Micro−Fluidic Research

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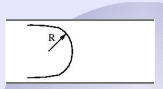
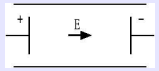
Introduction

Professor H.−C. Chang and his group have been studying micro−fluidic designs that can be used in future generation bio−chips for drug screening, medical −diagnostics, genomics and proteomics. These micro−devices cannot be scaled−down versions of their bench−scale counterparts because of new physical mechanisms that dominate at the small length scales of the devices. Quite often completely new designs must be developed to exploit and/or accommodate the new physics at micro−scales. Examples of physical mechanisms unique to micro−fluidics are:

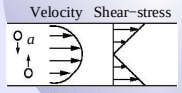
* Capillary Force σ/R



* Large Electro−osmotic and electrophoretic fields $E=\frac{\Delta V}{R}$



* Shear−induced particle migration $U a^2/R$

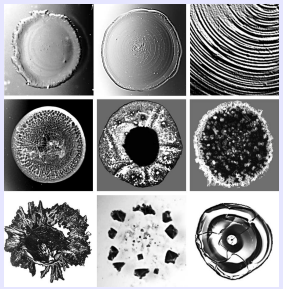


* Wetting and contact angle singularity $ln R$

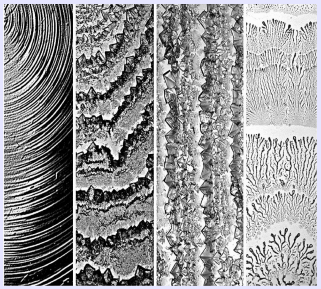
All terms blow up as R−>0 in the devices. Professor Chang's group investigates these microscopic mechanisms theoretically and experimentally to develop a new micro−fluidic paradigm. They are seeking industrial and academic collaborators to fabricate and test their new designs.

Current Projects:

(1) Designing Protein Stain Libraries



1 *mm*

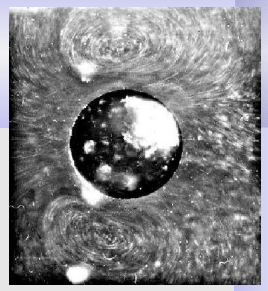


100 μ *m*

Instead of storing proteins and drug candidates in wet wells, next generation of high−throughput drug screening kits will store them in high−density protein stain libraries. These libraries consist of micron−size stains that are formed when nano−liter drops evaporate on a chip or a slide. Due to contact−line dynamics and capillary forces, however, such stains are often irregular and even fractal, making a regimented matrix library impossible. The group has investigated the stain pattern formation dynamics at micro−scales and has developed a strategy for making highly regular stain libraries with micron−size stains.

P. Takhistov and H.−C. Chang, " Complex Stain Morphology," Industrial Engineering and Chemistry Research, (2002, In Press).

(2) Micro−Mixing Chambers



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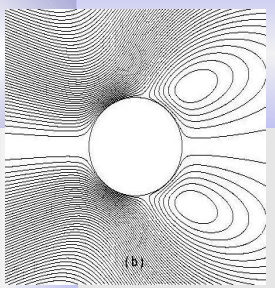
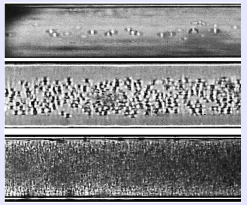


Despite their sub−millimeter scales, the miniscule diffusivity of proteins and drugs compounds (10^{-7} − 10^{-6} cm^2/sec) stipulates that most reactions/biochemical docking are diffusion limited with an excessively high diffusion time of minutes to hours. Stirring and mixing are the usual remedies at larger scales to enhance the transport rates. However, stirring is difficult for micro−devices as inertial pumping and moving parts are unavailable at such scales. The group has been able to generate sub−mm vortices with a novel non−linear electrokinetic mechanism.

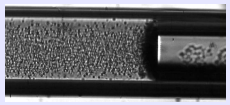
Y. Ben and H.−C. Chang, "Nonlinear Smoluchowski Slip Velocity and Vortex Generation," Journal of Fluid Mechanics, Vol. 461, 229 (2002).

(3) Blood Glucose Detection Kit

Blood cells migrate to the middle of a micro−channel due to the enhanced shear−induced migration rate of Ua^2/R. If a blood sample enters a channel by wetting, this migration will cause the blood cells to pack onto the meniscus and arrest further sample transport. Recent interaction with Bayer Diagnostics indicates that this is the major obstacle in designing micro−fluidic Blood Glucose Detection Kits.

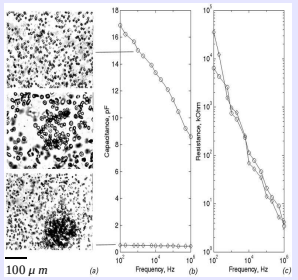


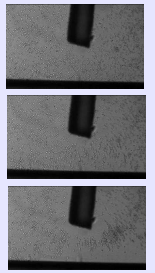
100 μ *m*



(4) Microfluidic Blood Cell / Cancer Cell /Bacteria Separation and Detection Methods

Because of the shape, size, elasticity and surface protein/ion−channel densities of blood cells, cancer cells and bacteria affect their migration speed due to hydrodynamic shear, linear electrophoresis and nonlinear dielectrophoresis, the group is exploiting these fundamental differences to separate and detect these bioparticles. AC dielectrophoresis and Impedance Spectroscopy especially are promising as the polarization of bioparticles due to ion migration are highly frequency dependent.





A. R. Minerick, A. E. Ostafin and H.−C. Chang, "Electrokinetic transport of red blood cells," Electrophoresis, Vol. 23, 2165(2002).