Emergent Cooperative Response to Single-Molecule Affinity Binding in Large-Area Biolayers

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How can a single biomolecular binding event generate a measurable response across a sensor containing a macroscopically large ensemble of recognition elements? Addressing this question requires considering the biofunctionalized interface as a soft, polar and collectively responding system.

I will discuss physisorbed antibody monolayers on gold and their integration into electrolyte-gated transistors and graphene-based optoelectronic devices. Experimental evidence indicates that very few binding events can trigger an electrostatic reorganization of the protein layer, producing pronounced changes in surface potential. Kelvin probe force microscopy probes this spatially extended response, while infrared spectroscopy and two-dimensional correlation spectroscopy reveal a non-random structural organization governed by a surface-density-dependent spreading–packing competition. Non-faradaic electric-field cycling further acts as an annealing-like process, reducing the dispersion of biolayer polarization and improving reproducibility.

These results frame large-area biofunctionalized surfaces as complex systems in which molecular dipoles, ionic screening, structural organization and spatial correlations jointly enable electronic and optical sensing at the single- or few-molecule limit.