Dynamics in a Broad Scale: Biological Inspiration for Charge Transfer and Interfaces

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Photophysical dynamics will be the common theme of this talk encompassing charge transfer in the femto and picosecond time domains and spanning to the sub-second scales of microflows. The presented examples will demonstrate some of the impacts of photophysics on several different fields of science and engineering. The importance of molecular-level and nanoscale control of charge transfer cannot be overstated. Electrets, systems that possess ordered electric dipoles, present an excellent choice for a source of fields that can guide movement of charges. Electrets, however, are dielectrics, unable to efficiently mediate long-range charge transduction. To overcome this challenge, we undertake bioinspired approaches. Adopting principles from proteomics, we design molecular electrets comprising de novo non-native aromatic amino acids that are capable of holding charges. While the electrets still possess large intrinsic dipoles originating from ordered amide and hydrogen bonds, the aromatic moieties along the electret backbones provide pathways for efficient long-range charge transfer. In addition to their utility for attaining charge-transfer rectification, the molecular electrets prove the foundation for discovering new fundamental principles of the dynamics of long-range charge transfer. We observe for the first time that, against the accepted notions, the dipole-modulated electronic coupling can prevail over the dipole effects on the Franck-Condon contributions to the kinetics, i.e., over the dipole-modulated electron-transfer driving forces. That is, rates of electron transfer toward the negative poles of the macrodipoles can be 10 times larger than those toward the positive poles. While leading to new understanding of field effects on charge transfer, bringing the molecular electrets to materials interfaces allows for emergence of unique phenomena out of the complexity of such assemblies. Concurrently, we also resort to bioinspired approached for interfacing inorganic substrates with organic and biological media. Controlled level of disorder and entropic repulsion, for example, yields abiotic surfaces with specific functionality that we employ for biomedical optical imaging and therapy, as well as for exploration of single-molecule mechanics, thus, interfacing basic science and applied engineering. While the focus of this talk is on our bioinspired molecular electrets and their charge-transfer properties, the additional examples reinforce the notion for the importance of photoinduced dynamics for energy enegineering and biomedical applications.