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Monitoring Single-Molecule Protein Dynamics with a Carbon Nanotube Transistor

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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 press this concept further by not just detecting molecules but also monitoring their dynamics in real time. Recent measurements have demonstrated this premise by monitoring the single-molecule processivity of three different enzymes: lysozyme [1], protein Kinase A [2], and the Klenow fragment of DNA polymerase I [3]. With all three enzymes, single molecules tethered to nanotube transistors were electronically monitored for 10 or more minutes, allowing us to directly observe a range of activity including 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. 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. Research on transduction mechanisms provides the design rules necessary to further generalize this architecture and apply it to other proteins [4]. The purposeful incorporation of just one amino acid is sufficient to fabricate effective, single molecule sensors from a wide range of enzymes or proteins.

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