Electronic Supplementary Material (ESI) for Nanoscale.

Top-down Fabricated Gold Nanostrip on Silicon-on-insulator Wafer: A Promising Building Block towards Ultra-compact Optical Device

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S1. Polarization dependence of the end scattering intensity through the gold nanostrip plasmonic waveguide.

Simulated (solid line) and experiment (dots) results of the polarization dependence of the end scattering intensity of gold nanostrip waveguide on the SOI substrate. The best coupling condition occurred when the incident polarization parallel to the long axis of the gold waveguide (θ = 0 degree).

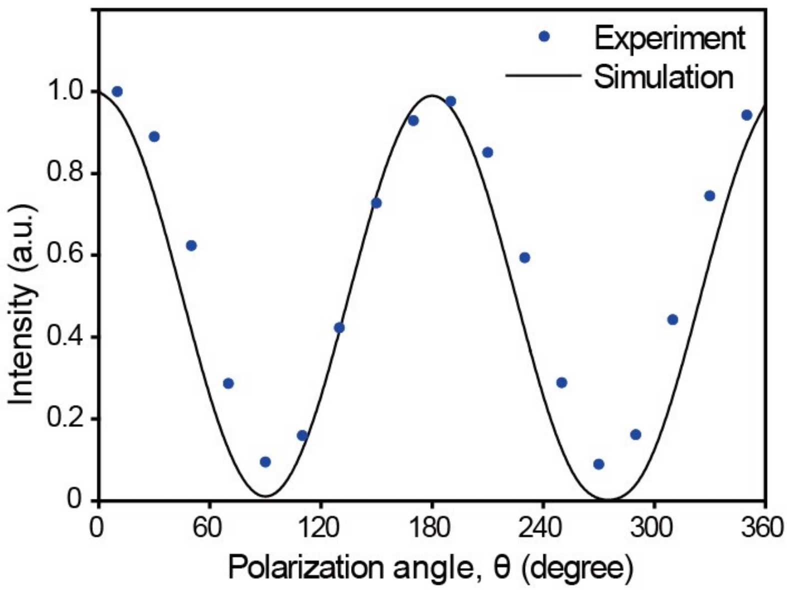


Figure S1. The gold nanostrip is 150 nm in height and 300 nm in width. The substrate has a 50 nm thick silicon top layer and the wavelength is 660 nm.

S2. Surface roughness characterization and MPTMS served as the adhesive layer.

The AFM morphology comparison of silicon wafer (a), MPTMS modified silicon (b), gold film on silicon (c) and gold film on MPTMS modified silicon (d) is given. We can see that after the treatment of the MPTMS self-assemble layer, the gold surface roughness is slightly decreased compared with that of no MPTMS treatment (e). What's more, after the same ultrasonic washing process, part of the gold film peeled off from the substrate without MPTMS treatment, while the gold film on the substrate with MPTMS treatment remains intact (f). This phenomenon proved that the MPTMS molecule also can improve the adhesion between gold and silicon.

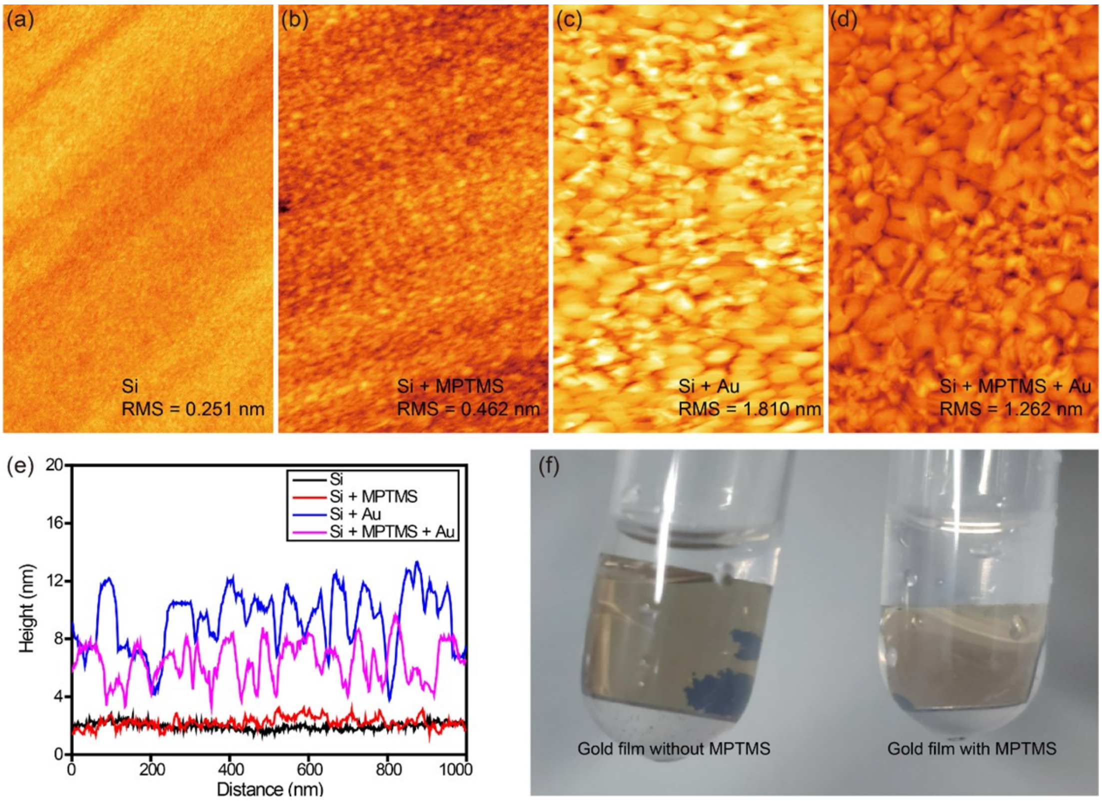


Figure S2. (a-d) The Atomic Force Microscope morphology of silicon wafer, MPTMS modified silicon, gold film on silicon and gold film on MPTMS modified silicon, respectively. (e) The cross profiles of the AFM images in (a-d). (f) The photograph of a gold film on a silicon substrate without/with MPTMS treatment after an ultrasonic process.

S3. Comparison of the end scattering spectra of different plasmonic waveguide configurations with direct light excitation.

The end scattering spectra were simulated by FDTD. The results showed that the gold strip waveguide on SOI gives the second strongest end scattering intensity in the range of 650 nm to 750 nm among all kinds of the plasmonic waveguides on the same Gaussian beam terminal excitation in air.

The thick red solid line represents the SPPs' end scattering spectra of the nanostrip on the SOI substrate. The thick black solid line shows the gold nanostrip in air and the solid blue line shows the gold nanostrip on a silica substrate. The dashed red line represents a CdS nanowire on a composite substrate with a 20 nm thick SiO_2 and 60 nm gold film on a silicon substrate, and the diameter of the CdS nanowire is 220 nm [1]. The result of a silicon nanostrip waveguide on a silica substrate is showed with the green dashed line, and the height is 220 nm and the width is 445 nm [2]. The dashed blue and purple line represents the channel plasmon polariton with a V-shape and gold gap on silica [3]. The degree of the V-shape is 17° and the depth is 1.7 μm. A gold nanostrip pair on silica substrate has a size of 40 nm in height and 100 nm in width and the gap is 100 nm [4].

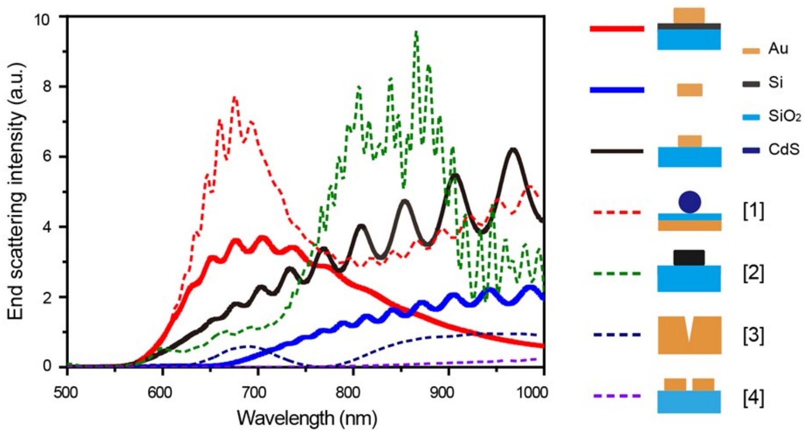


Figure S3-1. The gold nanostrip is 150 nm in height and 300 nm in width and the silicon thickness of the SOI is 45 nm.

The waveguide's optimized geometric parameters with low propagation loss and high coupling strength in a specific wavelength range are highly dependent on the strip's cross-section geometry. Our simulation results show that increasing the nanostrip's height and width can improve the Strip/Air waveguide's end-scattering intensity in the range of 650-750nm (dotted black line vs. solid black line in the figure below). However, the Strip/SOI can provide better waveguiding behavior in the range of 750-950 nm for the same size strip (solid red line in the figure below).

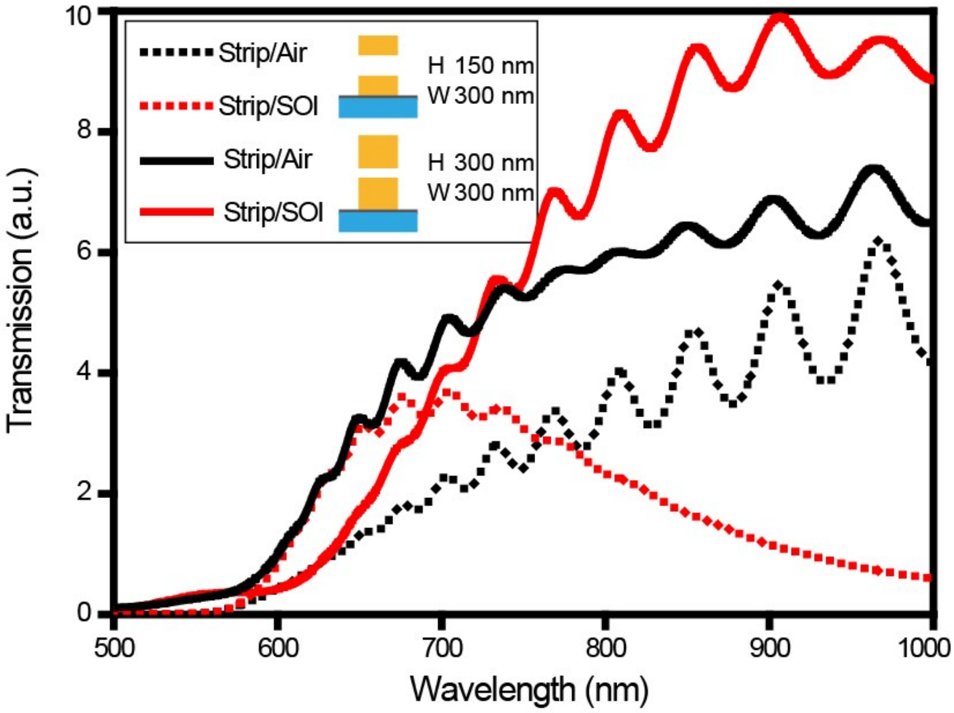


Figure S3-2. The end-scattering spectra for the gold nanostrips with different heights (150 nm and 300 nm) and different substrates (air or SOI).

S4. The dependence of the effective refractive index and propagation length on silicon top layer thickness.

The dependence of the real part of the effective refractive index and the propagation length on the silicon top layer thickness which was calculated by the mode analysis with COMSOL. It can be seen that the reason for the high coupling efficiency of gold nanostrip waveguide with free space light is that the real part of its effective refractive index is close to the refractive index of air, which reduced the momentum mismatch between the incident photon and the hybridized plasmonic mode.

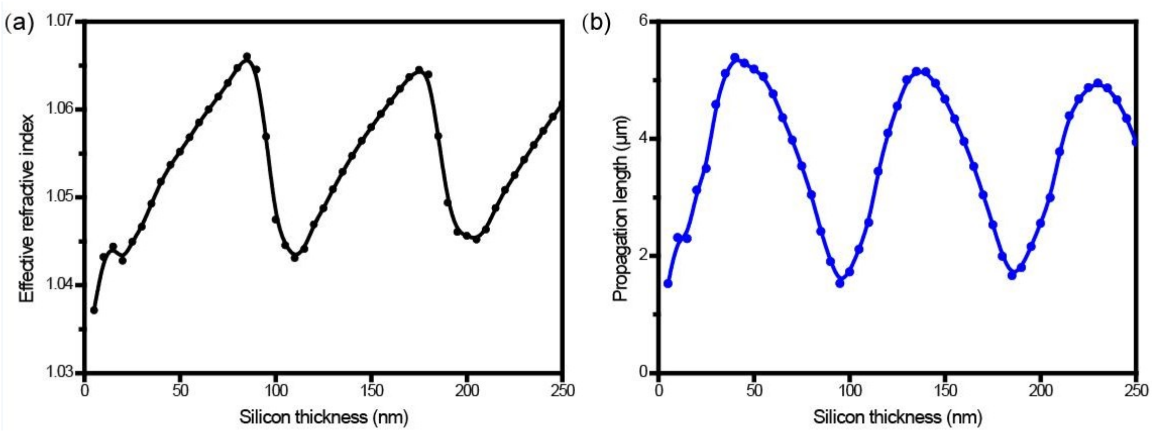


Figure S4. The structural parameters of gold nanostrip are the same as the experiment, the width is 300 nm and the height is 150 nm. The wavelength is 660 nm.

S5. Dependence of end scattering intensity on gold nanostrip widths.

Experimental (blue dots) and simulation (solid black line) results showed that the end scattering intensity increased with the gold nanostrip's increasing width. The drop of the end scattering intensity with decreasing gold nanostripe width in the experimental result is faster than the simulation result. This is due to the larger surface roughness and polycrystalline structure influence on the plasmon propagation loss for thinner gold nanostrip.

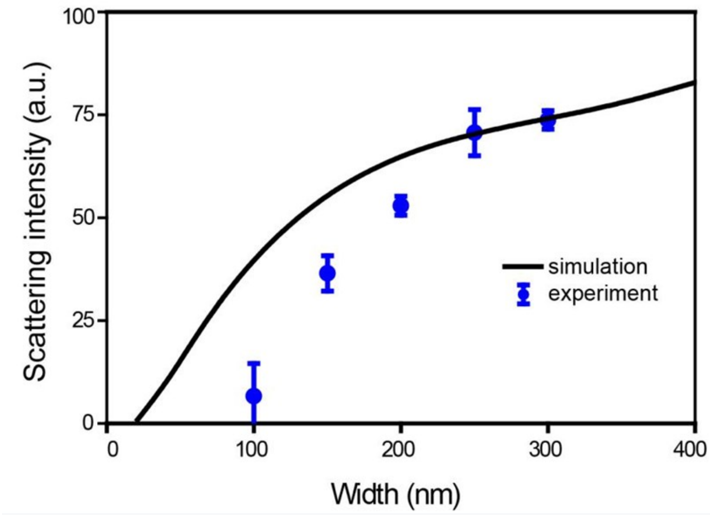
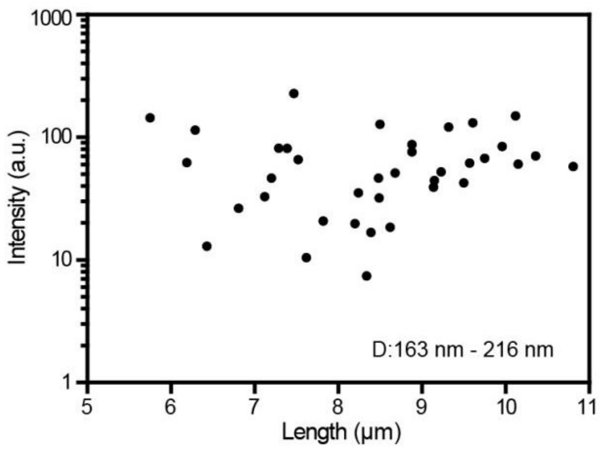


Figure S5. The thickness of the silicon top layer of the SOI substrate is 50 nm. The height of the nanostrip is 150 nm and the wavelength is 660 nm.

S6. The end scattering intensity measurement of randomly dispersed chemical synthesized gold nanowires on the SOI substrate.

The chemical synthesized gold nanowires were randomly dispersed on the SOI substrate with a 50 nm thick silicon top layer. The end scattering intensity was measured with the same optical excitation condition. The results showed poor controllability and repeatability due to the poor length, diameter and terminal shape control of the chemical synthesized gold nanowires.



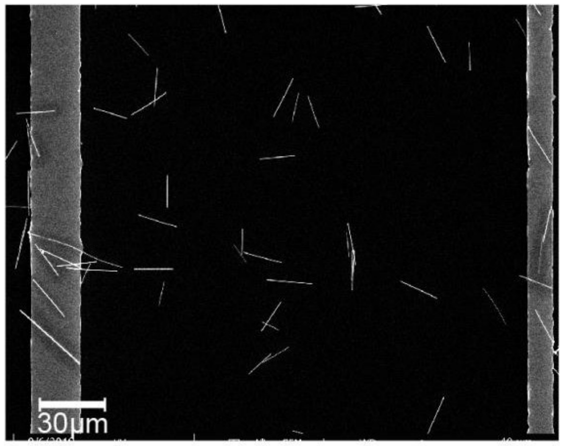


Figure S6. (a) The end scattering intensity of chemical synthesized gold nanowires with different diameters and lengths on the SOI substrate. (b) The SEM image of the gold nanowires on a substrate shows randomly distributed orientations and sizes.

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