A New Nucleic Acid Detection Platform based on Nanofluidics : Exploiting Non-Equilibrium Ion Distribution and DNA Conformation Dynamics

Focus topic 5: Micro and Nanofluidics

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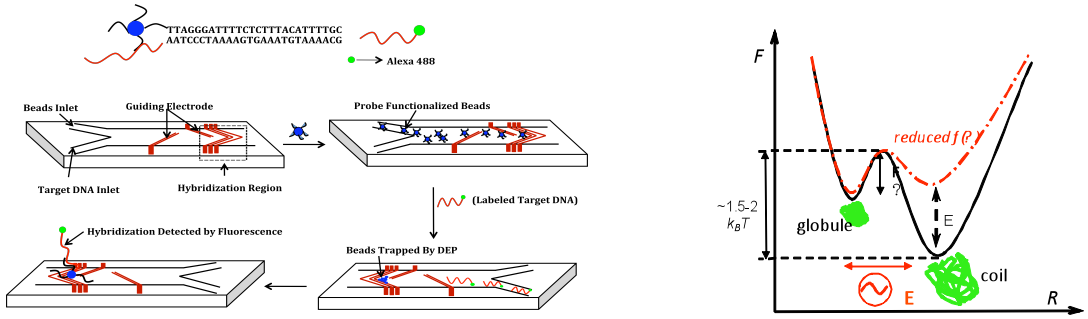
We exploit the rectification, hysteretic, polarization and water-splitting characteristics of ion currents through a nanoporous membrane to design a new class of molecular assays. The hybridization efficiency and selectivity of molecular probes functionalized to the on-chip membranes, nanoslots and nanocolloid assemblies are optimized by exploiting the non-equilibrium (non-Poisson) ion distributions near the surface, due to open-flux ion currents through the membranes, to dynamically control the local pH and ionic strength. The detection sensitivity is likewise enhanced by using charge inversion and ion depletion to produce sharp impedance and cyclic-voltametry signatures of the hybridization events. In addition, DC and AC electro-osmotic flow is used to concentrate and selectively remove molecules at the sensor. Several integrated platforms will be reported with picoM (one-million nucleic acids) detection limit, single-mismatch selectivity and assay time less than15 minutes. We present some preliminary data that suggest that the kb-long ssDNA is being stretched by the AC field and the nanofluidic hydrodynamic shear. Some evidence of stochastic resonance transition from the collapsed globule conformation to the stretched coil conformation will be presented to further expedite the hybridization assay. [Refs: Yossifon, G. and Chang, H.-C., "Selection of Nonequilibrium Overlimiting Currents:Universal Depletion Layer Formation Dynamics and Vortex Instability", Phys Rev Lett., 101, 254501(2008). Basuray et al, "Shear and AC Field Enhanced Carbon Nanotube Impedance Assay for Rapid, Sensitive and Mismatch-Discriminating DNA Hybridization", ACS Nano, 3, 1823 (2009).]



Scheme 1