Supplementary Information for:

Large-area blown bubble films of aligned nanowires and carbon nanotubes

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Supplementary Methods

Estimation of drift velocity of NWs during bubble expansion. The drift velocity (U_{NW}-U_{fluid}) of NWs in a polymer fluid can be calculated as U_{NW}-U_{fluid} = $c^2\nabla^2U_{fluid}/6$ = $(c^2/6\mu)(\partial p/\partial r)$,[1] where U is the velocity along the normal direction (subscripts denote NWs or fluid), c is NW radius (10 nm), μ is solution viscosity (25 Pa·s) and $\partial p/\partial r$ is the pressure gradient along the normal to the interface. Assuming a uniform pressure gradient, we evaluate $\Delta p/\Delta r$, where Δp = 150 – 100 = 50 kPa is the pressure difference at the inner wall and outer surface of bubble and Δr = 200–500 nm and 2–5 μm in the fully expanded regions and near to the die, respectively. The Faxen laws[1] predict an increasing drift velocity (U_{NW}-U_{fluid}), ca. 10 to 100 nm/s from the beginning to the final stage of the expansion. During the expansion the NWs can move a distance of hundreds of nanometers, which is comparable to the expanded BBF thickness. Hence, this estimate is consistent with the observation that all of the NWs are located at the outer surface film surface.

Calculation of the Peclet number for NW/NT polymer system. We have calculated the Peclet number (Pe) based on the lengths (L) of NWs/NTs using Pe = L^3 μ γ/kT, where μ is solution viscosity, γ is the shear strain rate, and kT is the thermal energy.[2] Given the variation of parameters – NT and NW lengths from 2 to 20 μm, solution viscosity from 15 to 25 Pa·s, shear strain rate during bubble exapansion of ca. 5 /s, and temperature of 300 K – the value of Pe was calculated to be within 10^3 to 10^6, much larger than 1. The calculation results support the observed alignment of NTs/NWs.

References

1. Kim, S. & Karrila, S. J. Microhydrodynamics: Principles and Selected Applications. (Butterworth – Heinemann, Boston, 1991, 1st Ed.), pp. 76-128.

2. Bruinsma, R., Gelbart, W. M. & Ben-Shaul, A. Flow-induced gelation of living (micellar) polymers. *J. Chem. Phys.* **96**, 7710-7727 (1992).

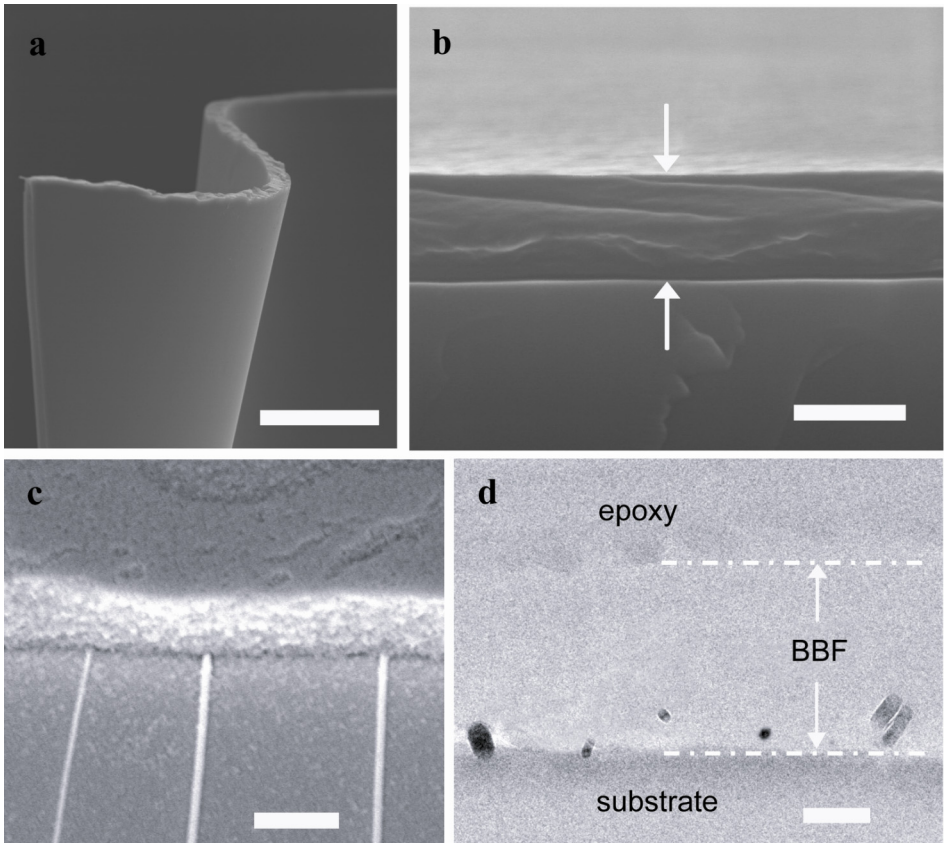

Figure S1. Cross section characterization of BBFs. **a,** SEM image of a free-standing SiNW-BBF. Scale bar is 10 μm. **b,** A 500 nm thick film transferred to a planar silicon substrate. Scale bar is 500 nm. **c,** SEM image of SiNW-BBF film on a silicon substrate following RIE etching to remove the epoxy matrix in the lower half of the image. The vertical white linear structures correspond to 3 SiNWs that are on outer surface of the BBF and in contact with the substrate. Scale bar is 500 nm. **d,** TEM cross sectional image of a SiNW-BBF showing SiNWs (dark spots) near the lower edge (outer surface) of the film. Scale bar is 100 nm. The SiNW-BBFs were transferred to plastic cover slips (substrate), embedded in an epoxy resin (epoxy), sectioned ca. perpendicular to the SiNW alignment direction with a diamond ultramicrotome.

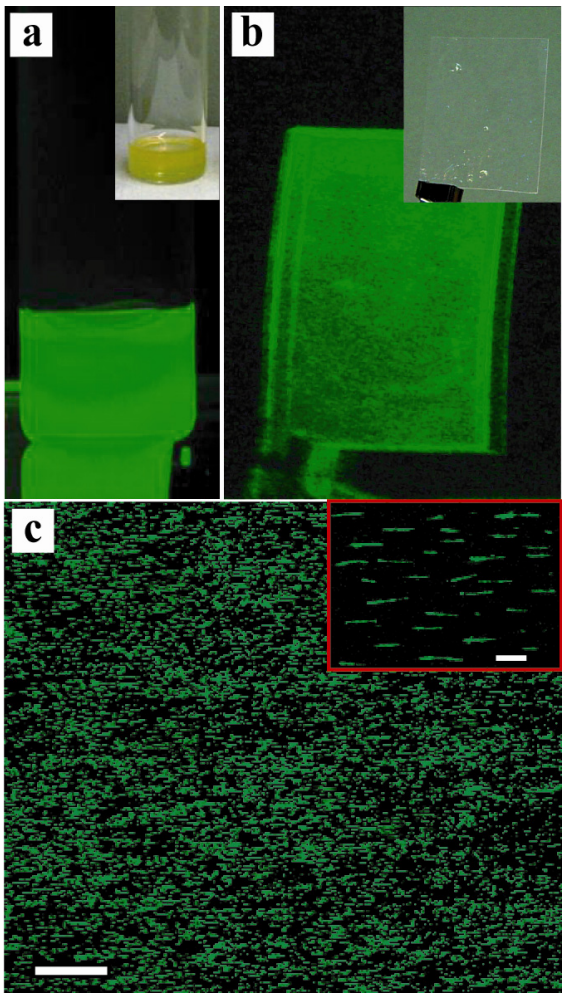

Figure S2. Aligned CdS NW in BBFs. **a,** Fluorescence image of a 0.15 wt% CdS NW solution. Inset: bright-field image of the solution. **b,** Optical image of a CdS NW-BBF transferred to a 3 × 4.5 cm^2 100 μm thick mylar substrate under UV excitation. Inset: bright field image of the same substrate. **c,** Confocal microscopy image of CdS NW-BBF transferred to a silicon wafer; scale bar is 50 μm. Inset: higher-resolution confocal microscopy image showing well-aligned individual CdS NWs; scale bar is 10 μm. The confocal microscope (LSM 510 Meta, Zeiss) was used with 458 nm excitation and luminescence was collected over 505-550 nm range.

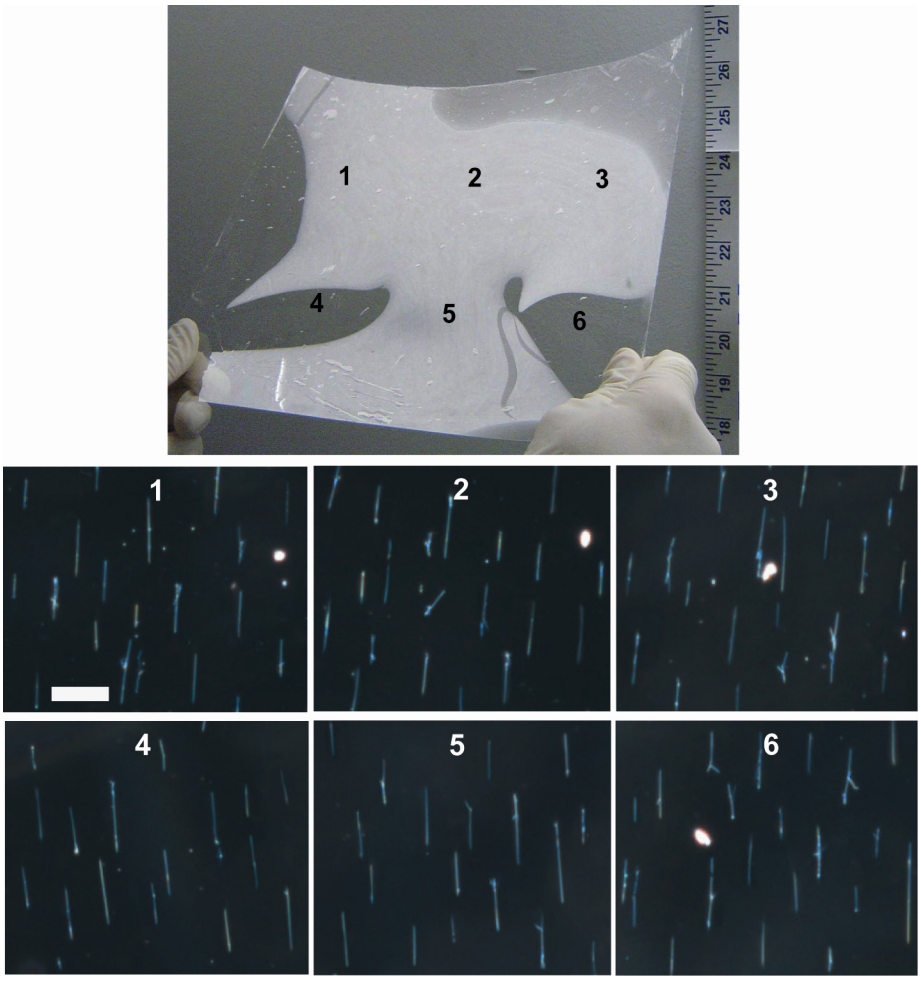

Figure S3. Characterization of SiNW-BBFs on large plastic sheets. Photograph of 0.10 wt% SiNW-BBF transferred to a 9" × 12" plastic by the semi-automated setup (image from Fig. 3f). Numbers highlight the locations where DF optical micrographs **1-6** were recorded. These DF images show relatively uniform alignment of SiNWs in the film. The scale bar in **1** is 10 μm, and the same for all six images.

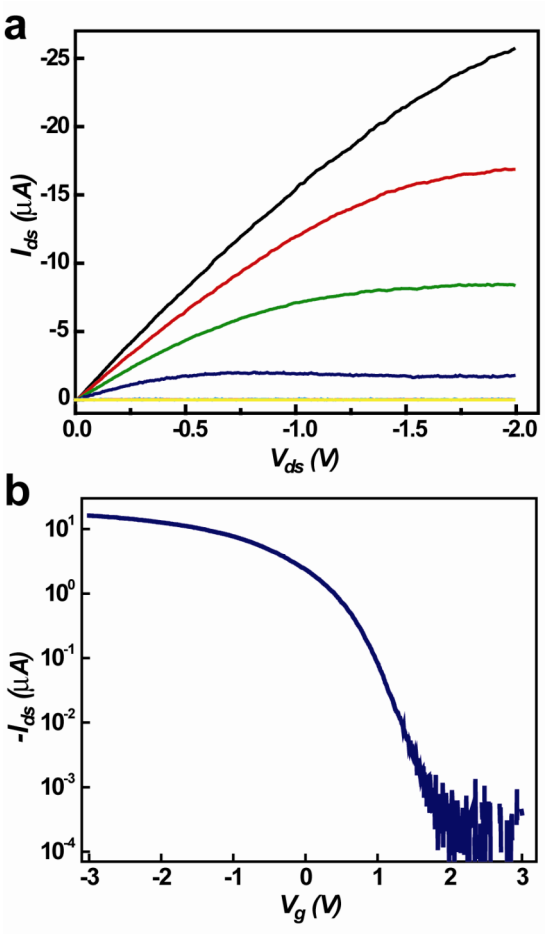

Figure S4. a, Typical I_{ds}-V_{ds} characteristics of a 12 SiNW FET device vs. V_g; -3 to 3 V top to bottom in 1 V steps, where curves for V_g = 1, 2, and 3 V overlap on this current scale. **b,** Log scale plot of I_{ds}-V_g recorded with V_{ds} = -1 V. These data are taken from the same device shown in Fig. 4b.