SUPPORTING INFORMATION

Multicolored vertical silicon nanowires

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1. METHODS

Nanowire fabrication and characterization. Vertical silicon nanowire arrays were fabricated from a single crystalline silicon wafer by dry etching. Nanodisk arrays were patterned in poly(methyl methacrylate) photoresist (MicroChem) using electron-beam lithography. After developing the pattern, aluminum was deposited to a thickness of 40 nm and lifted off to leave aluminum nanodisk arrays on the single crystalline silicon wafer. Inductively coupled plasma-reactive ion etch (STS) was used for anisotropic deep silicon etching at room temperature using the aluminum nanodisk arrays as the mask. During this process, 60 sccm of SF_6 and 160 sccm of C_4F_8 gases were used for the etching and surface passivation, respectively. After etching, the aluminum masks were removed using an aluminum etchant – type A (Transene). SEM images were taken on a Zeiss Ultra55.

Reflection measurements. Reflection measurements on each pattern were carried out with focused and collimated illumination. In the focused incidence case, the incident light was focused by a 20× objective (NA = 0.5), with the reflected light being collected by the same objective. In the collimated incidence case, a collimated white light beam illuminated the structure through a beam splitter, with the reflected light being collected by a 10× objective. The reflected light was also collected into a spectrometer. An iris was used at the image plane of the objective to ensure that only the light reflected by the array was detected. The spectra were normalized by the spectrum acquired with a silver mirror (Thorlabs, #PF10-03-P01).

Electromagnetic simulations. The nanowire optical response was simulated using the FDTD and MODE solvers of Lumerical Solutions, Inc. Two dimensional models were constructed in MODE solver by specifying wire radius, pitch and material properties. Periodic boundary conditions were imposed in the xy plane. These modes were used to study the evolution of the fundamental mode as a function of wavelength. Three dimensional models were constructed in Lumerical's FDTD solver. Periodic boundary conditions in the xy plane and absorbing boundary conditions along the z axis were imposed. A plane wave pulse source of the appropriate bandwidth was launched along the z axis and monitors were placed to compute the total absorbed, transmitted and reflected fluxes as a function of wavelength. The optical properties of silicon used for the simulation were obtained from Reference 21 in the main text.

2. Incident angle dependence of the reflection spectra

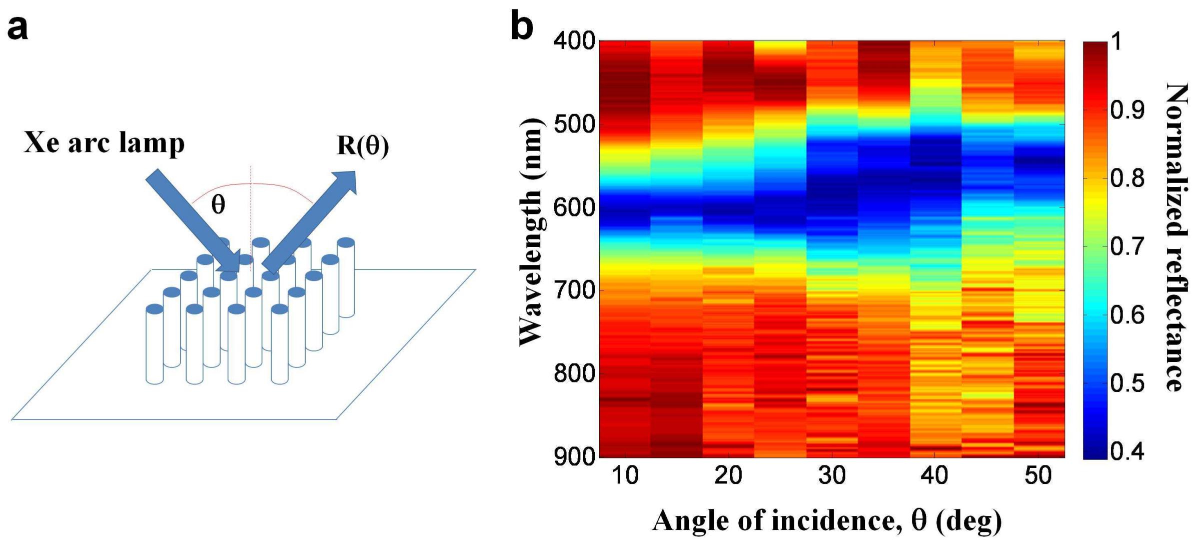

Figure S1. Incident angle dependence of the reflection spectra. (a) Schematic illustration of the angle resolved reflection measurement. (b) Normalized angle resolved reflection spectra from a vertical nanowire array with a pitch of 1 μm. The nanowires have radii of about 50 nm and are 1 μm long.

Light from a Xe arc lamp was focused into an optical fiber. The unpolarized output from the fiber was collimated with a lens and directed onto the sample at an incident angle θ to the normal of the sample plane. The illumination spot was larger than the extent of the nanowire array and the reflected light was collected by an objective lens (20 × magnification). An iris was placed at the image plane to ensure that only the light reflected by the nanowire array, rather than that reflected from the surrounding regions, was measured. After passing the iris, the light was focused by a lens into a second optical fiber, and input to a spectrometer. The sample and collection arm were mounted on two rotation stages, enabling both the angle of incidence and the angle of collection to be changed. The incident angle was changed from 10º to 50º in 5º steps.

For each angle, the reflection spectrum from the nanowire arrays was normalized with the reflection spectrum from the etched silicon surface without the nanowires in order to remove the contribution of angle dependent Fresnel reflection from the substrate. Figure S1b shows the incident angle dependence of the reflection spectra on the vertical nanowire arrays. The spectral dip position and intensity is relatively independent of the incident angle up to 25º. Above 25º, spectral dip shape becomes broader and the dip position tends to blue-shift, but by less than 10 %.

3. Surface roughness of etched silicon nanowires

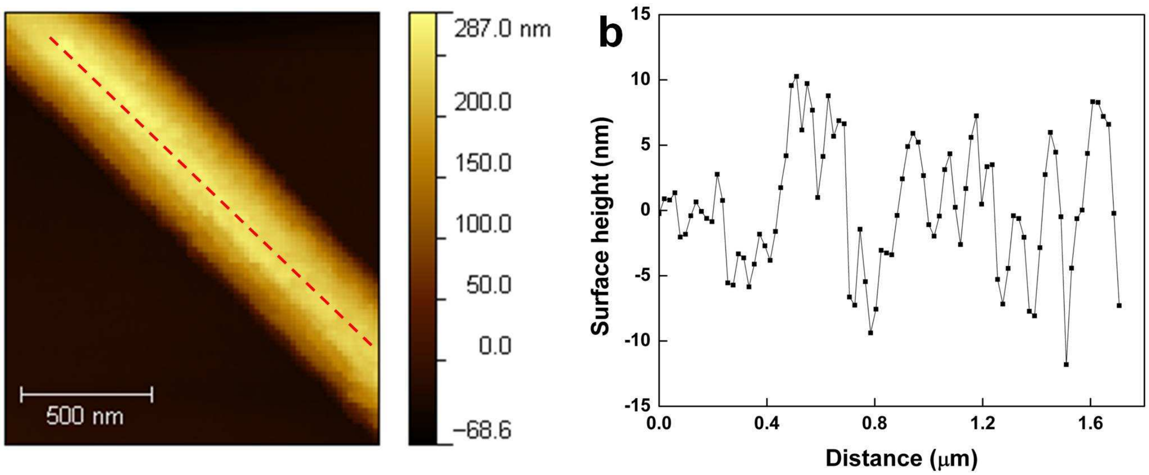

Figure S2. Surface roughness of the etched nanowire. (a) AFM image of a representative etched silicon nanowire. (b) Nanowire surface height profile along the red dashed-line in Figure S2a.

In order to investigate surface roughness of the etched nanowires, we performed atomic force microscopy (AFM, Asylum MFP-3D) on a typical nanowire (Figure S2a). An AFM tip with a radius of curvature below 10 nm was used. The surface profile sampled along the nanowire axis is shown as Figure S2b. The nanowire used in this measurement had a radius of about 200 nm and was chosen partly on the basis of it being comparatively long (5 μm), to make it easier to find. The root mean square (RMS) value of the surface height deviations is about 5 nm, corresponding to about 2.5 % of the nanowire radius.

4. Nanowire length dependence of reflection spectra

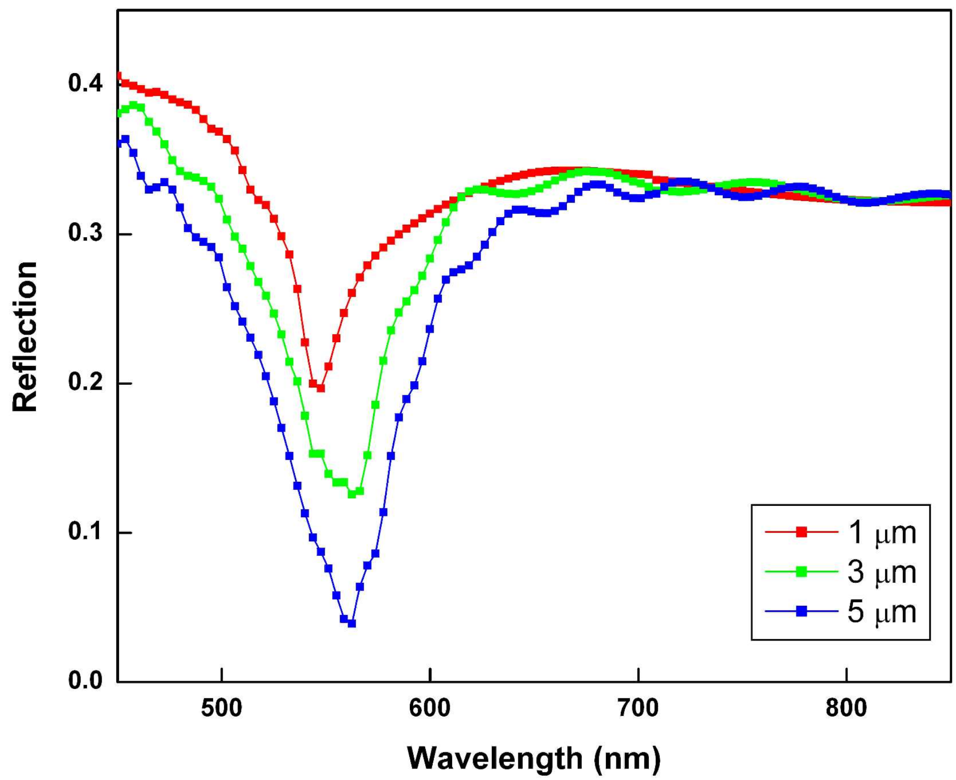

Figure S3. Dependence of reflection spectrum upon nanowire length. FDTD simulations of reflection spectra of nanowire arrays of different lengths. Radii of the nanowires are 45 nm.

Figure S3 shows the effect of nanowire length on the reflection spectra. The spectral dip deepens significantly as the length increases. This implies that the amount of light absorbed in the nanowire strongly depends on the length of the nanowire.