

EDUCATIONAL ACCOMPLISHMENTS:

- Developed multidisciplinary and multinational vertical teams including faculty, postdocs, graduate and undergraduate students to internationalize engineering education at graduate level
- Collaborated with partners at Technical University of Braunschweig (TU-BS) to find innovative strategies for integrating research and education
- Built on success of our undergraduate International Engineering Program (IEP) to create new dual-degree masters and doctoral programs
- Impacted other curricula at URI and at TU-BS to explore multidisciplinary dual-degree concept
- Offered a model for other institutions of higher education to adopt
- Enhanced the development of students through mentoring and career development
- Provided graduate students with multidisciplinary and international research experiences to increase their abilities to compete in global market

RESEARCH TOPICS and ACCOMPLISHMENTS:

- Capitalized on complimentary research strengths to create innovative discoveries
- Teamed across disciplines of engineering, chemistry and biology at URI to collaborate with partners at TU-BS to conduct research in microfluidics technologies and applications for point-of-care diagnostics
- Developed a prototype lab-on-a-chip and paper-based microfluidic devices for detecting disease biomarkers
- Discovery of disease biomarkers
- Coarse-grained Molecular Dynamics simulations of red blood cells in capillary flows
- Developed microfluidic-based ocean applications

EDUCATION MODEL:

DUAL-DEGREE MASTERS AND DOCTORAL PROGRAMS

Dual Degree Masters Program (MS/Diplom)

- First year at home institution
- Second year at host institution
- Thesis completed at host institution
- Mutually supervised
- Mutually accepted
- Defense with Braunschweig participation (real or by video-conference)

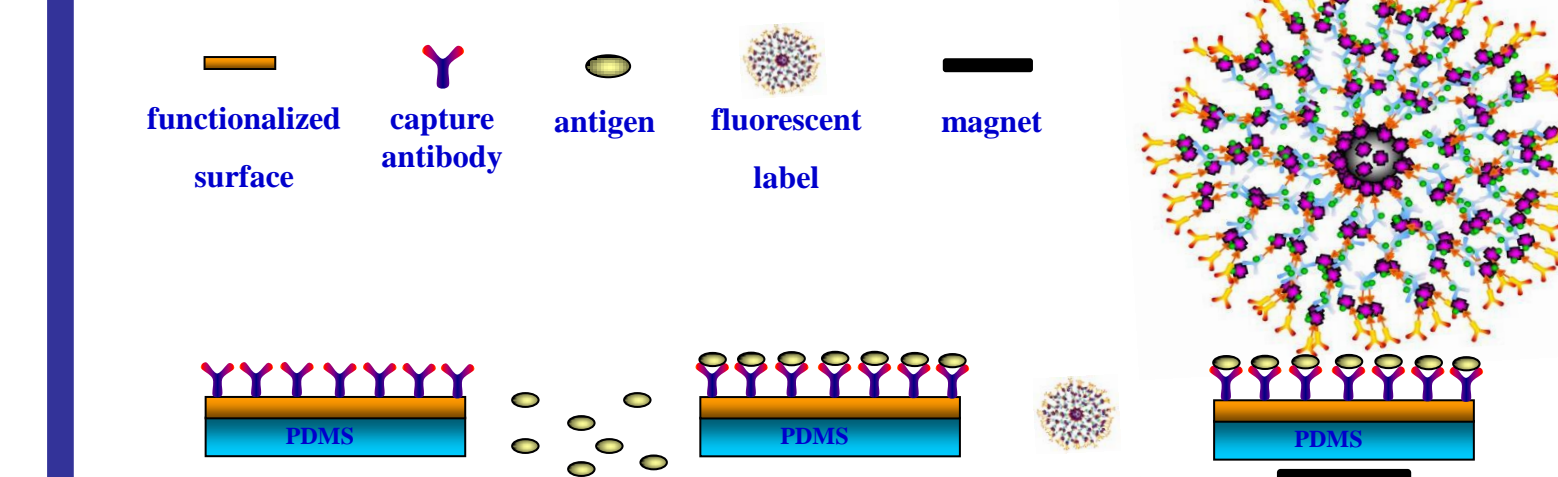
- MS degree from URI
- Diplom from the TU-BS
- 10 URI students have completed the program

Dual Degree Doctoral Program: Ph.D. / Dr.-Ing.

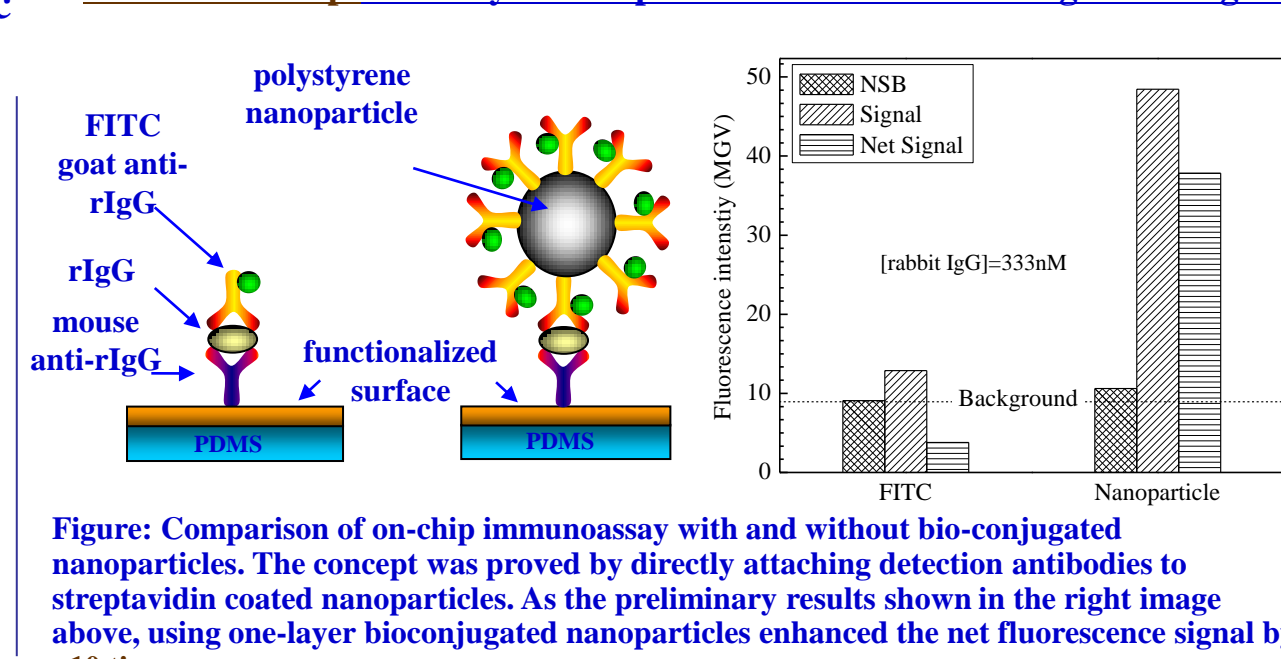
- Requires:
- At least 1.5 years abroad
 - Fulfillment of all requirements at both schools
 - Thesis to be accepted by both institutions
 - Thesis to be chaired by cooperating faculty from both universities
 - 2 URI students have completed the program

Magnetic Nanoparticles Encapsulated in Hyperbranched Protein Networks on a Biofunctional Microstructured Surface for Signal Amplification of Microfluidic Fluorescence Immunosensors

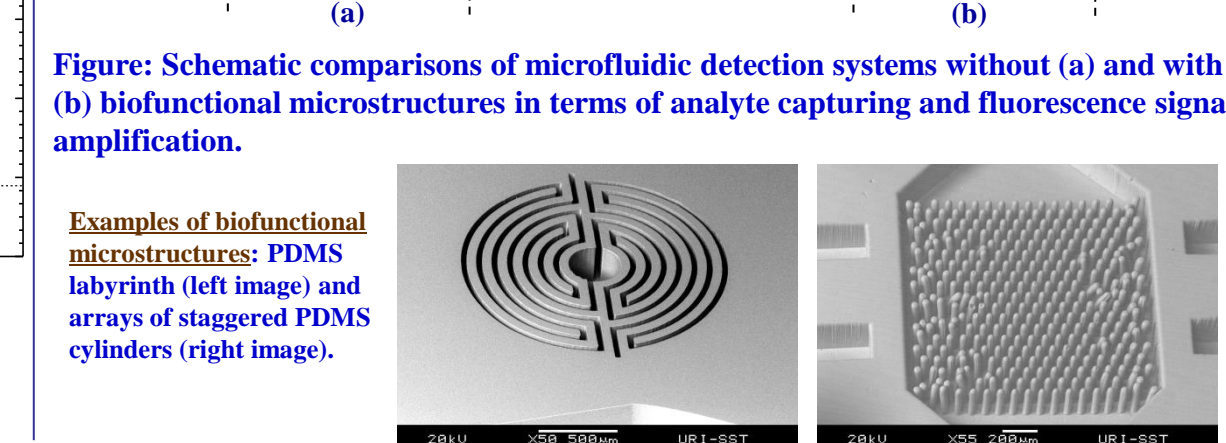
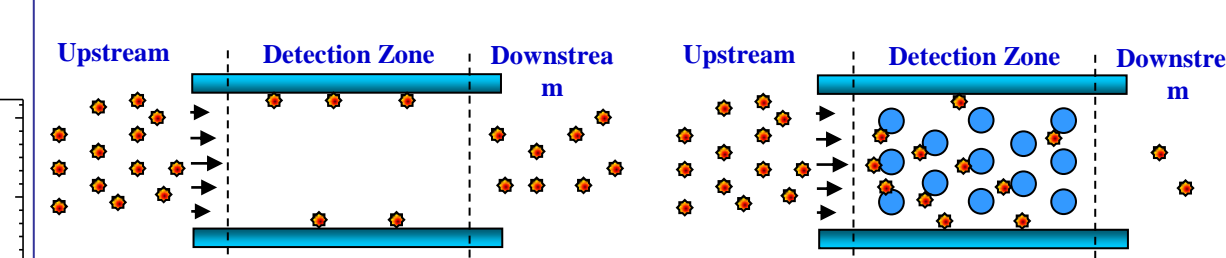
Method I: Bioconjugated Nanoparticle Probes



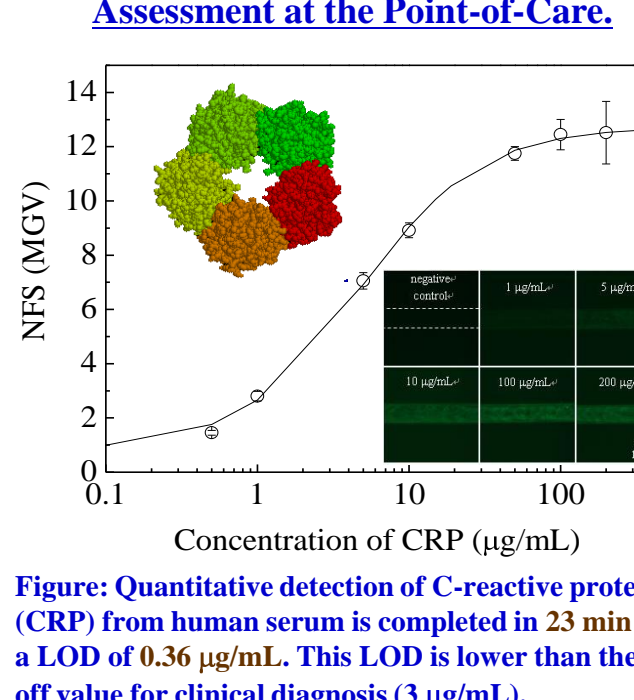
Proof-of-Concept: One-layer Nanoparticle Probe for Detecting Rabbit IgG.



Method II: Biofunctional Microstructures



Applications: Rapid Cardiac Risk Assessment at the Point-of-Care



Paper-based Microfluidics

Paper-based microfluidic devices consist of hydrophilic channels photopatterned in layered hydrophobic paper (left figure). The channels are "defined" by wettability contrast, not by physical walls. We fabricated paper devices consisting of multilayers of channels to distribute fluids (above, a, b, c and d) and to move fluids in 3D without mixing (above, e, f and g).

Microfluidic Inverse-phase Immunoassay

Moving magnetic beads from the reagent to oil (top) moving them back from oil into the reagent (bottom)

What is the total weight of magnetic beads we manipulated?

Immobilization and Characterization of Antibodies for Mass-sensitive Detection of Influenza Viruses

Influenza virus
In this work, Influenza virus H3N2 (Hemagglutinin type 3, Neuraminidase type 8 surface proteins) was tested.

Self Assembled Monolayers
SAMs form spontaneously upon immersion in surface-activated or organic substrates and form well defined and uniform monolayers. In these experiments SAMs were formed on the surface of the quartz resonator's gold electrode that had specific functional groups to allow the covalent bonding of biological molecules. Cystamine, Chloroacetylchitosan (Ch), and 3-(3-dimethylammonio)propyl carbodiimide (DAP) were used.

Fabrication
Using MEMS manufacturing techniques, (wet etching, sputtering of metals, etc.) a miniaturized quartz resonator with dimensions of roughly 5 mm x 5 mm and a thickness of 120 µm is possible. The resulting natural frequency is ~20 MHz.

Quartz Crystal Microbalance
QCM uses the well known piezoelectric effect in quartz, due to its stability over large temperature ranges and large output, in order to detect changes in mass loading as prescribed by the Sauerbrey equation:

$$\Delta f = -\frac{2f_0^2}{\sqrt{\rho_q \mu_q}} \left(\frac{\Delta m}{A} + \sqrt{\frac{\eta_1 \rho_1}{4\eta_2}} \right)$$

Where Δf is the frequency change, f_0 is the natural frequency, η_1 is the shear modulus of quartz, ρ_q is the density of the quartz, A_q is the area of the electrode, η_2 is the dynamic viscosity of the fluid, and ρ_1 is the density of the fluid.

The mass loading Δm , is therefore directly detectable through the respective frequency change.

Results
The resulting signal produced from the quartz resonator (through a control system) produces a direct signal that has the benefit of possible complete automation. Using a simple peristaltic pump, the various sample fluids can be introduced and the resulting signal recorded.

Collaborative Research between URI and TU-Braunschweig

Biomarker Detection via Antibody Phage Display

Developing Antibodies against the Salivary Gland Homogenate of *Ixodes scapularis*

Design for Capturing of Antigen(s) Binding to Three Isolated scFv Antibody Fragments:

BLF3-IB5
BLF4-IB10
BLF4-ID10

Incubation with Salivary Gland Homogenate
Precipitation
Attachment of scFv Antibody Fragments
9E10 Anti-sheep Antibody
Fur scFv Attachment and Stability

After Washing and Elution of Bound Protein:
Sequencing of scFv Fragment and Bound Protein from SGH
Comparison of Results with Genetic Databases for *I. scapularis*

After Competition, a Titration ELISA Confirms Binding and Quantifies scFv/Antigen Interaction (Putative)

ELISA Absorbance

Antibody Specificity

Current Experiments in Parallel

- Generation of Final IgG Candidates
- Generation of IgG Candidates from Two Previously Constructed Libraries
- Attempt to Match scFv/Antigen Binding Using Antigen Phage Libraries
- Previously Constructed from Additional Project

Development of a Lab-on-Chip Fluorescent Imaging System and its Applications to the Detection of Alzheimer's Disease Biomarkers

Kelly Cook
Dual MS Degree Candidate

Advisors: Mohammad Faghri, Constantine Anagnostopoulos, Assem Abolmaaty, Stefanie Demming, Andreu Llobera

PDMS Chip

Fiber Optic Excitation

Image Analysis

Green Intensity vs FITC Concentration

CCD Image 500 µm

Technische Universität Braunschweig

Handheld Biological Lens-less Detector for Point-of-Care Diagnostics

University of Rhode Island

Overview

- Design of a handheld lens-less detection device for C-Reactive protein.
- UV light is transmitted via wave guides built into a PDMS chip.
- A webcam with the lens removed will capture the emission light from the detection zone.
- The resulting images will be sent wireless to a server which will then be interpreted.
- The results will then be displayed in a customized iPhone App.

Reflective surface
Detection site
UV LEDs
Lens-less Charge Coupled Device (CCD)
PDMS chip

Prototyping and Testing Equipment

- Uses Proven Fluorescence Lab-on-chip Technology
- Reflective surface on top and side of detection zone will be utilized to enhance emission signals.
- Automated and manual control of handheld device using iPhone.
- Disposable PDMS cartridges will significantly reduce the cost of each test.
- Accurate and clear cut defined results.

DETECTION & NANOPARTICLE TRANSPORT

E Coli Separation and Detection Device

Three-layer pumping mechanism
All-in-one chip
Two separate chips
Pumping chip
channel chip
Oscillation Flow Streaming

Micro Pump for Particle Transport

Flow Streaming Experiments in Tapered Channel

Simulations of Particle Transport using Flow Streaming

Lab-On-Chip with Components
Hydrogel Valve

Micro Heater

A Portable Microfluidic Immunosensor for Point-of-care Diagnostics

University of Rhode Island

Introduction

The device here describes a portable and automated sensor capable of performing rapid and quantitative analysis of disease biomarkers or pathogens at resource-poor settings. The biosensor consists of a "shoebox" size reader and a silicone cartridge that has the footprint of a credit card.

Lab-in-a-Box

The biosensor consists of a compact light source and a miniature spectrometer for fluorescence detection, a micropump for fluid delivery, a disposable microfluidic cartridge, and a micro-controller and a touch-screen user interface. The weighs 3.3 lbs, and can be powered by, two nine-volt batteries.

Touch screen user interface allows for intuitive operation of the Lab-in-a-Box

Each disposable cartridge costs only \$1.50, and all reagents and wastes are contained in the cartridge so there can be no cross-contamination between tests.

LOD = 130 ng/mL

Concentration of CRP (µg/mL)

low risk
average to high risk
serious infection

Three-dimensional Simulation of Red Blood Cells via Dissipative Particle Dynamics in Capillary Flow

RBC membrane

Minimum energy principle is utilized to achieve the optimum shape of the RBC in equilibrium and/or under shear

- The total energy is based on stretch/compression, bending of membrane and constraint of total internal area and volume of the cell.
- Starting with the circular shape, RBC shape in equilibrium is achieved by decreasing the volume to 65%.
- 3-D RBC membrane is constructed as cluster of DPD particles connected through elastic spring network.

$E_{total} = E_{stretch} + E_{bend} + E_{area} + E_{volume}$

$E_{stretch} = \sum_{i,j} \frac{1}{2} k_{ij} (r_{ij} - r_{ij}^0)^2$

$E_{bend} = \sum_{i,j,k} \frac{1}{2} k_{ijk} (\theta_{ijk} - \theta_{ijk}^0)^2$

$E_{area} = \sum_{i,j} \frac{1}{2} k_{ij} (A_{ij} - A_{ij}^0)^2$

$E_{volume} = \frac{1}{2} k_v (V - V_0)^2$

$F_i = \sum_j F_{ij}$

Velocity and position of each RBC head is determined by integrating the force equation.

The mechanical characteristics of the RBC membrane was verified by simulating "Stretch Experiment". The results were compared with the available experiments.

In capillary flow RBC takes characteristic parachute type shape (As shown below).

- Moves along the centerline of the channel, to reduce the drag and minimize the total energy.