Supplementary Material

Integrative plasmonics: optical multi-effects and acousto-electric-thermal fusion for biosensing, energy conversion, and photonic circuits

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Table S1. A summary of plasmon-enhanced sensing technologies.

Technique	Mechanism	Key Features	Typical Applications	Performance	Ref.
Plasmon-Based Refractive Index (RI) Sensing	Changes in the local refractive index alter plasmon resonance conditions	High sensitivity, label-free detection, real-time monitoring	Aptamer-functionalized gold nanodisc array for psa detection	113 nm/RIU sensitivity and 1.49 ng/mL LOD	1
			Plasmonic nanohole array for exosome detection	-	2, 3
			Opto-microfluidic platform for sars-cov-2 antibody detection	0.5 pM LOD	4
			Functionalized plasmonic metasurfaces for sars-cov-2 variant detection	Detection limit two orders of magnitude lower than commercial immunoassays	5
			Plasmonic-coupled optical microfiber for dopamine detection	Single-molecule detection	6
SEIRA (Surface-Enhanced Infrared Absorption Spectroscopy)	Localized surface plasmon resonance (LSPR) enhances infrared absorption	Enhances molecular IR absorption signals (10^4–10^6 enhancement factor)	Plasmonic bowtie nanantenna with a 3 nm gap for detection of 4-nitrophenol molecules	Detection of a trace amount (approximately 500 molecules) of aromatic thiol derivatives	7
			Multi-hotspot nanantenna combined with MOF-polymer enrichment membrane for CO_2 gas detection	Low detection limit (ppb level) and high sensitivity (0.18%/ppm)	8
			Overcoupled plasmonic resonators for multianalyte detection	Detection of 13 analytes Sensitivity for PMMA is 7.25%/nm	9, 10
			Surface plasmon phonon polarization for dynamic monitoring of glucose enzymatic reactions	Accurately resolve overlapping vibration modes	11
			Multiresonant plasmonic nanoantenna integrated with artificial intelligence for VOC gas monitoring	Low LOD (IPA: 1.99 ppm, ethanol: 3.43 ppm, acetone: 9.82 ppm) and 100% classification accuracy for 125 VOC mixing ratios	12
SERS (Surface-Enhanced Raman Spectroscopy)	LSPR and electromagnetic enhancement boost Raman scattering	High signal-to-noise ratio, single-molecule detection (10^6–10^{14} enhancement factor)	SERS artificial nose for high dimensionality fingerprinting	Differentiating multiple analytes using mildly selective self-assembled monolayers	13
			Flexible plasmonic metasurface for sweat monitoring	Detection limit of 0.01 nM for mitoxantrone	14
			Wearable plasmonic paper–based microfluidics for continuous sweat analysis	Detection limit of 0.1 μM for uric acid	15
			In vivo plasmonic nanoprobes for	SERS EF of 2.9×10^7 and a signal-to-	16

			monitoring stress signaling molecules in plants	noise ratio of up to 64	
Surface Plasmon-Enhanced Chiral Spectroscopy	LSPR enhances circular dichroism (CD) or chiral Raman signals	Increases sensitivity of chiral molecule detection, enhances chiral optical response	Plasmonic planar chiral metamaterials for biomolecule detection	Characterization of picogram quantities of adsorbed molecules	17
			Achiral plasmonic nanostructures for inducing chiral responses	-	18
			Quadruple-resonance metasurface for glucose enantiomer detection	0.26%/mm sensitivity and 0.03 mm LOD	19
			Infrared chiral plasmonic metamaterials for protein detection	Detection limit as low as ~23 zeptomolar	20
			Patterned plasmonic sheets for terahertz circular dichroism spectroscopy	-	21
SEF (Surface-Enhanced Fluorescence)	LSPR enhances fluorescence signals, modifying fluorescence lifetime and quantum yield	Boosts fluorescence probe sensitivity, enables fluorescence lifetime control	Bowtie nanantenna for large-scale single-molecule fluorescence enhancement	Fluorescence enhancement of a single molecule by 1,340 times	22
			Single-molecule reaction detection using silver nanantenna thin films coupled with nanoporous cavity substrates	Single-molecule detection	23
			Stacked plasmonic nanowell–nanopore biosensor for single-molecule fluorescence detection	0.1 nM LOD	24
			Silver decahedral nanoparticles for detecting lactoferrin in milk	1.25 pM LOD	25
			Framework gold nanoparticle structures for assessing SARS-CoV-2 nucleocapsid protein	44 fg/mL sensitivity and 0.84 ag/mL LOD	26
Nanospectroscopy via PIRET (Plasmon-Induced Resonance Energy Transfer)	Resonant energy transfer between plasmons and molecules improves spectral sensitivity	Non-radiative energy transfer, enhances spectral resolution	Conjugated metal-ligand complexes and single gold nanoparticle plasmonics for Cu^{2+} detection	1 nM LOD	27
			Al disk metasurfaces for detecting multiple biomolecules	4.48 µM sensitivity and 0.4 µg/mL LOD	28

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