Recording Single Molecule Chemistry with Nanotube Electronic Devices

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Nanoscale electronic devices like field-effect transistors have long promised to provide sensitive, label-free detection of biomolecules. Single-walled carbon nanotubes in particular have the necessary sensitivity to detect single molecule events and the bandwidth to monitor single molecule dynamics in real time. Recent measurements have demonstrated this premise by monitoring the dynamic, single-molecule processivity of three different enzymes: lysozyme [1-2], protein Kinase A [3], and the Klenow fragment of DNA polymerase I [4].

With all three enzymes, single molecules were electronically monitored for 10 or more minutes using nanotube devices. These long recordings allowed us to directly observe rare enzyme transitions to chemically inactive or hyperactive conformations. The high bandwidth of the nanotube transistors further allow every individual chemical event to be clearly resolved, providing a record of tens of thousands of turnovers by a single enzyme molecule. While the statistical means establish values for processivity and turnover rates, the measurements also reveal variability, dynamic disorder, and the existence of intermediate states. Initial success with three different enzymes indicates the generality and attractiveness of the nanotube devices as a new tool for single molecule science, and our focused research on transduction mechanisms provides the design rules necessary to fully generalize this architecture [2]. This presentation will summarize these rules, and demonstrate how the purposeful incorporation of just one amino acid is sufficient to fabricate effective, single molecule nanocircuits from a wide range of enzymes or proteins.