Plasmonic Hot-Carrier-Based Biosensors

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Abstract: Hot carriers, i.e., non-thermal electrons or holes with excess kinetic energy, are generally considered detrimental in conventional semiconductor devices due to device degradation. However, hot carriers generated from plasmons can be harnessed for optical-to-electrical signal conversion when extracted before thermalization. Metal nanoparticles allow incident light to directly excite their free electrons into collective oscillation in a coherent way, known as localized surface plasmons, by relaxing momentum-matching constraints. Plasmons subsequently undergo non-radiative damping in the nanoparticles such as phonon-assisted intra-band absorption and Landau damping to generate hot electrons and holes with excess energy above and below the Fermi level, respectively.

Here, we demonstrate the use of plasmon-generated hot carriers as a signal-transduction mechanism for biosensing. To prove the concept, this new approach was applied to the detection of 17β-estradiol, the low-molecular weight biomarker associated with precocious puberty, and present in human blood and urine. We achieved ultrahigh sensitivity, a broad dynamic range and reasonably good reproducibility. This new mechanism may break the barrier that limits the detection of low-molecular-weight biomarkers in conventional plasmonic biosensors, which rely on local refractive-index changes.