This is an Accepted Manuscript, which has been through the Royal Society of Chemistry peer review process and has been accepted for publication.

Accepted Manuscripts are published online shortly after acceptance, before technical editing, formatting and proof reading. Using this free service, authors can make their results available to the community, in citable form, before we publish the edited article. We will replace this Accepted Manuscript with the edited and formatted Advance Article as soon as it is available.

You can find more information about Accepted Manuscripts in the Information for Authors.

Please note that technical editing may introduce minor changes to the text and/or graphics, which may alter content. The journal’s standard Terms & Conditions and the Ethical guidelines still apply. In no event shall the Royal Society of Chemistry be held responsible for any errors or omissions in this Accepted Manuscript or any consequences arising from the use of any information it contains.
Hydrothermal synthesis and formation mechanism of photocatalytically active SrTiO$_3$ nanocrystals using anatase TiO$_2$ with different facets as a precursor

Jingmiao Peng$^{[a][b]}$, Ying Zhou$^{[a][b]}$, Hao Wang$^{[c]}$, Haoran Zhou$^{[b]}$, Shiyi Cai$^{[b]}$

1 Received (in XXX, XXX) Xth XXXXXXXXX 20XX, Accepted Xth XXXXXXXXX 20XX
DOI: 10.1039/b000000x

Strontium titanate (SrTiO$_3$) nanocrystals have been synthesized by a hydrothermal reaction route using anatase TiO$_2$ nanosheets with dominant {001} facets and commercial anatase TiO$_2$ nanoparticles as precursors. Time resolved quenching experiments showed the velocity of hydrothermal formation of SrTiO$_3$ was relatively fast (in minutes). The initial particle morphology and exposed crystal facets of anatase TiO$_2$ precursor cannot be retained in the final SrTiO$_3$ products. SrTiO$_3$ nuclei is formed by the reaction between Ti(OH)$_x$, and Sr ions at the TiO$_2$ solid/liquid interface. As surface adsorbed F$^-$ is necessary to stabilize the {001} facets of anatase TiO$_2$, the hydrothermal crystallization of SrTiO$_3$ from TiO$_2$ with {001} facets not only exhibits a slower reaction rate but also a higher activation energy. Moreover, the photoelectrochemical and photocatalytic activity studies indicated that the SrTiO$_3$ products obtained from TiO$_2$ with {001} facets showed enhanced photocurrent density and photocatalytic hydrogen production activity. The present study sheds some light on the understanding of the crystal facets of precursor on the hydrothermal formation process as well as their photocatalytic activities of the corresponding products.

1 Introduction

Strontium titanate (SrTiO$_3$) is a typical representative of the family of perovskite-type oxides (ABO$_3$), which have wide applications in oxygen gas sensor, photocatalysts, storage batteries and photoelectrodes for dye-sensitized solar cell, etc.$^{1-4}$ It is generally accepted that the application performances of materials are strongly related to their size, morphology, defects and surface properties, which on the other hand depend on the preparation methods and conditions.$^5$ Traditionally, SrTiO$_3$ are synthesized by solid-state-reaction of strontium carbonate and titanium dioxide with temperature typically higher than 900$^\circ$C.$^6$ Later on, hydrothermal method has been reported as a mild approach to synthesis of SrTiO$_3$ with temperature below 200$^\circ$C.$^7$ Since then, intense efforts have been focused on the size and morphology modification of SrTiO$_3$ by hydrothermal method. Some groups have prepared SrTiO$_3$ via an one-step hydrothermal method through the use of organic and inorganic additives as a tool of morphology control and structure-directing template. For example, SrTiO$_3$ nanocrystals were obtained by adjusting the concentration of KOH and silicate.$^8, 9$ Oriented aggregate SrTiO$_3$ were formed by the aid of organic additives.$^{10-13}$ Alteration of the additives has a significant effect on the morphology and characteristics of the final products, and thus the corresponding properties can be tuned by varying time, additives and some other preparation parameters.

Compared to the use of liquid Ti precursor, solid TiO$_2$ with different morphology were prepared in advance and then they react with Sr precursor and simultaneously play a role as template. Consequently, the final product could retain the morphology of the solid precursor, which brings a new insight on the use of self-template approaches to prepare nanofibers,$^{14-16}$ nanotubes$^{17-19}$ and porous SrTiO$_3$.$^{20, 21}$ In addition to the advantage of morphology control, through adjusting the preparation parameters, SrTiO$_3$/TiO$_2$ nanocomposite can be fabricated by this strategy as well.$^3$ Due to the well matching of the position of the conduction band (CB) and valence band (VB) between SrTiO$_3$ and TiO$_2$, SrTiO$_3$/TiO$_2$ nanocomposite exhibited improved charge transfer and separation efficiency as well as enhanced photocatalytic activity.$^{15}$ Although in situ X-ray diffraction (XRD) technique has been performed to understand the hydrothermal crystallization of BaTiO$_3$,$^{22}$ and CaTiO$_3$,$^{23}$ using TiO$_2$ as a precursor and two extreme models have been proposed: the dissolution-precipitation mechanism and in situ heterogeneous transformation mechanisms,$^{22}$ little is known about the hydrothermal formation mechanism of SrTiO$_3$.

Moreover, the crystal structure of TiO$_2$ precursor could have significant influence on the hydrothermal crystallization of SrTiO$_3$. Kutty et al. demonstrated that amorphous TiO$_2$ gels reacted fastest, rutile TiO$_2$ reacted most slowly, and anatase phase exhibited intermediate kinetics.$^{24}$ Recently, the pioneer work from Yang et al. indicated that anatase TiO$_2$ with {001} facets whose surface energy (0.90 J/m$^2$) is much higher than that of thermodynamically stable {101} facets (0.44 J/m$^2$) can be
stabilized by F.\textsuperscript{25} They further investigated the hydrothermal stability of [001] facetted anatase TiO\(_2\), which tend to eliminate steadily along [001] crystallographic direction.\textsuperscript{25} Contrarily, anatase TiO\(_2\) with dominant \{101\} facets is highly stable under hydrothermal condition.\textsuperscript{25} Therefore, it can be expected that even the TiO\(_2\) precursor with the same crystal structure but with different exposing crystal facets could have different chemical reactivity and thus affect the hydrothermal crystallization of SrTiO\(_3\). Unfortunately, the role of crystal facets of TiO\(_2\) precursor reactivity and thus affect the hydrothermal crystallization of SrTiO\(_3\). In the following, we investigate the hydrothermal crystallization of SrTiO\(_3\) using anatase TiO\(_2\) nanosheets with dominant [001] facets and commercial anatase TiO\(_2\) nanoparticles as precursors by time resolved quenching experiments. Moreover, the photoelectrochemical (PEC) properties and photocatalytic hydrogen production activities of SrTiO\(_3\) products obtained from different TiO\(_2\) precursors are compared.

2 Experiment

2.1 Anatase TiO\(_2\) precursors with different crystal facets

The synthesis of TiO\(_2\) nanosheets with exposed [001] facets (denoted as “TO-NS” below) was carried out via a hydrothermal route using tetrabutyl titanate [Ti(OC\(_4\)H\(_9\))\(_4\)] as Ti source and hydrofluoric acid (HF) solution as solvent, according to previously reported method.\textsuperscript{27} Caution! Hydrofluoric acid is extremely corrosive and a contact poison, and it should be handled with extreme care. In a typical procedure, 3.75 mL Ti(OC\(_4\)H\(_9\))\(_4\) was placed into a dried Teflon-lined stainless steel autoclave with a capacity of 15 mL. Then 0.6 mL of HF solution was dropped into the above liquid slowly. The mixture was heated to 100 °C and kept for 24 h in oven. After reaction, the products were neutralized and washed with deionized water and ethanol for several times, and dried at 50 °C for 60 h.

2.2 Synthesis of SrTiO\(_3\) nanocrystals and quenching experiments

Both TO-NP and TO-NS were used as Ti precursors. In a typical procedure, 2.5 mmol Ti precursor and 2.5 mmol Sr(OH)\(_2\) were dissolved in 15 mL deionized water in a Teflon-lined stainless steel autoclave with a capacity of 40 mL. The mixture was heated to 160 °C and kept for 24 h in oven. After reaction, the products were filtered and washed with deionized water and ethanol for several times, and dried at 50 °C for 24 h.

In order to investigate the crystallization process of the products from different Ti precursors, the reaction was performed by rapid cooling experiment using Duran quartz glass tubes. The tube was acted as an autoclave to produce high temperature and pressure, 0.25 mmol Ti precursor and 0.25 mmol Sr(OH)\(_2\) were dissolved in 1.5 mL deionized water, and the pH was adjusted to be larger than 13 using 8 M KOH. The mixture were kept in oil bath at 100, 120, 140, 160 °C for 2, 5, 10, 30 min and inserted into the mixture of water and NaCl with temperature as low as -8 °C. Finally, the precipitate was collected after centrifuged and washed with deionized water and ethanol and dried at 50 °C for 24 h. It is noteworthy that the same stirring condition should be performed to maintain the diffusion rate caused by stirring.

2.3 Characterization

X-ray diffraction (XRD) was performed with a PANalytical X’pert diffractometer operated at 40 kV and 40 mA using Cu \(\text{K} \alpha\) radiation. Raman spectroscopy was performed on a Renishaw Ramascope 1000 with a green SpectraPhysics Argon laser with a wavelength of 524.5 nm. Transmission electron microscopy (TEM), high-resolution TEM (HRTEM) and selected area electron diffraction (SAED) images were recorded on a FEI Tecnai G2 20 microscope operated at 200 kV. Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDXS) were carried out on an EVOMA 15 microscope equipped with EDAX detector. Diffuse reflectance spectra (DRS) data were recorded on a Shimadzu UV-2600 spectrophotometer equipped with an integrating sphere using BaSO\(_4\) as the reflectance standard sample. The nitrogen sorption isotherm and Brunauer-Emmett-Teller (BET) surface area were determined by nitrogen adsorption method (Quadrasorb SI), the sample was degassed at 150 °C for 4 h under vacuum atmosphere. X-ray photoelectron spectroscopy (XPS) measurements were measured on a Thermo ESCALAB 250Xi with Al Ka emission at 1486.6eV, and all of the binding energies were referenced to the C1s at 284.8eV.

2.4 Photoelectrochemical and photocatalytic activity tests

The PEC properties were studied by the CHI 660 electrochemical workstation in 0.5 M Na\(_2\)SO\(_4\) solution, with a saturated calomel electrode (SCE) as the reference electrode, platinum wire as the counter electrode and fluorine-doped tin oxide (FTO) conducting glass covered with SrTiO\(_3\) as the working electrode. The MVL-210 (MEJIRO GENOSSEN) visible light source was used as the light resource (\(\lambda > 378\) nm). The SrTiO\(_3\) films were coated by a doctor blading technique. For photocatalytic hydrogen production test, 20 mg SrTiO\(_3\) obtained from different precursors were dispersed in 10 mL mixed solution of ethanol/water (V/V = 1/1). Before illumination, the system was deoxygenated with Ar for 20 min. Under constant magnetic stirring, the system was exposed to the illumination of high pressure mercury lamp (Hanovia, 500 W, 100 mW·cm\(^{-2}\)). The amount of hydrogen evolved was periodically detected by GC/TCD (Shimadzu, GC-14B) with a 5 Å molecular sieve column, using CH\(_4\) as the internal standard. The two different SrTiO\(_3\) samples were investigated under the same condition.

3 Results and discussion

3.1 Crystal structure

Fig. 1a shows the XRD patterns of the prepared TO-NS and commercial TO-NP. All of the diffraction peaks are consistent with anatase TiO\(_2\) (tetragonal, I4\(_1\)/amd, lattice constants \(a = 3.785\) Å, \(b = 3.785\) Å, \(c = 9.514\) Å, JCPDS 21-1272). Nevertheless, the full width at half maximum (FWHM) of TO-NS and TO-NP exhibited different behaviors. The FWHM of both (101) and (200)
peaks for TO-NP is 0.544, whereas the corresponding FWHM for TO-NS is 0.420 and 0.305, respectively, revealing the anisotropic morphology of TO-NS. Moreover, although the Raman modes at 140, 390, 513 and 534 cm\(^{-1}\) of both TO-NS and TO-NP can be assigned as \(E_g\), \(B_{1g}\), \(A_{1g}\) (or \(B_{1g}\)), \(E_g\) modes of anatase TiO\(_2\) (inset of Fig. 1a),\(^{27}\) the intensity of TO-NS is relatively lower than that of TO-NP, which indicated the chemical adsorbed F\(^-\) on the surface of TO-NS influences the vibration modes of TiO\(_2\).\(^{28}\)

Hydrothermal treatment of anatase TiO\(_2\) and Sr(OH)\(_2\) in alkaline condition affords the formation of SrTiO\(_3\). The dominated diffraction peaks of the products are identical to cubic SrTiO\(_3\) (JCPDS 35-0734) (cf. Fig. 1b). In addition, the XRD patterns also reveal small traces of unreacted anatase TiO\(_2\) and Sr(OH)\(_2\). Especially, Sr\(_2\) is found in the final products if using TO-NS as precursor, which on the other hand demonstrated F\(^-\) adsorbed on the surface of TO-NS, agreeing well with the observation from Raman spectra (inset of Fig. 1a). The diffraction peaks of SrTiO\(_3\) prepared from TO-NS exhibited a slight shift to lower angle compared to that prepared from TO-NP. Hence, the unit cell parameters have been determined to be \(a = 3.904 (1)\) Å and \(a = 3.892 (2)\) Å, respectively.
TiO$_2$ nanosheets with dominant {001} facets. After 2 min of reaction, it was observed that the products still contained sheet-like morphology. However, some additional tiny particles with size of several nanometers were clearly observed (cf. Fig. 4c).

According to the HRTEM image (Fig. 4d), the (001) surface of TO-NS can be maintained after hydrothermal treatment of 2 min, but an additional fringe spacing of 0.276 nm corresponding to the (110) atomic planes of SrTiO$_3$ was already observed, which is consistent with the results from XRD (Fig. 3b) and SAED (inset of Fig. 4d). Although {011} facets of anatase TiO$_2$ have a lower energy than that of {001} facets, {011} facets were not observed during the hydrothermal transformation process within the time resolution of our experiments. Prolong the reaction time to 5 min, the products were finally dominated by SrTiO$_3$ nanocrystals with particle size from 10 to 50 nm (Fig. 4e and f). On the whole, the morphology and crystal facets of TO-NS cannot be maintained during the hydrothermal transformation process, which differs from the previous reported topochemical reaction.\cite{30}

To compare with the hydrothermal formation of SrTiO$_3$ from TO-NS with dominant {001} facets, Fig. 5 shows the TEM, HRTEM images and SAED patterns of TO-NP precursor and the products at different reaction time. TO-NP exhibited irregular morphology and the fringe spacing of 0.352 and 0.317 nm with an angle of 68º match well with the (101) and (003) planes of anatase TiO$_2$ (Fig. 4a and b), indicating that they have different morphology and crystal facets from TO-NS. Similar to the use of TO-NS as precursor, some tiny particles were already formed only after 2 min of reaction (Fig. 5c). Except the fringes spacing from anatase crystal structure of TiO$_2$, another set of the fringes spacing measures 0.276 nm, corresponding to the (110) lattice of SrTiO$_3$ (Fig. 5d). After 5 min of reaction, the products were dominated by SrTiO$_3$ nanocrystals, which have tendency to aggregate into larger agglomeration to reduce their surface energy (Fig. 5e). All in all, it can be concluded that the hydrothermal formation of SrTiO$_3$ under our reaction conditions is not based on the solid-solid transformation. Otherwise, these tiny nanoparticles should not be observed during the initial reaction process (cf. Fig. 4c and 5c). The formation process of SrTiO$_3$ could be similar to our previous work on the hydrothermal growth of Bi$_2$SeO$_4$ nanowires using commercial Bi$_2$O$_3$ particles as starting materials.\cite{31,32} At the early stage, the surface hydrolysis could occur to form hydroxotitanium complexes (Ti(OH)$_{4-x}$) under hydrothermal condition and subsequent slight dissolution of the starting anatase TiO$_2$ nanoparticles.\cite{29} The difference for using TO-NS as precursor is that Ti-F bonds were also broken via hydrolytic attack except for Ti-O bonds. Then, the Ti(OH)$_{4-x}$ is capable of reaction with Sr ions to form SrTiO$_3$ nuclei at the solid/liquid interface, which appears to be a heterogeneous nucleation process. Therefore, the growth of SrTiO$_3$ is based on the expense of the dissolution of TiO$_2$ precursor. As perovskite SrTiO$_3$ has isotropic cubic crystal structure, no anisotropic morphology was observed for the hydrothermal products (Fig. 4e and 5e). Based on this formation mechanism, the rapid dissolution of TiO$_2$ precursor is crucial to provide the solution with a sufficient supply of titanium species. Thus, the particle size of TiO$_2$ precursor could have significantly influence on the hydrothermal formation rate of SrTiO$_3$. Fig. S4 compares the XRD patterns of the products using TiO$_2$ with bigger particle size...
TO-BP, several hundreds of nanometers) to the products obtained from TO-NS and TO-NP. After 10 min of reaction time, the ratio of SrTiO$_3$ in the products is much lower if using TO-BP as precursor, indicating a slower reaction rate. Moreover, the products were dominated by TiO$_2$ and SrTiO$_3$ particles with the size of hundreds of nanometers instead of nanocrystals (cf. Fig. S5).

In order to further investigate the hydrothermal formation mechanism of SrTiO$_3$, the kinetics of the products from different precursors at 100, 120, 140 and 160 °C by the time-resolved quenching experiments were studied. Kinetic analyses are performed by fitting the data of the most intense reflection (110) of SrTiO$_3$ to the expression that correlate the extent of reaction $\alpha$ to time. Fig. 6 shows the extent of reaction $\alpha$ of the SrTiO$_3$ (110) reflection as a function of temperature from different precursors. No induction time $t_{ind}$ could be observed at all the investigated temperatures within the time resolution on the experimental setup, indicating that the formation of SrTiO$_3$ sets in immediately. As expected, the reaction was accelerated with increasing the reaction temperature which was reflected from the reduction of half-life time $t_{0.5}$ of SrTiO$_3$ formation: $t_{0.5}$ decreased from 5 to 1.2 min and 7.8 to 1.5 min for using TO-NP and TO-NS as precursors, respectively, when the temperature was raised from 100 to 160 °C (Table 2). In addition, the shape of the growth profile revealed the growth mechanism. At lower temperature (100 and 120 °C), the SrTiO$_3$ growth curves exhibited distinctly difference for using TO-NP and TO-NS as precursors, indicating that they were dominated by different reaction mechanisms. These results revealed that Ti-F bonds on the surface of {001} facets of TO-NS could affect both the reaction rate and growth mechanisms. However, as the velocity of the SrTiO$_3$ formation is relatively fast (in 2 min), it is extremely difficult to perform Sharp-Hancock plots for a further evaluation of the obtained kinetic data giving the time resolution of the experiments.

Moreover, the activation energy $E_a$ for the hydrothermal crystallization of SrTiO$_3$ from anatase TiO$_2$, was calculated according to Arrhenius equation. Fig. 7 shows the Arrhenius plots for the crystallization of SrTiO$_3$. The linearity of the plot demonstrated the feasibility to determine the $E_a$. The $E_a$ determined by linear regression is 5.5
and 9.7 kJ mol\(^{-1}\) for using TO-NP and TN-NS as precursor, respectively. The \(E_a\) of TO-NS is larger than that of TO-NP. It could be attributed to the hydrolysis of Ti-F bond on the surface of TO-NS. Therefore, higher energy is needed for nucleation. Furthermore, the \(E_a\) of SrTiO\(_3\) in our current work is much lower than the previous reported \(E_a\) of BaTiO\(_3\) (21.0 kJ mol\(^{-1}\)).\(^{22}\) Tsumura et al have previously demonstrated that SrTiO\(_3\) is more easily formed than BaTiO\(_3\) under the same reaction condition,\(^2\) which is in line with our current \(E_a\) calculation. In addition, the nanoscale dimension of the precursor could be another reason (Fig. S4).

### 3.3 Optical properties and photocatalytic activities

The UV-vis absorption spectra of the SrTiO\(_3\) products prepared from TO-NP and TO-NS precursors were showed in Fig. 8. The SrTiO\(_3\) obtained from TO-NS exhibited a slight stronger absorption in the visible-light range compared to the products obtained from TO-NP. The band gap \((E_g)\) of these two samples was determined to 3.26 and 3.37 eV, respectively, according to the onset of the absorption edge.

![UV-vis spectra of SrTiO\(_3\) products](image)

**Fig. 8** UV-vis spectra of the SrTiO\(_3\) products prepared from different TiO\(_2\) precursors.

![Photocurrent and photocatalytic activity](image)

**Fig. 9** (a) Photocurrent versus time measurements of SrTiO\(_3\) prepared from TO-NP and TO-NS precursors; (b) Photocatalytic hydrogen production evolution of SrTiO\(_3\) prepared from TO-NP and TO-NS precursors.

Fig. 9 shows the transient photocurrent responses for SrTiO\(_3\) products obtained from different precursors. It is worth noting that the photocurrent of SrTiO\(_3\) obtained from TO-NS is about three times higher than that of the products obtained from TO-NP. In accord with the photocurrent measurements, the SrTiO\(_3\) obtained from TO-NS display a five times higher photocatalytic hydrogen evolution rates (95 \(\mu\)mol/h/g) compared to that of products obtained from TO-NP (19 \(\mu\)mol/h/g). All of these results clearly indicated that the crystal facets of TiO\(_2\) precursors could not only affect the hydrothermal crystallization of SrTiO\(_3\) but also have significantly influence on their properties and application performances. As the BET surface area (25.3 m\(^2\)/g) of SrTiO\(_3\) obtained from TO-NS is even lower than that (29.6 m\(^2\)/g) from TO-NP, the enhanced \(\text{H}_2\) production activity cannot be attributed to the surface area.

The electronic structures of SrTiO\(_3\) products are further investigated by XPS. The characteristic peaks of Sr 3d, Ti 2p and O 1s for both SrTiO\(_3\) keep almost unchanged (Fig. 10a, 10b and 10c). Fig. 10d shows the valence band XPS spectra of SrTiO\(_3\) products. The VB maximum of SrTiO\(_3\) prepared from TO-NS is 1.95 eV, which is 0.07 eV lower than that prepared from TO-NP. Considering the 0.09 eV difference of the band gap (Fig. 8), these two SrTiO\(_3\) products have very similar CB minimum which is around -1.33 eV. The Mott-Schottky (MS) measurements were performed and Fig. 11 shows the MS plots of the SrTiO\(_3\) products. The flat band potential, \(V_{fb}\), calculated from the x intercepts of the linear region, was -1.15 vs. SCE for SrTiO\(_3\) obtained from TO-NS, whereas SrTiO\(_3\) prepared from TO-NP was -1.14 vs. SCE. All of these results confirmed that both SrTiO\(_3\) products have very closed CB minimum, which is large enough to reduce \(\text{H}^+\) to \(\text{H}_2\) (0 eV vs. NHE). Therefore, \(\text{H}_2\) production under light irradiation was observed for both samples. F 1s XPS spectra of SrTiO\(_3\) products obtained from TO-NS indicated the existence of \(F^-\) in the final products (Figure S6). Combining with the BET surface area measurements and band structure investigations, \(F^-\) adsorbed on the surface of \{001\} facets of TiO\(_2\) could not only influence the hydrothermal crystallization of SrTiO\(_3\), but also affect their performances. Nevertheless, as SrF\(_2\) byproduct was observed from XRD (Fig. 1b), it is difficult to identify the \(F^-\) doping in SrTiO\(_3\), which needs further investigations.

![XPS spectra of SrTiO\(_3\) products](image)

**Fig. 10** (a) Sr 3d, (b) Ti 2p and (c) O 1s XPS spectra of SrTiO\(_3\) synthesized from different TiO\(_2\) precursors, (d) valence band XPS spectra of SrTiO\(_3\) products.
Fig. 11 Mott-Schottky (MS) plots of SrTiO$_3$ products

4. Conclusion

In summary, we compared the hydrothermal crystallization of SrTiO$_3$ using anatase TiO$_2$ nanosheets with dominant {001} facets and commercial anatase TiO$_2$ nanoparticles as precursors by time resolved quenching experiments. The velocity of hydrothermal formation of SrTiO$_3$ was relatively fast and the crystallization process of SrTiO$_3$ had almost finished in 30 min in the given interval. As surface adsorbed F$^-$ is indispensable to stabilize the {001} facets of anatase TiO$_2$, SrF$_2$ was observed during the whole reaction process if using TiO$_2$ with {001} facets as precursor, which could slow down the reaction rate. Nevertheless, no matter which kind of anatase TiO$_2$ precursors were used, the initial particle morphology and exposed crystal facets of TiO$_2$ precursor cannot be retained in the final SrTiO$_3$ products. Thus, a two-step sequence has been proposed for the hydrothermal formation of SrTiO$_3$ starting from a minute of dissolution of the solid TiO$_2$ precursor, followed by SrTiO$_3$ nucleation and growth at the solid/liquid interface. Moreover, the SrTiO$_3$ obtained from TO-NS exhibited a three times higher photocurrent and five times higher photocatalytic hydrogen evolution reaction rates compared to the SrTiO$_3$ prepared from TO-NP.

Acknowledgements

This work was financially supported by the Large Scientific Apparatus Joint Funds of the National Natural Science Foundation of China (U1232119), the Innovative Research Team of Sichuan Provincial Education Department and SWPU (2012XJST002) and Sichuan Provincial College Students' Innovation and Entrepreneurship Training Plan (S14014).

Notes and references

† Electronic Supplementary Information (ESI) available: [nitrogen adsorption-desorption curves; schematic crystal structures of anatase TiO$_2$ and SrTiO$_3$; the cross-section HRTEM image of TO-NS precursor; the XRD patterns of the products after 10 min of quenching experiments at 140 °C prepared from different anatase TiO$_2$ precursors; SEM images of TiO$_2$ particles with bigger size and the corresponding products; F 1s XPS spectra]. See DOI: 10.1039/b000000x/


© School of Chemistry and Chemical Engineering, Southwest Petroleum University, Xindu Rd. 8, Chengdu 610500, China

† School of Chemistry and Chemical Engineering, Southwest Petroleum University, Xindu Rd. 8, Chengdu 610500, China

This journal is © The Royal Society of Chemistry [year]