Single Molecule Bioelectronics with Carbon Nanotube Circuits

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Nanoscale electronic devices like field-effect transistors have long promised to provide sensitive, label-free detection of biomolecules. In particular, single-walled carbon nanotubes have the requisite sensitivity to detect single molecule events, and they have sufficient bandwidth to directly 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, allowing us to directly observe rare transitions to chemically inactive and hyperactive conformations. The high bandwidth of the nanotube transistors further allow every individual chemical event to be clearly resolved, providing excellent statistics from tens of thousands of turnovers by a single enzyme. Besides establishing values for processivity and turnover rates, the measurements revealed 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 to complement other single molecule techniques. Furthermore, our focused research on transduction mechanisms provides the design rules necessary to further generalize this architecture [5]. 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.

[1] Y. Choi et. al., Science **335** 319 (2012). [2] Y. Choi et. al., JACS **134** 2032 (2012). [3] P. Sims et. al., JACS **135** 7861 (2013). [4] T. Olsen et. al., JACS **135** 7855 (2013). [5] Y. Choi et. al., Nano Lett. **13** 625 (2013).