Our research centers on the interfacial and self-assembling properties of biologically relevant surfactants such as lipids and proteins. We try to understand how the fundamental chemistry and physics of lung surfactant monolayers and bilayers influence their physiological role of lowering surface tension in the human lung. Dysfunction of this system leads to neonatal and adult respiratory distress syndrome, which affects 100,000 people each year, with a 40% mortality rate. We believe that the problem is due to competition between serum proteins and lung surfactants for the interface during the inflammation that accompanies disease. We have built novel two-dimensional shear and dilatational rheometers that we couple to fluorescence imaging techniques to relate interfacial mechanics to composition and morphology. We are showing that the Laplace instability, caused by a lack of dynamic changes in surface tension during breathing, may be responsible for causing lung dysfunction during respiratory distress.

Our second area of interest is creating novel plasmon resonant gold nanostructures that strongly interact with near infrared (NIR) light. NIR is physiologically benign and can transmit through centimeters of tissue which makes it ideal for triggering local biological processes such as disrupting endosomes to release genetic materials to the cell cytoplasm with incredible spatial and temporal control. The laser pulses create cavitation-like nanobubbles around gold nanoparticles that can disrupt endosomes and nearly instantaneously release the desired protein or genetic material directly to the cytoplasm with high viability and efficiency. We are currently developing high throughput methods to create cell-based “drugs” by delivering mRNA to natural killer and T-cells to enhance the immune system response to cancer. The mRNA can code for chimeric antigen receptor proteins that help the immune cells target the cancer, but disappear after the cancer is gone. We create lipid based liposomes to encapsulate and protect the mRNA during endocytosis and delivery, then use the NIR light to generate nanobubbles to rupture the liposomes and endosomes to deliver the mRNA directly to the cytosol at high throughput and with high cell viability.

Awards
2014, Editorial Board Member, Biophysical Journal
Selected Publications


P. Dhar, Y. Cao, T. Fischer and J. A. Zasadzinski, Active Microrheology of Aging Protein Films. Physical Review Letters 2010; 104:016001