Membrane flow patterns in giant vesicles induced by inhomogeneous alternating electric fields

Margarita Staykova, Reinhard Lipowsky, Rumiana Dimova

Max Planck Institute of Colloids and Interfaces, Science Park Golm, 14424 Potsdam, Germany, E-mail: staykova@mpikg.mpg.de

Electric fields are widely applied for particle and fluid manipulation in numerous micro-scale systems, e.g. for moving, trapping or sorting cells; pumping and directing fluid flows, etc. Recently, a new class of electrically induced fluid flows has been demonstrated in the vicinity of electro-neutral, polarizable objects. These flows are driven by the displacement of the field-induced surface charges by the lateral component of the electric field. Such flows have been observed at various liquid and solid interfaces (drops, rigid particles, stripes, edges) but, to our knowledge, no experimental or theoretical studies have been pursued on lipid membranes. We use giant vesicles, which allow for direct microscopy observations on the effects of electric fields on membranes. These vesicles are not only bio-mimetic model for the cell membrane but also have large biotechnological application, e.g. as drug-delivery system, micro-reactors, etc. Their lipid membranes are incompressible fluids, which develop tension under forcing. Under homogeneous AC fields, membrane flow within the vesicle is not expected because the lateral electric stress is counterbalanced by the resulting axially symmetric gradient in the membrane tension. However, in most chambers and conditions used for electric manipulation, vesicles, cells or other particles experience inhomogeneous fields, due to screening by neighbors, sedimentation, chamber geometry, etc. Here, we show for the first time that even weakly inhomogeneous AC fields may induce a pronounced membrane flow in giant vesicles. The flow is visualized by fluorescently labeled lipid domains. The flow pattern differs substantially from any other previously reported. The influence of the field parameters and media properties will be discussed and a mechanism based on finite element calculations will be proposed. The AC-field induced membrane flow may possibly find significant application in microfluidic technologies, for lipid mixing, trapping and displacement, as will be demonstrated. We believe also that this method for visualization of the lipid displacement by intramembrane domains will be helpful for studies on membrane behavior in vesicles subjected to shear flows or mechanical stresses.