

Structural Coloring in Large Scale Core-Shell

Nanowires

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SUPPORTING INFORMATION:

We have provided core-shell nanowire production scheme (Figure S1); optical constants of chalcogenide glass, As_2Se_3 , and piezoelectric polymer, PVDF, (Figure S2); experimental set-up for the reflection and scattering measurements (Figure S3); reflection analysis from structures associated with cylindrical core-shell nanowires (Figure S4); Mie scattering analysis and mode profiles (Figure S5).

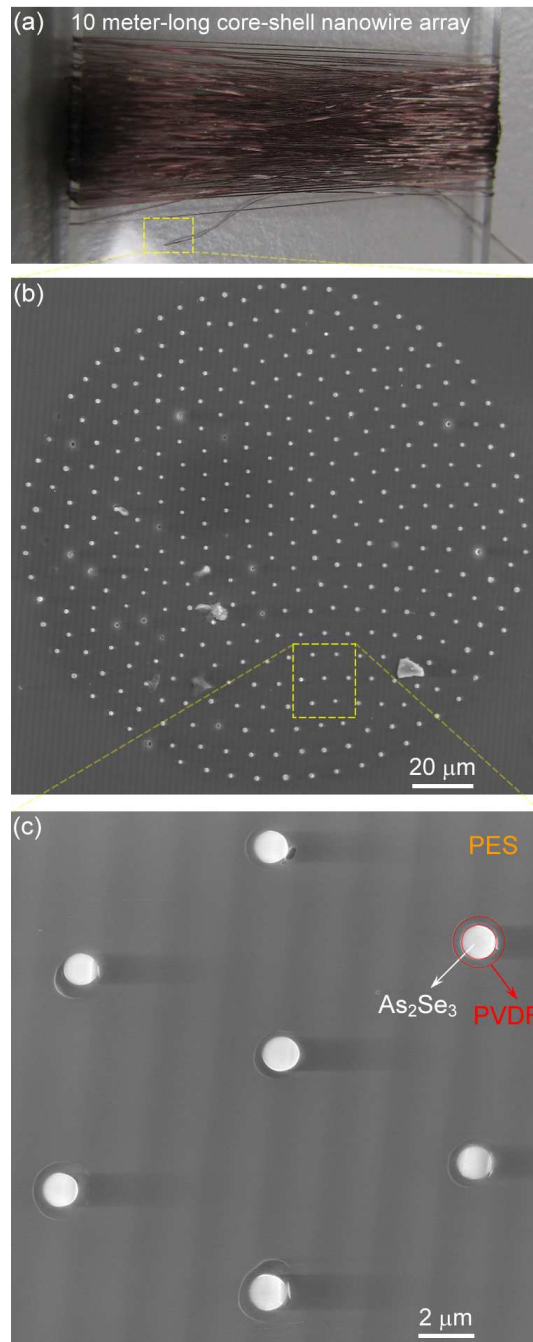


Figure S1. Cylindrical core-shell nanowire array production by iterative thermal size reduction technique. (a) Photograph of 10 meter-long nanowire array rolled on a microscope slide. The macroscopic nanowire array looks dark red originated from the thin film interference. Fiber embedded nanowire array structure is thermally drawn in an iterative manner from a composite that has arsenic selenide core, PVDF as an isolation polymer layer shell, and a wrapping second jacket polymer, PES. While the diameter of the core-shell structures continuously shrink during thermal drawing, the ratio of the core diameter to the shell thickness remains constant, and also the number of the wires could be dramatically increased at each subsequent step. (b) Ordered 360 micro/nanowires in a single macroscopic fiber were obtained after two sequential drawing procedures, which could be extended to thousands of nanowires when an additional thermal drawing is performed. (c) Uniform core-shell nanowires form a hexagonal lattice extending over whole macroscopic length of the fiber.

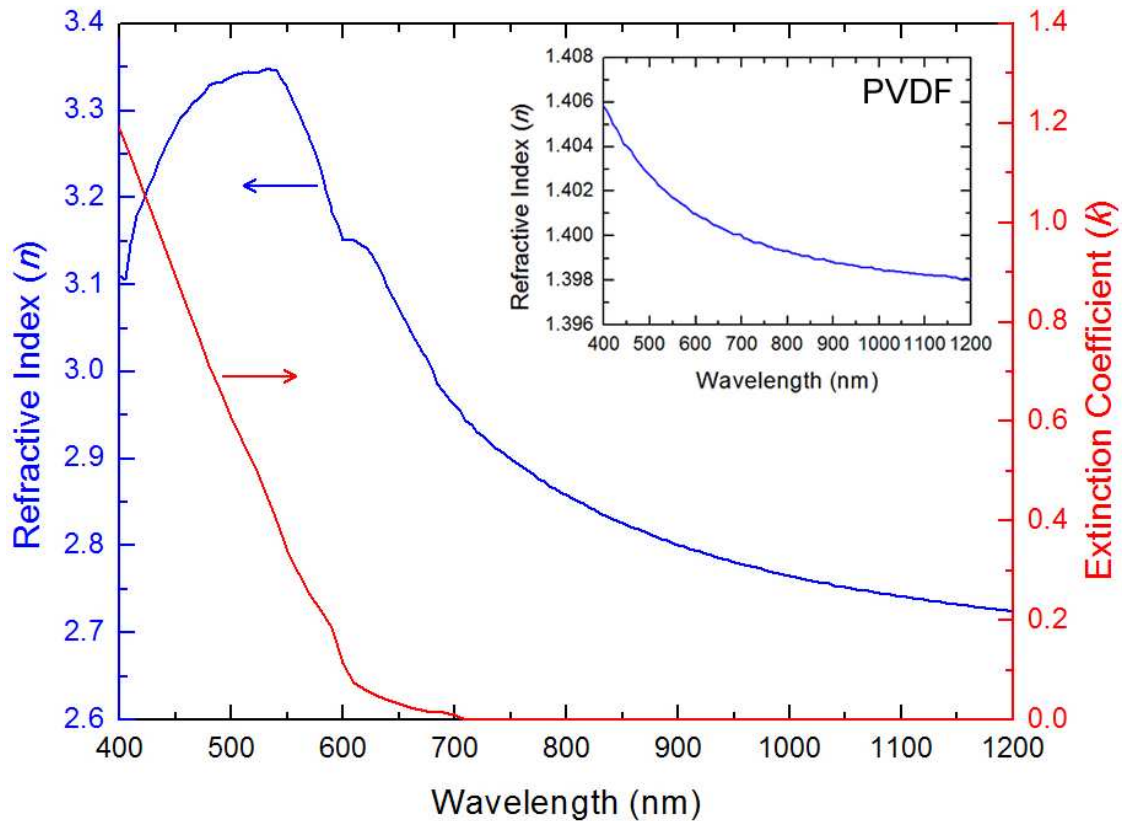


Figure S2. Optical properties of chalcogenide glass, As₂Se₃, and piezoelectric polymer, PVDF. Optical constants of arsenic selenide (As₂Se₃) and PVDF polymer were measured by the spectroscopic ellipsometry. As₂Se₃ is a high-refractive index material, which enables the confinement of light for Mie resonances in very small dimensions. Thin film interference is also facilitated by As₂Se₃, regarding the high index difference between the core and the shell. PVDF, on the other hand is a convenient material for the shell of nanowires, because it has a low refractive index and virtually no absorption in visible wavelengths.

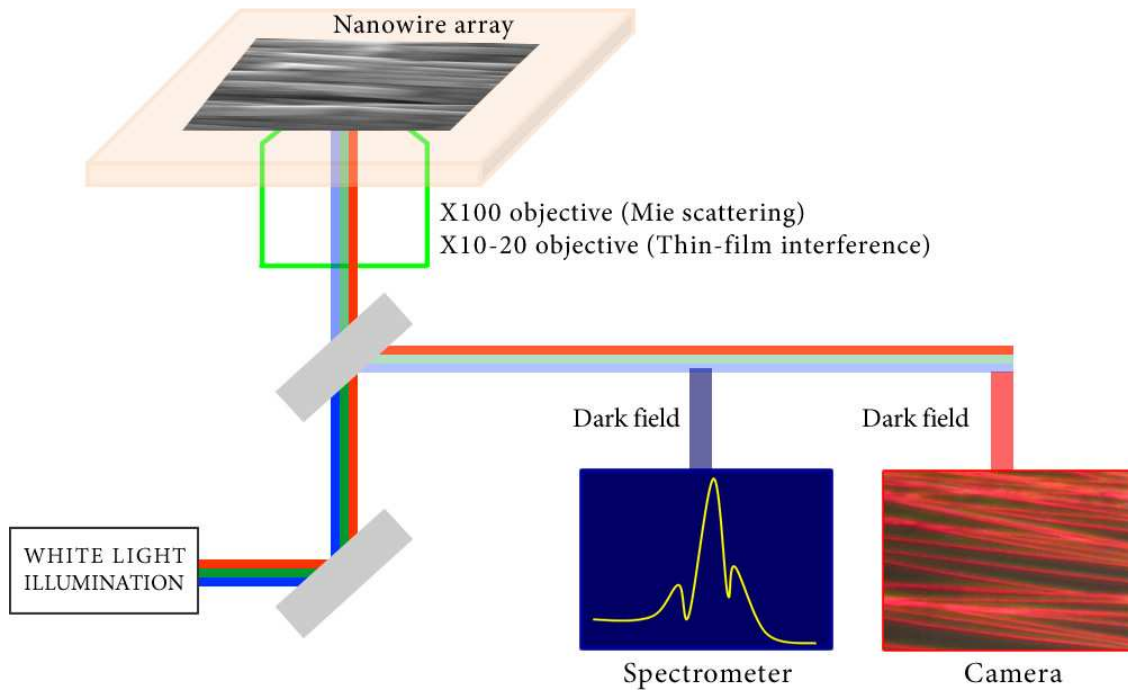


Figure S3. Schematics of experimental set-up for reflection and scattering measurements from nanowires. Optical image of nanowire array having nanowire diameters smaller than 200 nm was obtained in dark field mode of an inverted microscope. The wavelength-dependent scattering from a nanowire was taken by a UV-Vis spectrometer coupled to the microscope. For larger nanowires, both optical image and reflection were obtained in bright field mode of the microscope.

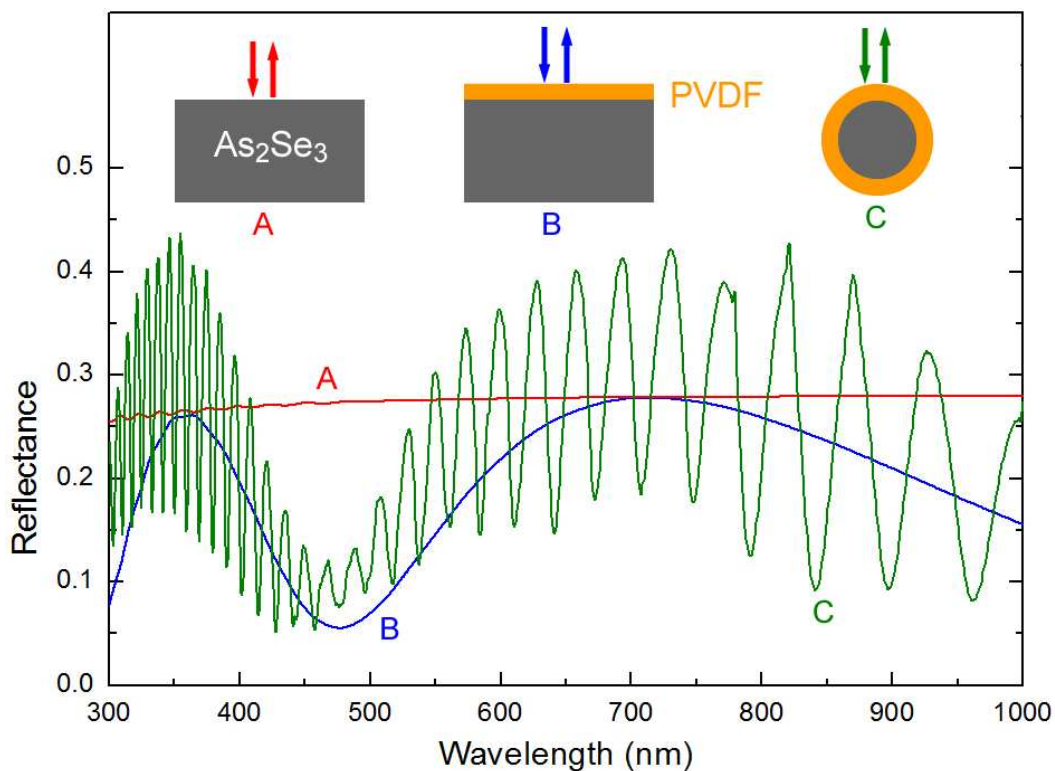


Figure S4. Theoretical analysis of structures associated with cylindrical core-shell nanowires. Reflection spectra of three different geometries were determined by FDTD simulations. Reflection from Arsenic Selenide (As_2Se_3) substrate (red) is constant throughout the spectrum, as expected from Fresnel equations. Spectra of thin film interference for PVDF film on As_2Se_3 substrate (blue), and shell on nanowire (green) exhibit similar behaviors. Oscillatory characteristic of the core-shell structure is the result of finite nanowire size, whereas in the substrate case, we considered thick PVDF layer to suppress oscillation. In the calculations, PVDF film thickness and nanowire diameter are 250 and 1000 nm, respectively.

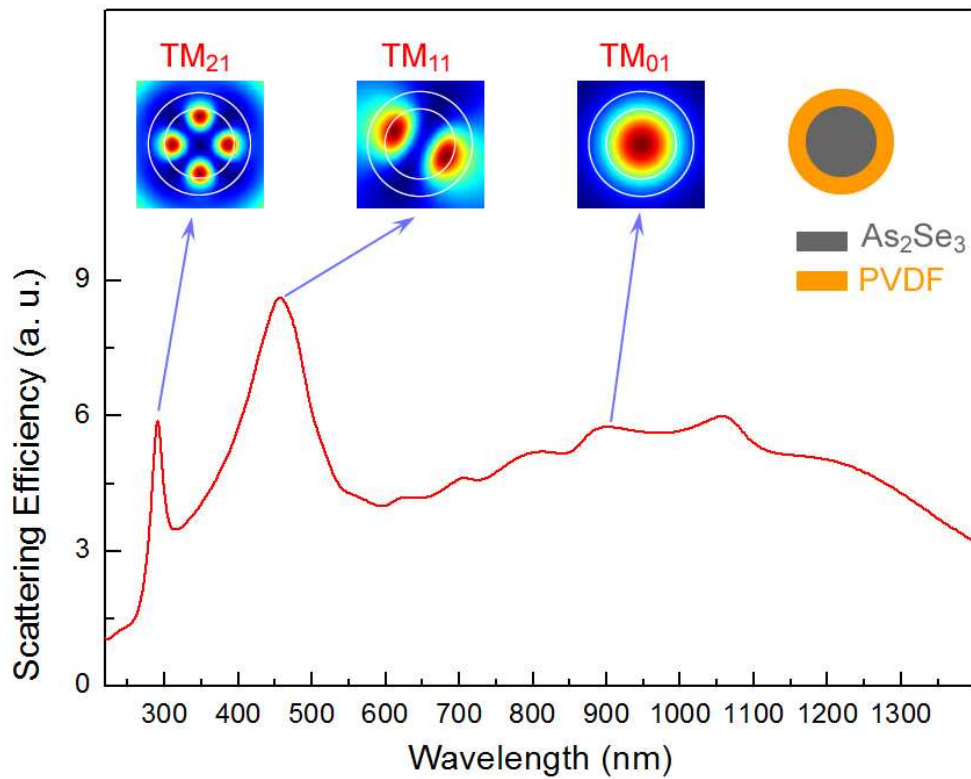


Figure S5. Mie scattering from cylindrical core-shell nanowires. Scattering from a 100 nm core and 25 nm shell structure is analyzed by using FDTD simulations to calculate the scattering efficiency and the supported modes. Fundamental mode (TM_{01}) and higher order modes (TM_{11} and TM_{21}) are present within the visible spectrum. Thin film interference effect is not observed in this geometry, because the thickness of the shell is extremely small to cause interference in visible wavelengths.