Supporting information

Insect-inspired nanofibrous polyaniline multi-scale films for hybrid polarimetric imaging with scattered light

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Experimental

Chemicals

Styrene, potassium persulfate (KPS), sodium dodecyl sulfate (SDS), aniline, ammonium persulfate (APS), were purchased from Sigma-Aldrich. Toluene, HCl, H_2SO_4 and H_2O_2 of chemical reagent grade were purchased from Fisher Chemicals. All the chemicals were used as received without further purification.

Synthesis of PS nanospheres

Monodispersed PS dispersions were prepared by emulsion polymerization.[1] 0.092 g SDS and 0.0836 g KPS were dissolved in 40 mL ethanol and 16 mL H_2O in a 250 ml three-neck flask with N_2 gas. Then 3.76 mL of styrene was added under rapid stirring. The emulsion solution was heated to 70 °C and maintained for 8 h. The PS nanospheres were washed with ethanol for 5 times before the assembly.

Interfacial assembly of PS nanospheres

A dispersion of 5 wt% PS nanoparticles and 0.3 mM Triton X100 in a mixture of ethanol/H_2O (v/v=1/1) was spread dropwisely at the air-water interface. The PS nanosphere assembly was collected on a glass substrate which has been pretreated with H_2SO_4/H_2O_2 (v/v=3/1) at 80 °C for 30 minutes. The PS nanosphere assembly was dried at room temperature.

Synthesis of PANI inverse-opal film

In a typical synthesis, 18 mL of 1 M HCl and 0.05 g APS was added to 18 mL of 1 M HCl and 20 µL of aniline to obtain a PANI growth solution. The PS assembly was then transferred to the top of the PANI growth solution by inserting the glass slide in the solution. After a certain amount of time, the PS-PANI film was collected by a new glass slide. The sample was dried at room temperature, followed by removal of the PS nanospheres by toluene.

Characterizations

The structure of the PANI-IOF was characterized by a Thermo Fisher Scientific NNS450 scanning electron microscope. The PANI-IOFs on glass substrates were sputter-coated with Pd/Pt and characterized at 20 kV. The morphology of the PANI-IOFs was characterized by a Tecnai T12 transmission electron microscope (TEM). The PS-PANI film was collected by a carbon-coated copper grid and allowed to dry at room temperature followed by rinsing with toluene to remove the PS nanospheres. Transmission spectra were sampled from a spatially-filtered collimated beam (7 mm in diameter) from a stabilized white light source (Thorlabs SLS301). Digital images were taken by using a Canon EOS Rebel T2i DSLR camera.

COMSOL simulations

The calculations for the scattering cross sections and the Electrical far field of the PANI nanowires were performed with the software COMSOL Multiphysics v. 5.5 using the RF Module. The sizes of the nanowires were 30 nm in diameter and 120 nm in length for a spectral range of 500-1000 nm. The medium above the PANI film was assumed to be air (n=1). Measurements of the optical constants of acidic-condition PANI index of refraction were taken from the Reference.[2]

Image reconstruction

A 2-layer neural network was used to realize lensless imaging with the PANI IOF.[3] A spatial light modulator (SLM) was used to adjust the polarization of the input light. 5000 images of the MNIST handwritten dataset were loaded to the SLM. A simple convex lens and bare CCD sensor (Thorlabs DCU224M) was used to image a plane that is 4 millimeters from the PANI IOF with 1024 x1280 pixel. 80% of the images were used to train the neural network, while the rest 20% images were used for testing. A block of 600x600 pixels was taken from the camera image, and downsized to 28x28 pixels. This array of 8-bit integer numbers is normalized to a range of 0 to 1, reshaped into a 1-D vector, and provided as an input to the neural network. Both layers of the neural network use a rectified linear-unit (‘relu’) activation function, a mean-squared-error (‘mse’) loss function, and adaptive moment estimation (‘adam’) strategy for updating the weights.

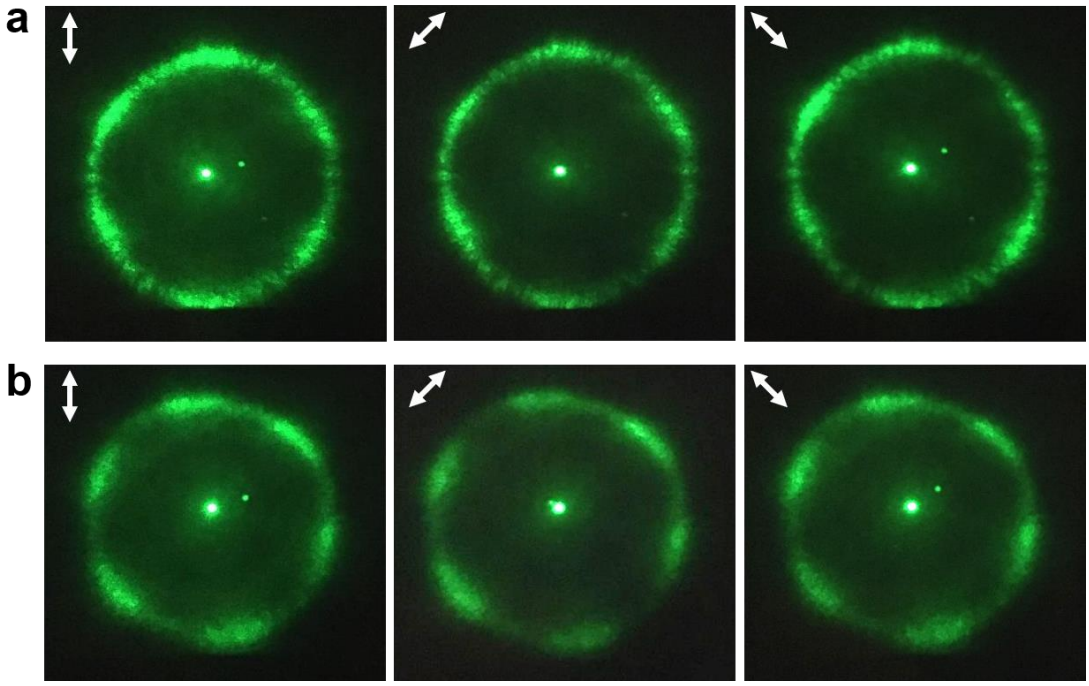

Figure S1. Debye rings of (a) PS nanospheres assembly and (b) PS nanospheres assembly coated with PANI in response to 0°, +45° and -45° polarized light. The white arrows indicate the polarization direction of the laser.

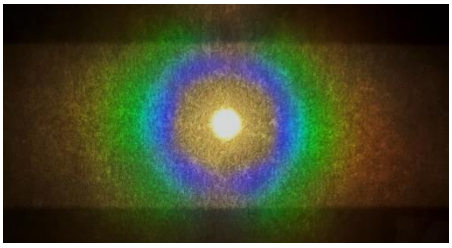

Figure S2. Digital image of a multi-colored Debye ring showing the color distribution.

1. Lu, Z.,Zhou, M., *J. Colloid Interface Sci.* 2011, **361** (2), 429-435.
2. Brasse, Y.,Ng, C.,Magnozzi, M.,Zhang, H.,Mulvaney, P.,Fery, A.,Gómez, D. E., *Macromol. Rapid Commun.* 2020, **41** (1), 1900415.
3. Muminov, B.,Vuong, L. T., *Optica* 2020, **7** (9), 1079-1088.