Interfacial Transport with Single Molecule Resolution

Daniel K. Schwartz
Department of Chemical and Biological Engineering
University of Colorado Boulder

Abstract: Interactions between molecules and surfaces lead to complex and highly-varied interfacial behavior, where heterogeneity may arise from spatial variation of the surface/interface itself, from structural configurations (i.e. conformation, orientation, aggregation state, etc.), or temporally, through inhomogeneous dynamic behavior. As an example of temporal heterogeneity, we have used high-throughput single-molecule tracking methods to study the interfacial transport of small molecules, polymers, and biomolecules. We universally observe intermittent motion, with periods of confined Brownian motion punctuated by long (Lévy) flights. The motion is described by a continuous time random walk (CTRW) model, with power-law distributions of both waiting times and flight distances. The specific CTRW parameters describing a particular system are sensitive to molecular characteristics including molecular weight, and surface properties such as chemical and topographical heterogeneity. CTRW-based search processes are widely predicted to improve efficiency compared with Brownian searches, and many biological systems have evolved intermittent search strategies. To directly measure the implications of intermittent interfacial molecular transport on molecular associations, search efficiency, and dynamics, we used single-molecule Förster resonance energy transfer (FRET) to observe the dynamic behavior of donor-labeled biomolecules (proteins and DNA) at the solid-liquid interface. We have found that enhanced interfacial transport is responsible for protein interactions and associations that lead to unfolding and surface layer formation, and for enhanced hybridization efficiency between “searching” and “immobilized” DNA oligomers.

Biography: Dan Schwartz is Chair of the Department of Chemical and Biological Engineering and the Glenn L. Murphy Professor at the University of Colorado Boulder. He has been a professor at CU-Boulder since 2001. He was previously a faculty member in the Department of Chemistry at Tulane University from 1994-2000. Dan received his Bachelor’s Degree in Chemistry and Physics and his PhD in Physics from Harvard, and subsequently performed post-doctoral fellowships in Chemical Engineering at UCSB and Physical Chemistry at UCLA. Dan's research interests focus on interfacial phenomena with specialties in surface modification, surfactant phenomena, biotechnology, liquid crystals, single-molecule microscopy, and biomimetic catalysis. He has published over 180 peer-reviewed manuscripts that have been cited more than 7000 times. His recognitions include the NSF CAREER award, the Dreyfus Foundation Teacher-Scholar award, the CU-Boulder Faculty Assembly Award for Excellence in Research, and selection as a Fellow of the American Physical Society and the American Chemical Society. Dan has been a Senior Editor of Langmuir, the American Chemical Society's journal of interfacial science, since 2004 and currently chairs the ACS Colloid and Surface Chemistry Division (COLL). He was the founding Director of the Tulane Science Scholars program (an enrichment program for high school students) and of the Summer Research Experience for Undergraduates Program in Functional Materials at CU-Boulder. He also developed a general education course at CU-Boulder, Creative Technology, that has communicated state-of-the-art technology concepts to more than 6,000 non-science undergraduates to date.