One-step synthesis of ultrathin nanobelts-assembled urchin-like anatase TiO_2 nanostructures for highly efficient photocatalysis

Xin Yu[a1], Zhenhuan Zhao[b1], Jian Zhang[c], Weibo Guo[d], Linlin Li[a*], Hong Liu[ae*], Zhong Lin Wang[a*]

[a] Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences; National Center for Nanoscience and Technology (NCNST), Beijing, 100083, P. R. China

[b] Institute of Fundamental and Frontier Sciences, University of Electronics Science and Technology of China, Chengdu, 610054, P. R. China

[c] Universite de lyon, ECL, INSA-Lyon, UCBL, CPE, CNRS, INL, UMR 5270, 36 avenue Guy de Collongue, 69134 Ecully cedex France

[d] Shandong provincial key laboratory of detection technology for tumor markers, college of chemistry and chemical engineering, Linyi university, Linyi 276005, P. R. China

[e] State Key Laboratory of Crystal Materials Shandong University, Jinan, 250100, P. R. China

*Corresponding author. E-mail addresses: lilinlin@binn.cas.cn, hongliu@sdu.edu.cn, zlwang@gatech.edu

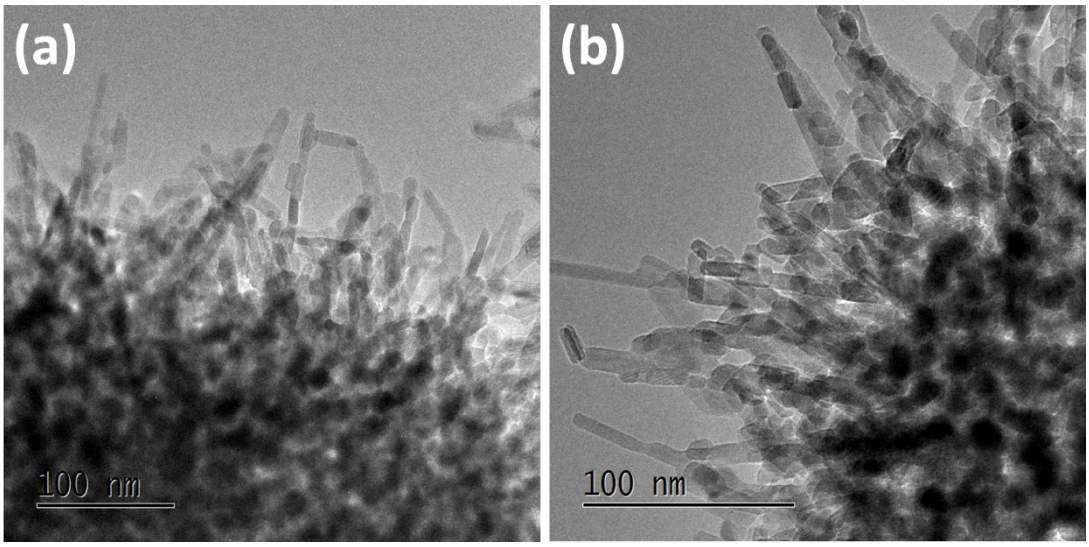

Fig. S1 TEM images of the urchin-like TiO_2 shell structure synthesized with 1.0 g urea.

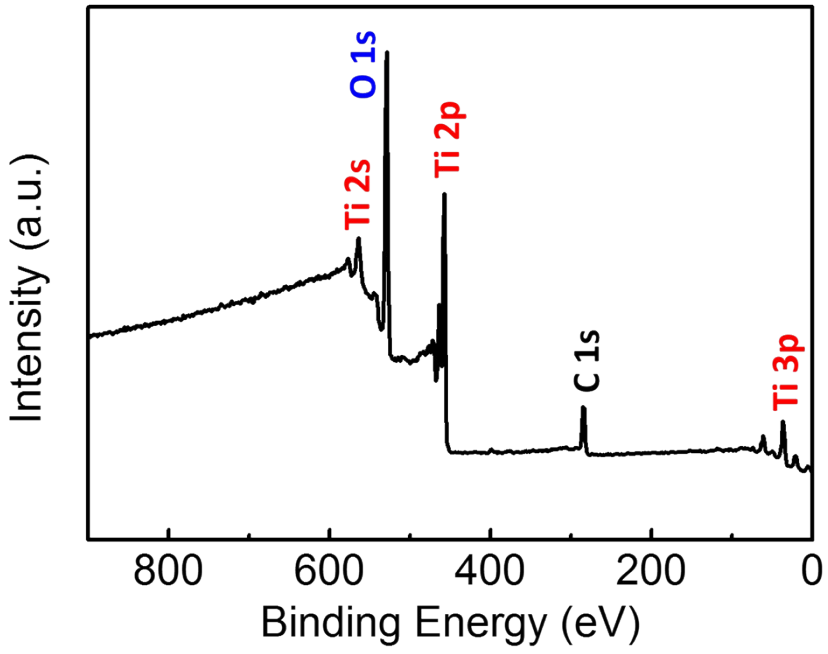

Fig. S2 XPS fully scanned spectrum of the urchin-like anatese TiO_2.

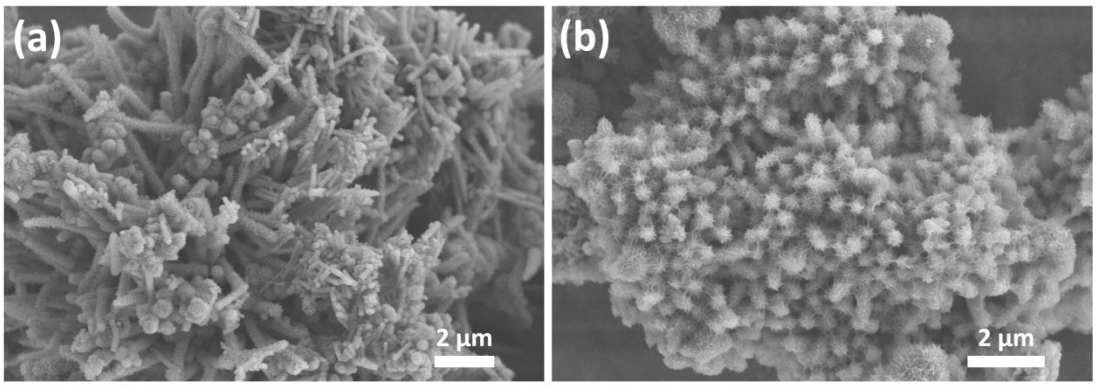

Fig. S3 SEM images of the TiO_2 nanorod structure with 0.1 g urea.

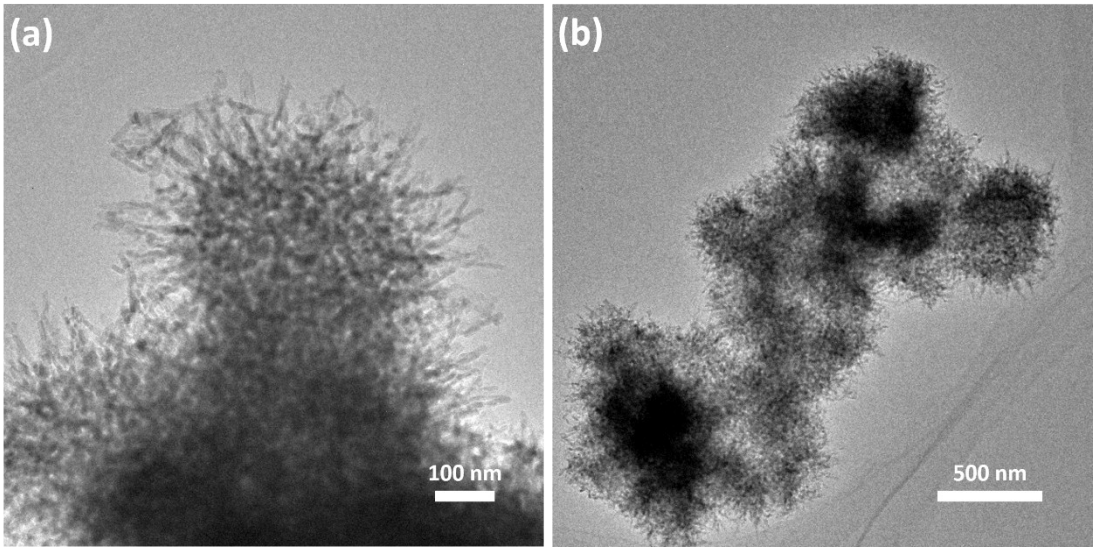

Fig. S4 TEM images of the TiO_2 sphere with solid core.

Form the TEM image in Fig. S4, it could be found that sample had solid structure with surface assembled nanobelts.

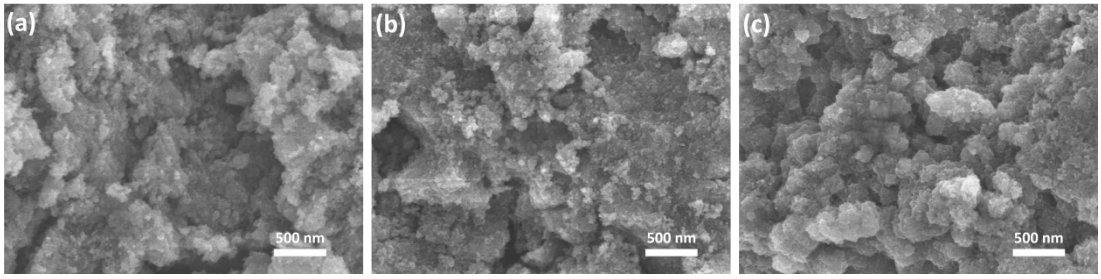

Fig. S5 SEM images of the TiO_2 samples with different amount of diethylene glycol. (a) 40 ml deionized water without diethylene glycol, (b) 30 ml deionized water, 10 ml diethylene glycol, (c) 20 ml deionized water, 20 ml diethylene glycol.

From the SEM images of the TiO_2 samples in Fig. S5, it can bee see that without the diethylene glycol or with less diethylene glycol compared to the 10 ml deionized water and 30 ml diethylene glycol it cannot form the TiO_2 ultrathin nanobelts and urchin-like structures. The TiO_2 nanoparticles agglomerated into big blocks.

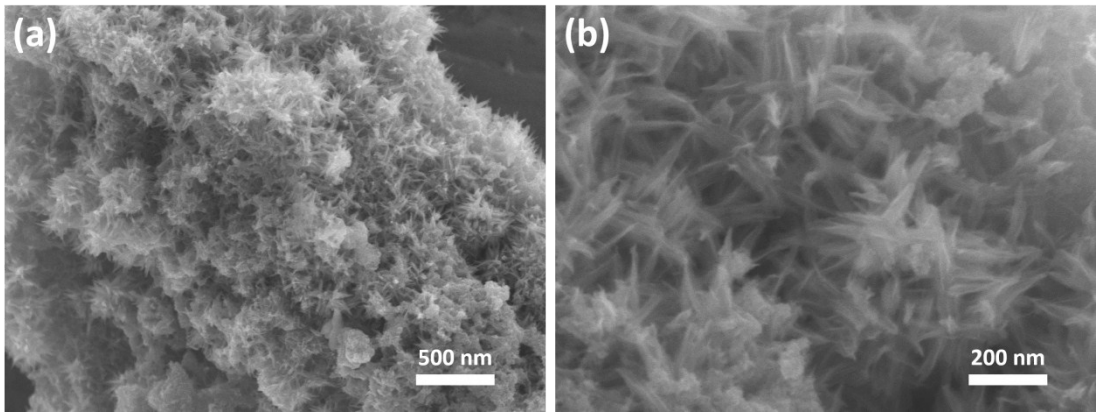

Fig. S6 SEM images of the TiO_2 sample with NH_4OH (1 ml wt 25%) instead of urea.

From the Fig. S6 it can be see that when used NH_4OH instead of urea the TiO_2 formed the ultrathin nanobelts, but the nanobelts agglomerated into blocks. So we can provenly concluded that it was CO_2 acted as the soft templates for providing

aggregation centers of TiO_2 seeds to form hollow structure.

Table S1 The TiO_2 yield of the different synthesis condition after 4 h reaction time. 0.35 g $K_2TiO(C_2O_4)_2$ was used as the titanium source. It can be seen that the production of TiO_2 increase with the urea increasing.

Urea	0 g	0.1 g	0.5 g	1.0 g
TiO_2 Yield [g]	0.015	0.043	0.061	0.075

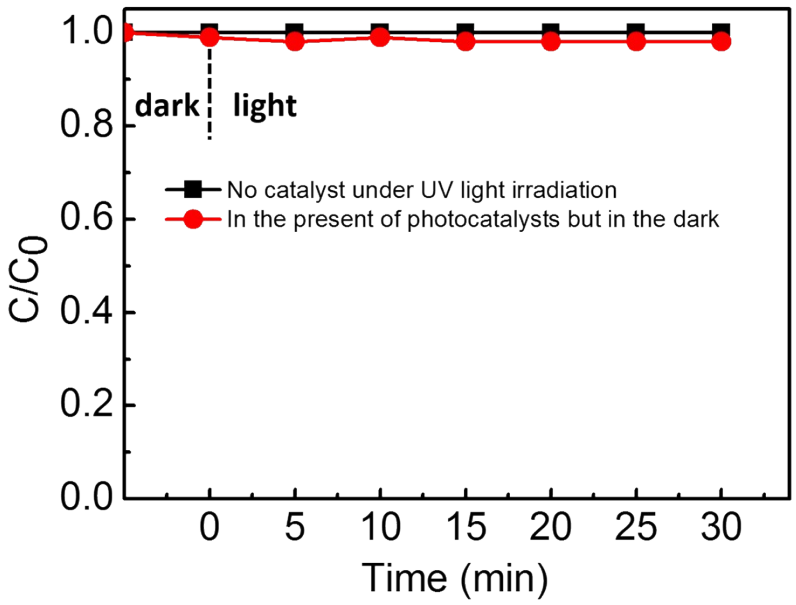

Fig. S7 Photocatalytic degradation of MO without any catalyst and in the presence of photocatalysts but in dark.

In the Fig. S7, to check if MO can be degraded under light irradiation without photocatalyst, 20 mg/L of MO solution was irradiated under UV and visible light,

respectively, and the degradation rate of MO were checked. The result showed that there was no decrease of MO concentration without photocatalyst under UV light irradiation. And these results indicated that the adsorption-desorption equilibrium of MO had been established within 5 min in the dark. And there was no appreciable degradation of MO after 30 min in the absence of photocatalysts.

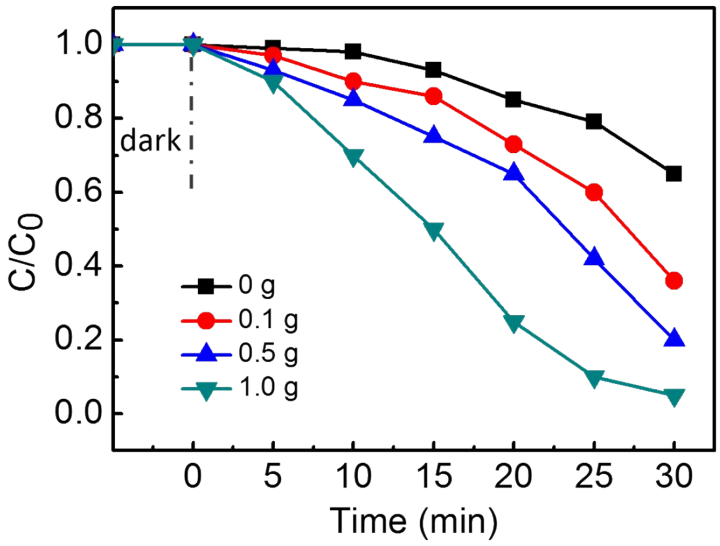

Fig. S8 Comparison of the photocatalytic activities of the TiO_2 samples synthesized with the different concentration of urea.

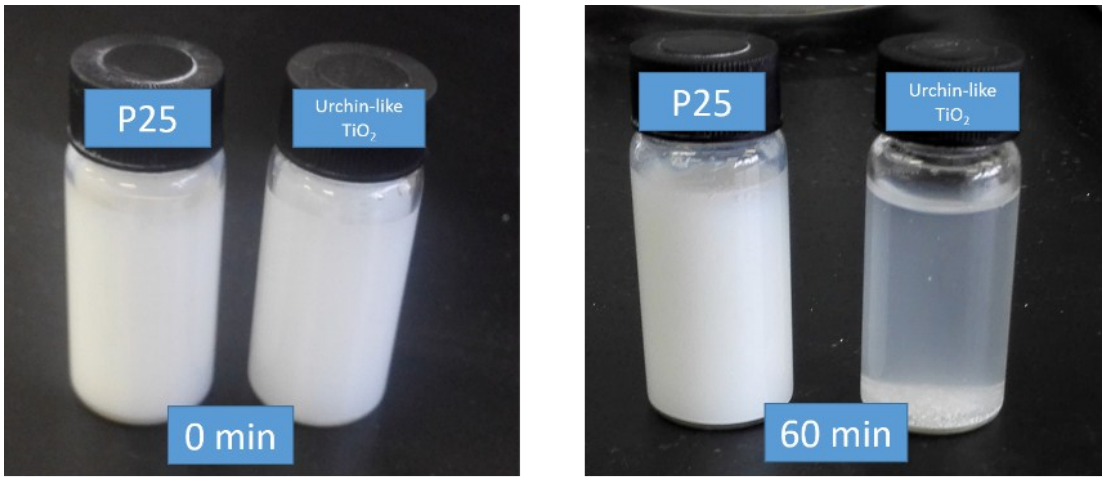

Fig. S9 photographs of Degussa P25 and urchin-like TiO_2 following sedimentation for 60 min.

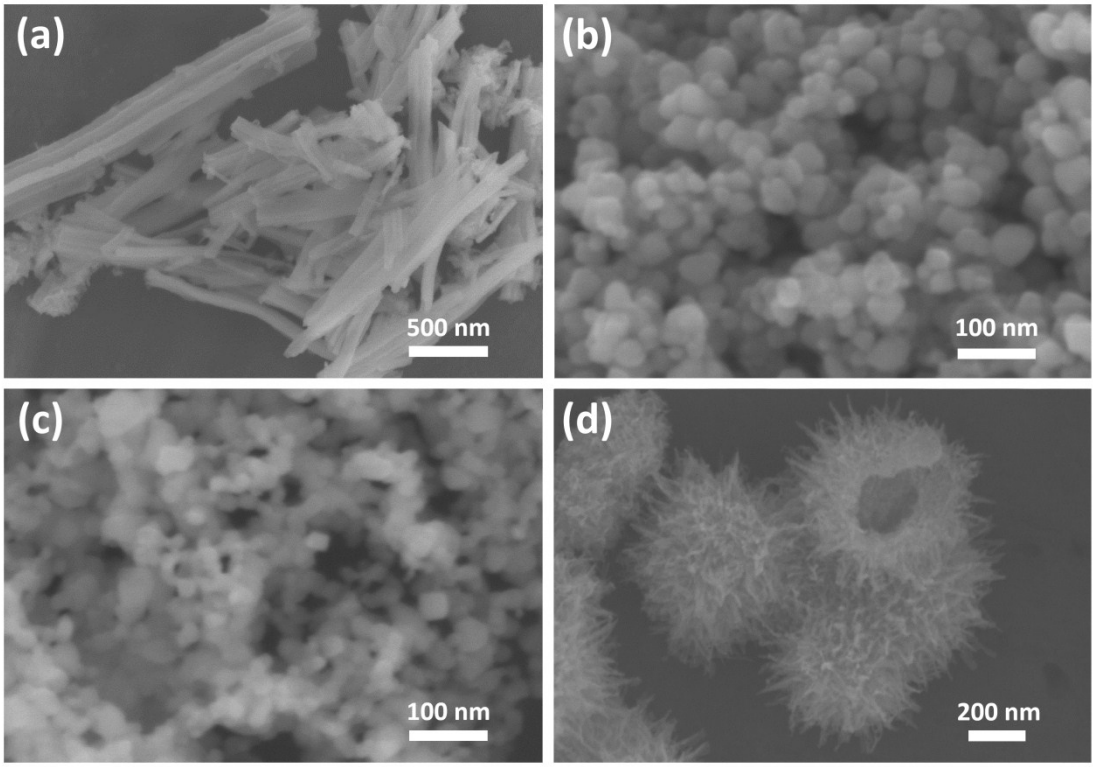

Fig. S10 SEM images of the (a) TiO_2 nanobelt (b) A-TiO_2 (c) P25 (d) urchin-like anatase TiO_2.

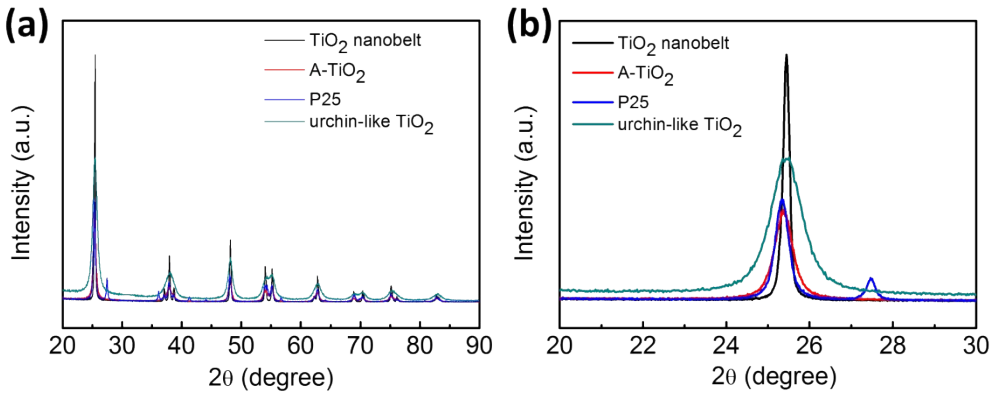

Fig. S11 XRD patterns of the TiO_2 nanobelt, commercial A-TiO_2, P25 and urchin-like anatase TiO_2.

The crystallite size of the TiO_2 nanoparticles, D, was calculated by using the Debye-Scherre formula from the major diffraction peak of the corresponding TiO_2. The Debye Scherrer formula is as follows:

$$D = \frac{K\,\lambda}{\beta\,cos(\theta)}$$

Where K is Scherrer constant (K = 0.89), λ is the X-ray wavelength used in XRD (1.5418 Å), β is the pure diffraction broadening of a peak at half-height and θ is the Bragg angle. The average diameter of the TiO_2 nanoparticles calculated is 17 nm. And the other samples had a relatively larger half peak width with the diameter 92 nm, 35 nm, 39 nm for the TiO_2 nanobelt, A-TiO_2 and P25, respectively.

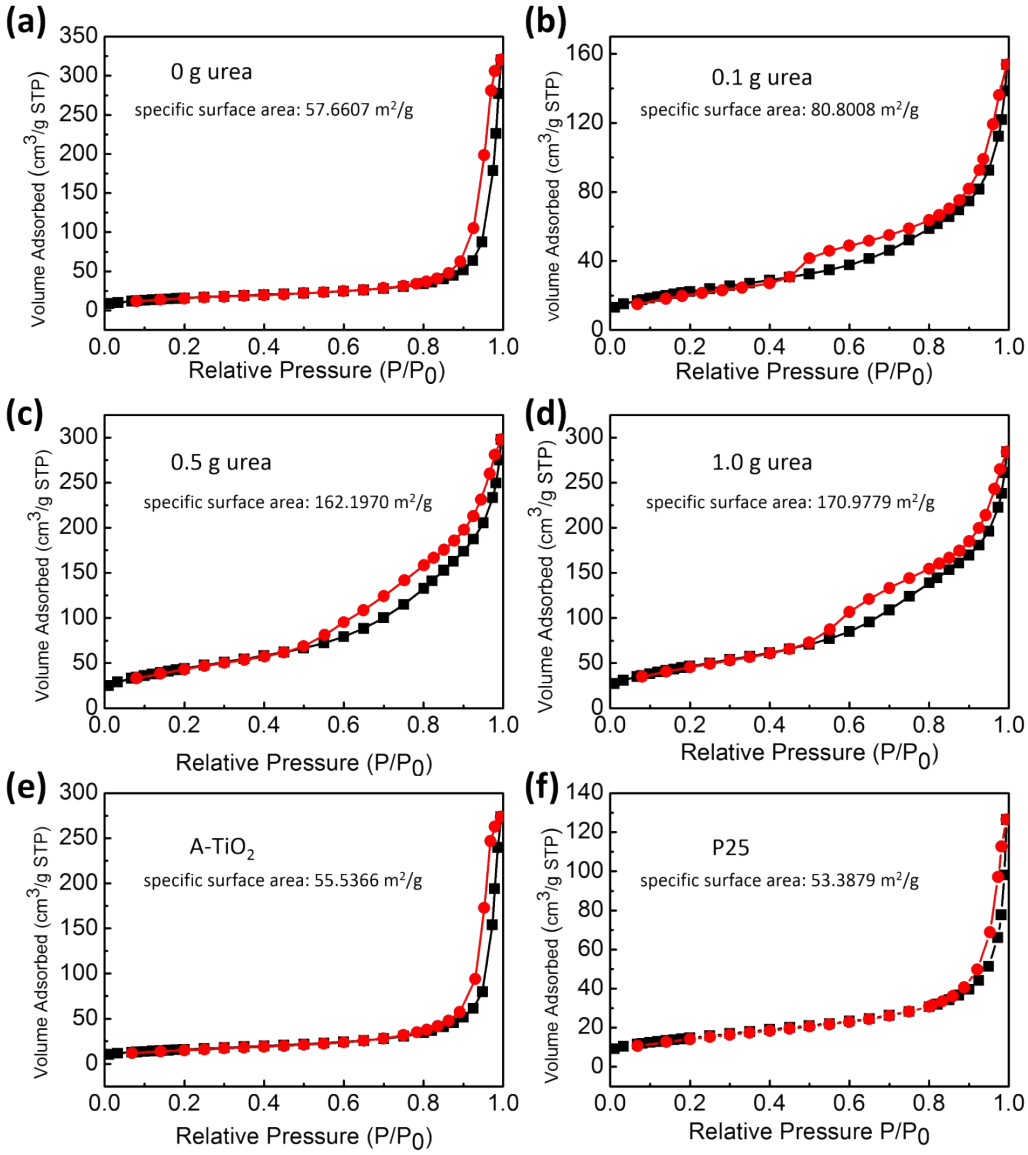

Fig. S12 Nitrogen adsorption-desorption isotherms of the different samples. (a) 0 g urea (b) 0.1 g urea (c) 0.5g urea (d) 1.0 g urea (e) commercial A-TiO_2 (f) Degussa P25.

Table S2 Brunauer–Emmett–Teller specific surface area of the different samples. (a) 0 g urea (b) 0.1 g urea (c) 0.5 g urea (d) 1.0 g urea (e) commercial anatase TiO_2 (f) Degussa P25.

Urea	0 g	0.1 g	0.5 g	1.0 g	P25	A-TiO_2
BET [cm^2/g]	55.6607	50.8008	162.1970	170.9779	53.3879	55.5366