the surface of a chip with microelectrodes will be chemically functionalized by silane groups. The variation of the distance from microelectrodes along the z-direction will be made by covering the surface with transparent dielectric layers of various thicknesses. Furthermore, the project will involve the utilization of various characterization methods and the comparison of the experimental results with numerical simulations.

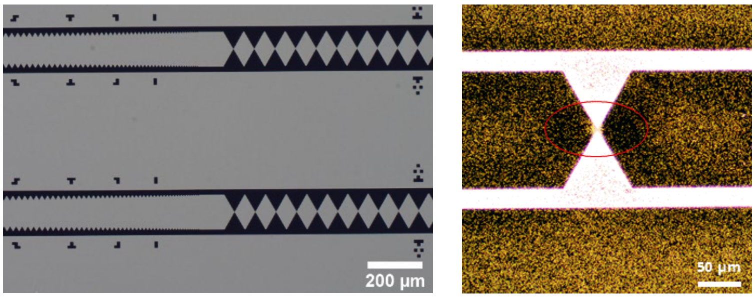

Figure. Left: Optical image of microelectrode array [1]. Right: Dark field image of Au nanoparticles adsorbed on the surface after DEP. The red circle indicates the boundary of a region where DEP force exceeds the thermal randomizing force

What the student will do. During this project, the student will use the cleanroom facilities of CMI and be introduced to the basics of plasma cleaning, photolithography, magnetron sputtering, electron beam evaporation, and characterization using an optical and electron microscope. The student will also be introduced to the NAM chemistry facility and learn the basics of surface chemistry, dark-field microscopy, and microfluidics. Furthermore, the student will gain theoretical knowledge concerning electrothermal, electrokinetic, and mass transport phenomena occurring on a microscale. This knowledge will be utilized to compare the experimental results with numerical simulations.

Benefits. Through this project, the student will gain vast hands-on experience in microfabrication, chemical functionalization, and characterization techniques. The project will also provide the interested student with sufficient theoretical knowledge to build their own numerical model, representing accurately the obtained experimental results. Besides, this project provides an opportunity to contribute to a scientific publication, to take part in extensive discussions with NAM researchers, and to practice the public presentation of scientific results.

References.

1. S. Zavatski, "Protein dielectrophoresis with gradient array of conductive electrodes sheds new light on empirical theory", Analytical Chemistry, vol. 95, p. 2958-2966 (2023)
2. A. Castellanos, "AC electrokinetics: a review of forces in microelectrode structures", Journal of Physics D: Applied Physics, vol. 31, pp. 2338-2353 (1998).