Electronic Supplementary information

Aging of Low-Temperature Derived Highly Flexible Nanostructured TiO_2/P3HT Hybrid Films During Bending

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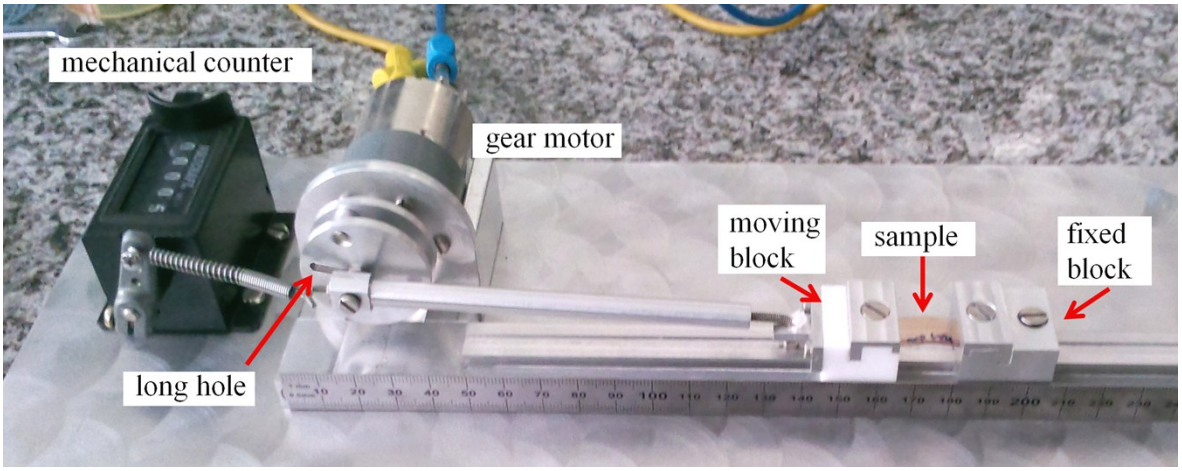

Fig. S1. Photo of the homemade two-point bending test setup. A gear motor is used to drive a disc on which a rod is fixed. By shifting the rod along the long hole, the amplitude of the moving block and thus, the bending radius and stress in the film can be adjusted. The samples are clamped between the fixed and the moving block and are bent periodically. The cycle number is counted with a mechanical counter.

2D GISAXS data

Fig. S2 shows the 2D data from the GISAXS measurements performed on the partially extracted titania film, the fully extracted titania film and the TiO_2/P3HT hybrid layer. To protect the detector from oversaturation, the specular X-ray beam is shielded by a rectangle-shaped beamstop (at q_z=0.74 nm^{-1}). The horizontal black stripes at q_z=0.88 nm^{-1} and q_z=1.38 nm^{-1} as well as the vertical one at q_y=0.26 nm^{-1} correspond to the inter-module detector gaps of the detector. Fig. S2a shows the GISAXS measurements of the partially extracted titania film and a zoom-in into the region indicated with the red box in Fig. S2a to highlight different Yoneda peaks of titania, PS-b-PEO and silicon (Fig. S2b). The X-ray wavelength used in this work is 1.54 Å. Thus, all scattering length densities (SLDs) are given for this energy. As the scattering length densities of PS-b-PEO and silicon are 0.92×10^{-5} and 2.01×10^{-5}, respectively, the top and bottom Yoneda peaks are results from PS-b-PEO and silicon. The Yoneda peak at the middle position originates from the mesoporous titania film.

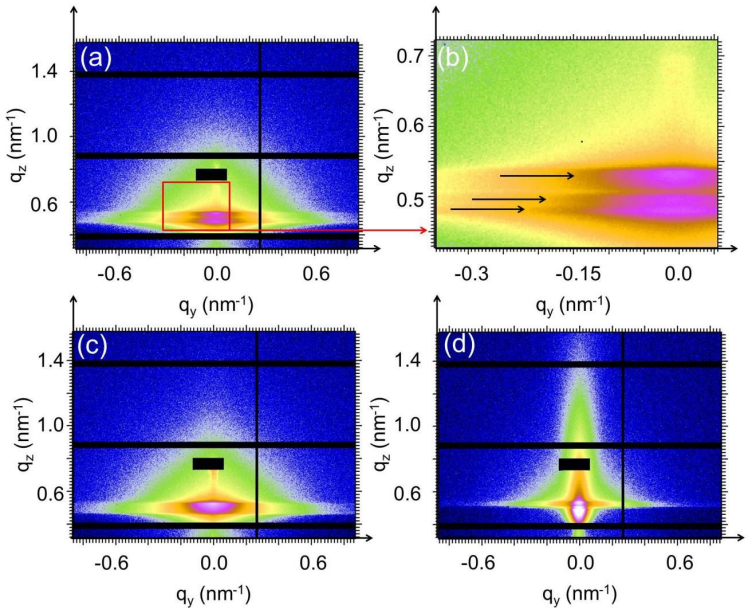

Fig. S2. 2D GISAXS data of (a) the partially extracted titania film and (b) enlarged zoom-in into the Yoneda region, (c) the fully extracted titania film and (d) the TiO_2/P3HT hybrid layer. The arrows in (b) indicate Yoneda peaks of PS-b-PEO, titania and silicon, respectively (from top to bottom).

Porosity determination

After complete removal of the PS-b-PEO template only mesoporous titania remains in case of the fully extracted titania film. Thus, the Yoneda peak is located at the critical angle of the mesoporous titania (α_c), which is material characteristic and α_c can be calculated by equation (S1)

$$\alpha_c \approx \lambda \sqrt{\frac{\rho}{\pi}} \qquad \text{(S1)}$$

where λ is the wavelength of the X-ray and ρ is the SLD of the mesoporous titania. In general, ρ depends on the material density of the probed titania film. Thus, ρ is reduced in the present work as compared to solid titania. Accordingly, the porosity (Φ) of the mesoporous titania films can be calculated by equation (S2)

$$\Phi = 1 - \rho_m/\rho_t \qquad \text{(S2)}$$

where ρ_m is the measured SLD of the fully extracted titania film and ρ_t is the theoretical SLD of the solid titania (3.17×10^{-5} Å^{-2}). Based on the Yoneda peak position, the SLD of the mesoporous titania in this work is calculated to be (0.76 ± 0.02) $\times 10^{-5}$ Å^{-2}. Thus, the porosity of the full extracted titania film is determined to be (76 ± 3) %.

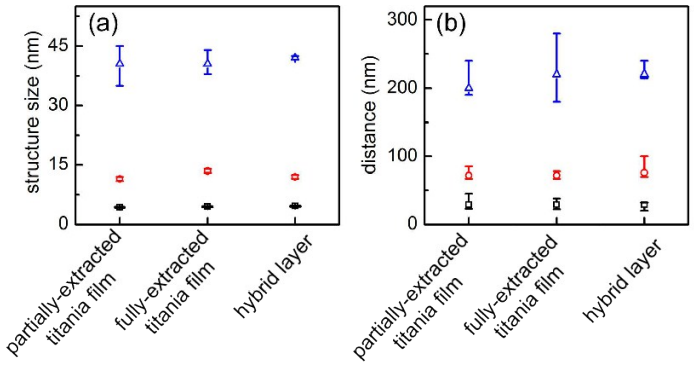

Fig. S3. (a) Structure sizes and (b) center-to-center distances extracted from 2D GISAXS data analysis of the partially extracted titania film, the fully extracted titania film and the hybrid layer.

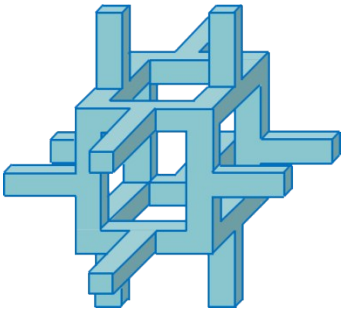

Fig. S4. Sketch of the unit cell of an idealized open-cell foam, modified from the reference [60].