Erythrocyte Polarizability: Nonlinear Electrokinetics in Medical Microdevices

The controlled manipulation of bioparticles with electric fields has become ubiquitous in biotechnology laboratories, usually in the form of gel or capillary electrophoresis. However, creative use of electric fields for bioparticle manipulation in microdevices has also opened doors to opportunities in medical diagnostics. Such analytical microdevices are also referred to as lab-on-a-chip or micro total analytical systems (μTAS) and offer the potential for rapid, point-of-care diagnostics with implications in geographically remote medical situations. With relatively small electric fields, neutral matter can be manipulated: cells can be accelerated or trapped, proteins can be separated, DNA can be precisely focused, and other separations/purifications can be conducted at low concentrations.

This talk will focus on a subset of electrokinetics known as dielectrophoresis (DEP) for the analysis of erythrocytes (red blood cells). Dielectrophoresis is the polarizability of neutral & charged particles in a non-uniform alternating current electric field or a spatially non-uniform direct current field. Recent work in our lab has demonstrated that DEP can be utilized for rapid blood typing, recognition of membrane molecule expression, and hemolysis. Two microdevices have been tested with the ABO-Rh blood groups including a batch AC perpendicular electrode configuration and a continuous sorting DC microchannel with bifurcation and remote electrode configuration. Membrane molecule expression has been systematically tested by comparing the DEP signatures of neat erythrocytes and those subjected to a β(1-3)-galactosidase enzymatic reaction to digest the A and B polysaccharides from the membrane surface. The presence or absence of the Rh transmembrane protein is also discernible from the DEP signature. Lastly, hemolysis has also been demonstrated in the low frequency range. By merging the fields of microfluidics, electrokinetics, and biology, handheld microdevices capable of rapidly screening and quantifying diseases, infections, or other ailments may one day become commonplace in medicine.