

Supporting Information

Electrically Conductive Polymeric Photonic Crystals

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Experimental Method

Sample Preparation

Monodisperse core-interlayer-shell (CIS) particles of polymeric styrene–methyl methacrylate–ethyl acrylate (PS-PMMA-PEA) were synthesized by stepwise emulsion polymerization as described in reference [15](main text). The polystyrene core was crosslinked with 10 wt% butanediol diacrylate, and the poly(methyl methacrylate) interlayer was crosslinked with 10 wt% allyl methacrylate. The weight composition of each component was C:I:S = 32.5:11.2:56.3, which corresponds to C:CI:CIS = 1:1.09:1.42 in terms of relative diameter. These particles were anionically stabilized, being negatively charged by sulfate-endgroups and adsorbed anionic surfactant molecules. Three different size particles with mean sphere diameters of 220, 245, and 290 nm were used in this study. The solid concentration of the emulsion was 30 wt%. Single-walled carbon nanotube (SWNT; Carbon Solutions Inc., P2-SWNT grade) and sodium dodecylbenzenesulfonate (SDBS; Aldrich) were used as received. SWNT (50 mg) was suspended in 50 cm³ of 1 wt% aqueous SDBS solution and was sonicated using a tip-type ultrasonic processor Cole Parmer CPX-750 equipped with 1/4-inch diameter tip for 48 min at 25% amplitude and a duty cycle of 5 sec on/3 sec off. The mixture was cooled in a water bath at 15 °C during sonication. The resulting dispersion was centrifuged at 7,000 × g for 30 min to remove large bundles and impurities, and the supernatant was used for the following sample preparation. The concentration of dispersed SWNTs in the supernatant was determined by Raman spectroscopy to be 0.89 mg cm⁻³, following the method described in C. G. Salzmann et al., (*Carbon* 2007, **45**, 907.). Predetermined amounts of the CIS polymer sphere emulsion and SWNT dispersion were mixed in a vial and water was removed from the mixture by freeze drying.

The obtained compounds were processed into film samples, with thicknesses of approximately 100 μm, via the shear ordering process described in detail in our previous report [14](main text). In brief, approximately 0.1 g of sample was encapsulated between two PET encapsulation tapes and placed on a glass plate heated to 150 °C. The sample was fed under a quartz roller, which maintained a compressive downward pressure, at a rate of 1 mm sec⁻¹ to form films of homogeneous thickness. The rolled film was then passed once over a brass edge with an apex of 90° at a rate of 5 mm sec⁻¹ in order to apply edge shear throughout the sample thickness. Thermal annealing of the shear-ordered film samples was carried out by heating the films in air on a hot plate held at 140 °C for different annealing periods of 1, 2, and 4 hrs.

Characterisation

Bright field reflectance was recorded with an OceanOptics QE65000 fibre optic spectrometer attached confocally to an Olympus BX51 microscope with a 5× objective lens, using a suitable white-light reflectivity standard. For impedance spectroscopy measurements, as prepared opal thin-films were carefully peeled off the encapsulating PET tapes and were sandwiched between two polished copper plates in a planar geometry. The area of overlap between electrodes was 1 cm² and film thicknesses were measured using a digital micrometer prior to mounting. After making suitable 2-probe electrical contacts, the capacitance ($C(\omega)$) and conductance ($G(\omega)$) were measured using a Hewlett Packard 4192A impedance analyzer, and from these measurements $Z'(\omega)$ and $Z''(\omega)$ were extracted. The analyzer had a bandwidth of 5 Hz to 13 MHz, and all measurements were taken at zero bias with an a.c. oscillation level of +/- 1 volt.

Microscopy

For transmission electron microscope (TEM) cross sectional imaging, the films were cryogenically cooled before being sectioned using a diamond knife in a Leica Ultracut Microtome, yielding sections with thicknesses of ~50 nm. The cross-sections were analyzed using a FEI Technai 12 TEM at an acceleration voltage of 120 kV. Scanning electron micrographs were obtained using a LEO ULTRA 55 scanning electron microscopy (SEM) with a Schottky-emitter (ZrO/W cathode). The acceleration voltage was 15.0 kV and secondary electron images were recorded at various magnifications.

Determination of Young's modulus in thin-film samples

The thin-film samples of ~ 100 micron thickness, as described in the *Experimental Section* of the text, were carefully cut into 10 mm x 4.9 mm test strips and mounted into a Linkam tensile stress stage [13](main text). Uniaxial strain is applied to the strips and the applied force is recorded, allowing the Young's modulus to be extracted from a linear fit of strain vs. stress, in the low strain limit (see Figure 9). The stretching speed was set to be 5 microns/sec for all tests. All samples were tested along the direction normal to the shear processing direction which controls the opaline self-assembly.