Nanostructure-Based Aluminum Sensors for Highly Sensitive Biosensors

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The studies of nanostructure-based aluminum sensors have attracted a large attention because aluminum is a more cost-effective plasmonic material. However, the intrinsic properties of the aluminum metal, having a large imaginary part of the dielectric function and a longer electromagnetic field decay length and problems of oxidation and material degradation, limit the surface sensing capability and applicability of nanostructures. We propose the combination of capped aluminum nanoslits and a thin dielectric protection layer to overcome these limitations. We find that the protection layer can enhance the wavelength sensitivities of the Wood's anomaly-dominant resonance and asymmetric Fano resonance in capped aluminum nanoslits. The maximum improvement can be reached by a factor of 3.5. Besides, there is an optimal layer thickness for the surface sensitivity because of different decrease rates between the refractive index sensitivity and decay length. We attribute the enhanced surface sensitivity to a reduced evanescent length, which is confirmed by the finite-difference time-domain (FDTD) calculations. The protein-protein interaction experiments verify the high surface sensitivity of the structures and a limit of detection (LOD) of 1 pg/mL anti-BSA is achieved. Such low-cost, highly sensitive aluminum-based nanostructures can benefit various sensing applications.

Keywords: Aluminum nanostructures, Biosensors, Fano resonance

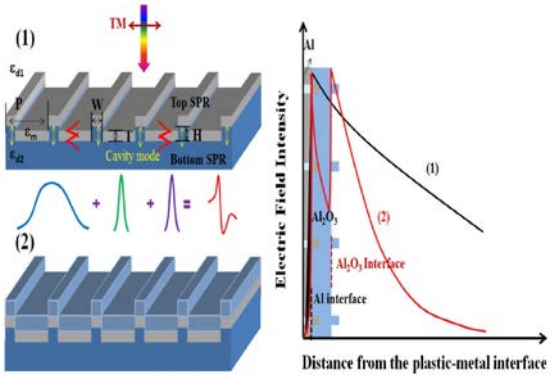

Fig. 1 Electric field distributions in alumina/aluminum capped nanoslits. The left panel shows a schematic configuration depicting the geometrical parameters of the alumina/aluminum capped nanoslits, the direction of the transverse magnetic (TM)-polarized incident light and the Fano resonance. The right panel shows a schematic diagram depicting the electric field distributions at metal and alumina interfaces for aluminum and alumina/aluminum capped nanoslits.

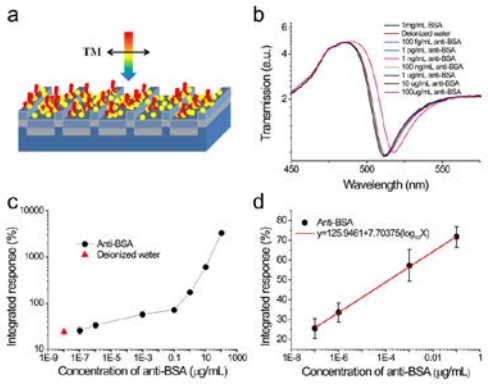

Fig. 2 Surface sensitivity tests of 470-nm-period alumina/aluminum capped nanoslits. a, A schematic cartoon showing the measurement of the interactions. b, The measured transmission spectra in different concentrations of anti-BSA solutions from 100 fg/mL to 100 μg/mL. c, The integrated responses caused by different concentrations of anti-BSA solutions. d, The integrated response as a function of the logarithm of the concentration of the anti-BSA solution.

References:

1. Kuang-Li Lee, Hsuan-Yeh Hsu, Meng-Lin You, Chia-Chun Chang, Ming-Yang Pan, Xu Shi, Kosei Ueno, Hiroaki Misawa & Pei-Kuen Wei*, "Highly Sensitive Aluminum-Based Biosensors using Tailorable Fano Resonances in Capped Nanostructures", Scientific Reports 7, 44104 (2017)