# Journal Name

COMMUNICATION

Information 1: Evaluation of the amount of surfactants adsorbed.

For the evaluation of the amount of surfactant, we used a larger size of CNTF sheet (Fig. 1a; area 2×2 cm^2; thickness, 1 mm; weight, ca. 2 mg), prepared by the same condition as the CNTF films used for CV experiments. This CNTF sheet was cut to a smaller pieces (weight, $0.1 \sim 0.6$ mg) and treated with surfactant by immersing in the 0.1 wt% surfactant solution in a vacuum for 1 h. The surfactant-modified CNTF pieces were thoroughly rinsed by immersing in the distilled water with stirring for 1h, followed by drying at 150 ℃ in a vacuum for 1 h. The amount of surfactants adsorbed (around 100 µg) was measured by weighting the CNTF pieces before and after the treatment by using a precision balance (Sartorius ME5, 0.1 µg accuracy). The density of adsorption (molecules / nm^2) were calculated by assuming the specific surface area of CNTF as 1300 m^2 g^{-1}, [1,2] and plotted in Fig. 1b for the three kinds of surfactants (n

(a)

(b)
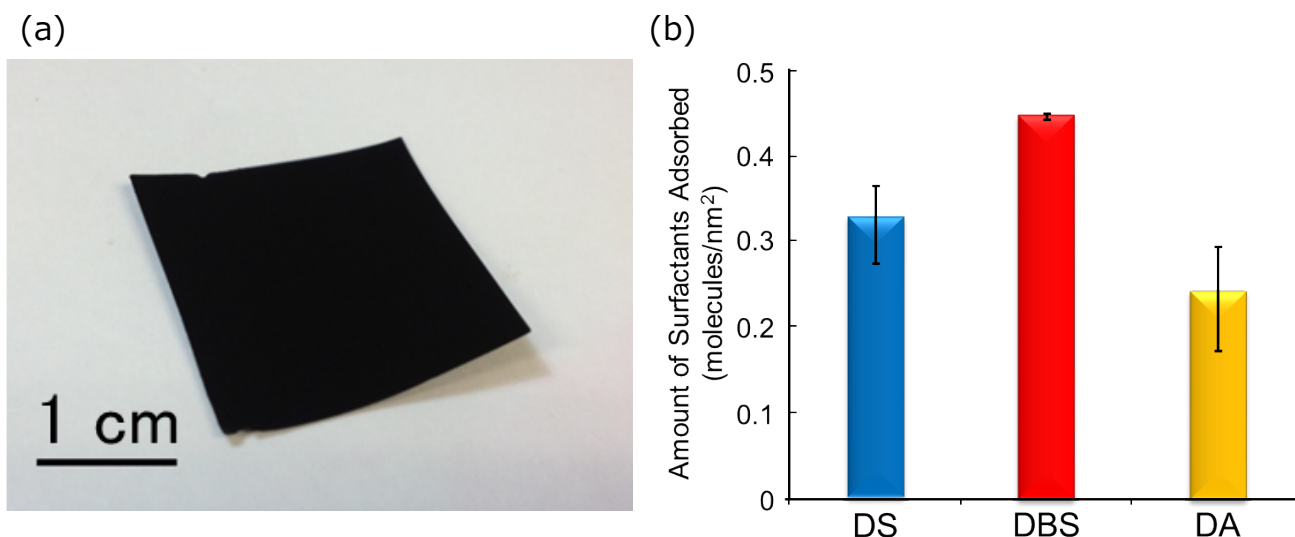
Fig. S1. (a) Photograph of the CNTF sheet used for evaluating the amount of surfactants adsorbed. (b) The density of surfactants adsorbed on CNTFs ($n = 4$).

= 4).

1   T. Miyake, S. Yoshino, T. Yamada, K. Hata, M. Nishizawa, *J. Am. Chem. Soc.*, 2011, **133**, 5129–5134.
2   D.N. Futaba, K. Hata, T. Yamada, T. Hiraoka, Y. Hayamizu, Y. Kakudate, O. Tanaike, H. Hatori, M.

Yumura, S. Iijima, *Nature Materials*, 2006, **5**, 987–994.

Information 2: Evaluation of the amount of enzymes inside a CNTF film

The amount of BOD inside CNTFs were evaluated by measuring the amount of extracted copper ionsin the extracts.[3] As shown in Fig. 2, three pieces of 1×1 mm BOD-modified CNTF films were dispersed in an aqueous solution of 1% sodium cholate by using a bath sonicator, followed by boiling with nitric acid
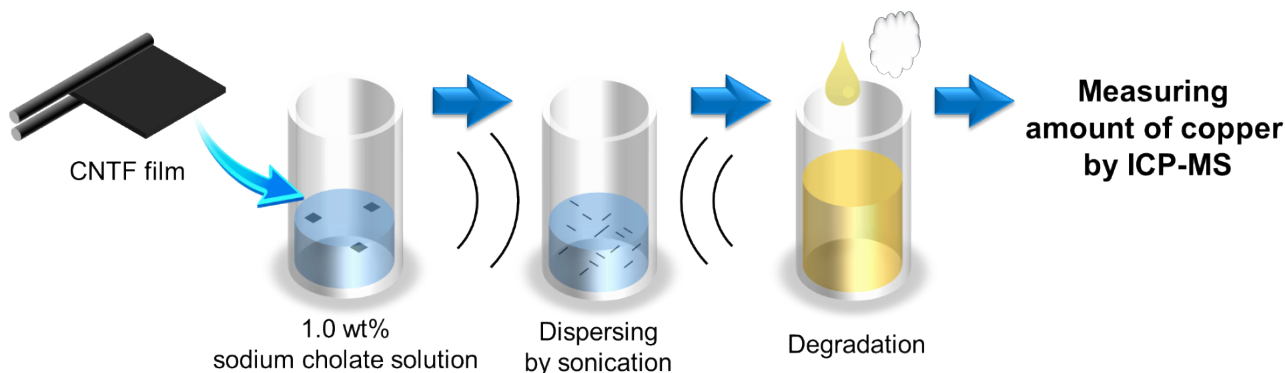
Fig. S2. Experimental procedure for evaluation of the amount of enzymes inside CNTF films.

and hydrogen peroxide at 120-140 ℃ for 2 h. The amount of copper ions in the solution was measured by ICP-MS (Aligent Technologies Aligent 8800), and converted to the amount of enzymes assuming 4 copper atoms / BOD molecule.[3,4]

3   K. So, S. Kawai, Y. Hamano, Y. Kitazumi, O. Shirai, M. Hibi, J. Ogawa and K. Kano, *PCCP*, 2014, **16**, 4823–4829.
4   N. Mano and L. Edembe, *Biosensors & Bioelectronics*, 2013, **50**, 478–485.

Information 3: Theoretical prospect of BOD content inside CNTF

The previous structural analysis of the as-grown CNTF revealed a mean tube diameter of 2.8 nm by transmission electron microscopy (TEM) and an intertube pitch of 16 nm by X-ray diffraction.[5] The number of BOD (N_{enz}) entrapped in a 12 μm thick CNTF is estimated from the following equation:

$N_{enz} = 4\,(H/r)\,(S/U)$

where $H = 1.0$ mm (CNT length), $r = 6.0 \times 10^{-6}$ mm (BOD diameter),[6] $S = 12 \times 10^{-3}$ mm^2 (cross-sectional
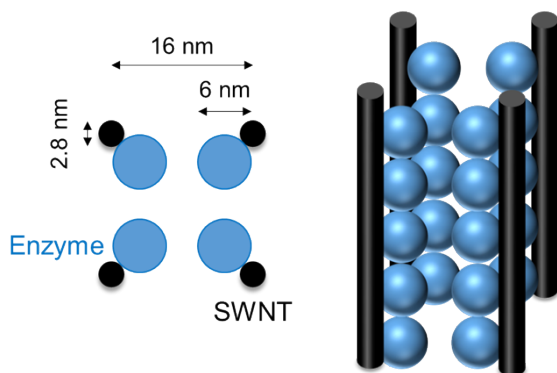
Fig. S3 Illustrations of a CNTF whose void volume is occupied by 6 nm diameter globular BOD that adsorbs on the side-wall of the CNT.

area of CNTF sheet), and $U = 2.6 \times 10^{-10}$ mm^2 (the area of the void space surrounded by 16 nm pitched CNTs). The entrapped mass (3.5 μg) is derived by multiplying N_{enz} by the molecular weight (68 kD) / Avogadro's constant.

5   D. N. Futaba, K. Hata, T. Yamada, T. Hiraoka, Y. Hayamizu, Y. Kakudate, O. Tanaike, H. Hatori, M. Yumura and S. Iijima, *Nature Materials*, 2006, **5**, 987–994.
6   M. Tominaga, M. Ohtani and I. Taniguchi, *PCCP*, 2008, **10**, 6928-6934.