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Controlling Surface Plasmon Propagation in Silver Nanowire Networks

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The miniaturization of optical devices to the scale compatible with modern nanoelectronic circuits demands the ability to manipulate light at subwavelength scale. Plasmonics has been a rapidly emerging field which offers various means to manipulate light at the nanometer scale using surface plasmons (SPs). SPs can strongly confine electromagnetic fields near metal-dielectric interface to overcome the conventional diffraction limit of dielectric optics. Therefore, SP-based nanophotonic devices are promising to build densely on-chip integrated circuits for next generation information technology. Plasmonic waveguide is one of the key elements for the plasmonic circuits [1]. Chemically synthesized crystalline silver nanowires (Ag NWs) can support propagating SPs with lower losses than lithographically defined nanowire waveguides, and can be easily manipulated to construct complex optical devices, which make them ideal candidates for proof-of-principle studies for plasmonic circuits. To investigate the SP propagating properties in metal NWs, we recently developed the method using quantum dot fluorescence to image the local electric field distribution of propagating SPs along Ag NWs [2]. By using this method, we have shown that the near field distributions of propagating NW plasmons depend strongly on the polarization and phase of the input light which can be used to realize an entire family of optical Boolean logic gates in NW networks [2-4].

Here, we discover an extremely large tunability of propagating SP near field pattern on Ag NWs using the QD fluorescence imaging technique [5]. By changing the thickness of the coated Al_2O_3 layer on the NW, we systematically investigate the period change of the near field pattern. The results show that the period is quite sensitive to the change of the coating thickness. By applying a 1 nm thick dielectric coating layer of Al_2O_3, the period is increased by about 90 nm. For bulk changes in the surrounding medium, we observe a period increase of about 16 μm per refractive index unit. This high sensitivity effect is explained by considering the propagation constants and the dispersion curves of NW SPs. We demonstrate that such giant modulation of SPs can be used to design functional plasmonic circuits (Fig. 1). In addition, the highly tunable near field distribution on supported Ag NWs can also be used for new types of ultrasensitive on-chip optical sensors.

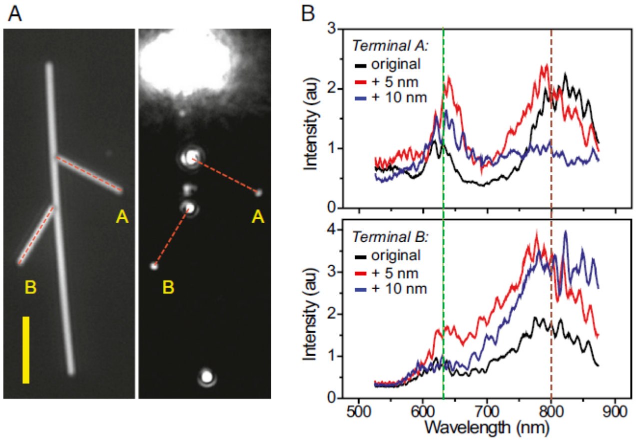

Fig. 1. (A) A structure composed of three NWs was illuminated by the supercontinuum light with the incident polarization parallel to the main NW. (B) The upper panel shows the emission spectra at the terminal A from the right branch for the original structure (black), and for 5 nm (red) and 10 nm (blue) Al_2O_3 layer deposited, respectively. The lower panel is for the terminal B from the left branch. (Scale bar in A, 5 μm.)

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