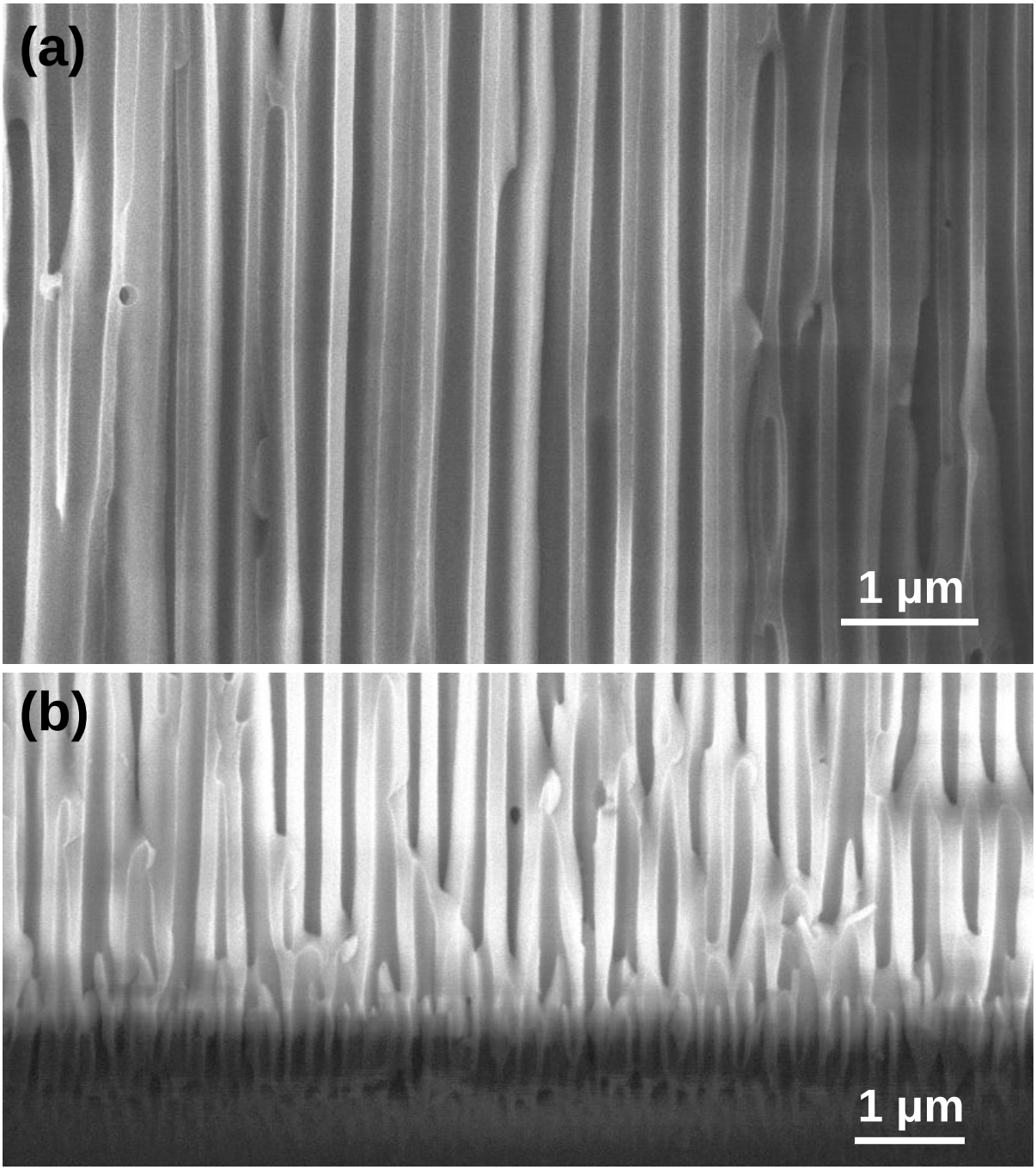
# Supporting Information

# Growth of Titanium Dioxide Nanorods in 3D-Confined Spaces

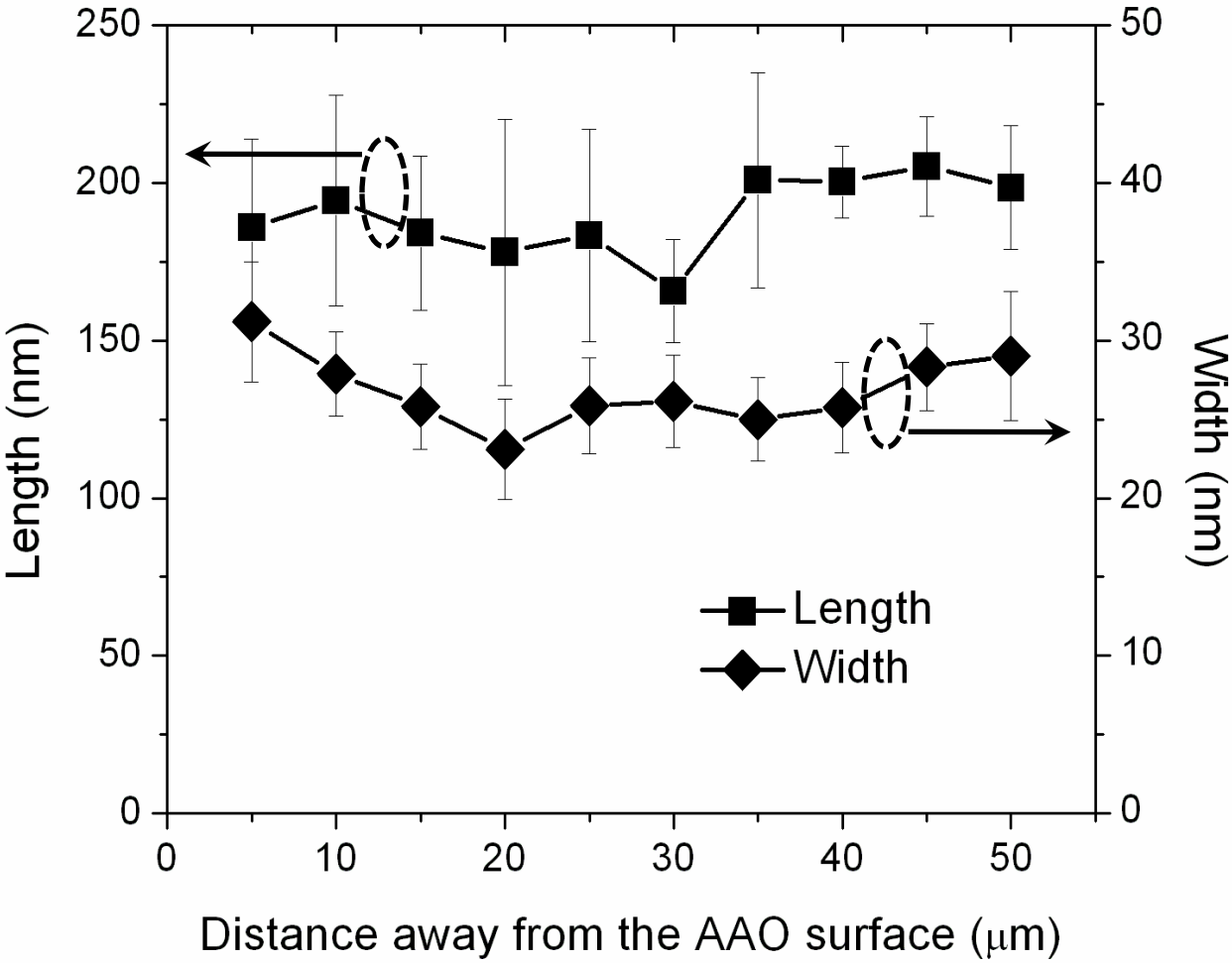
Jian Shi, Chengliang Sun, Matthew B. Starr, Xudong Wang*

Department of Materials Science and Engineering, University of Wisconsin-Madison, Madison, WI 53706

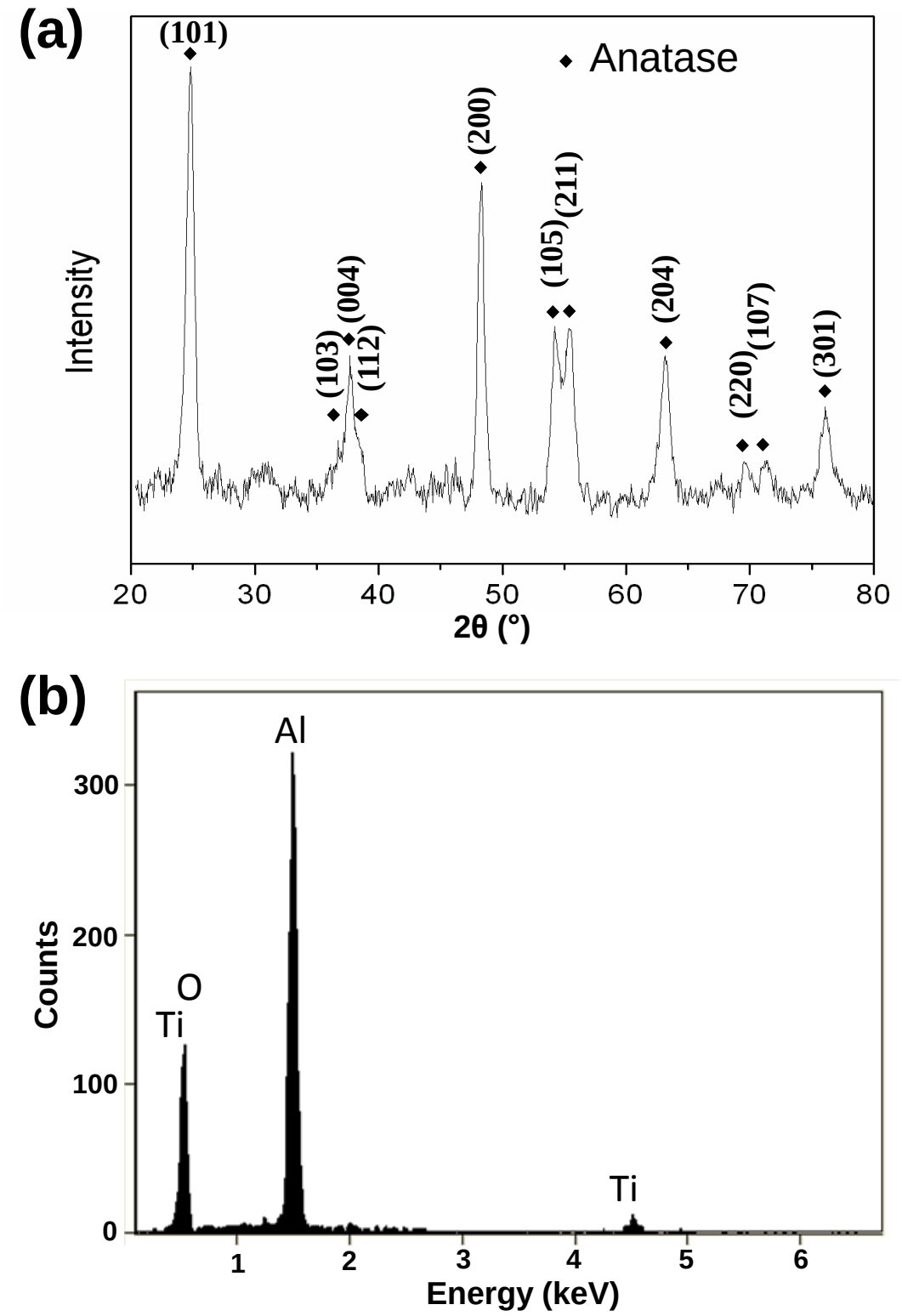
* To whom correspondence should be addressed. E-mail: xudong@engr.wisc.edu



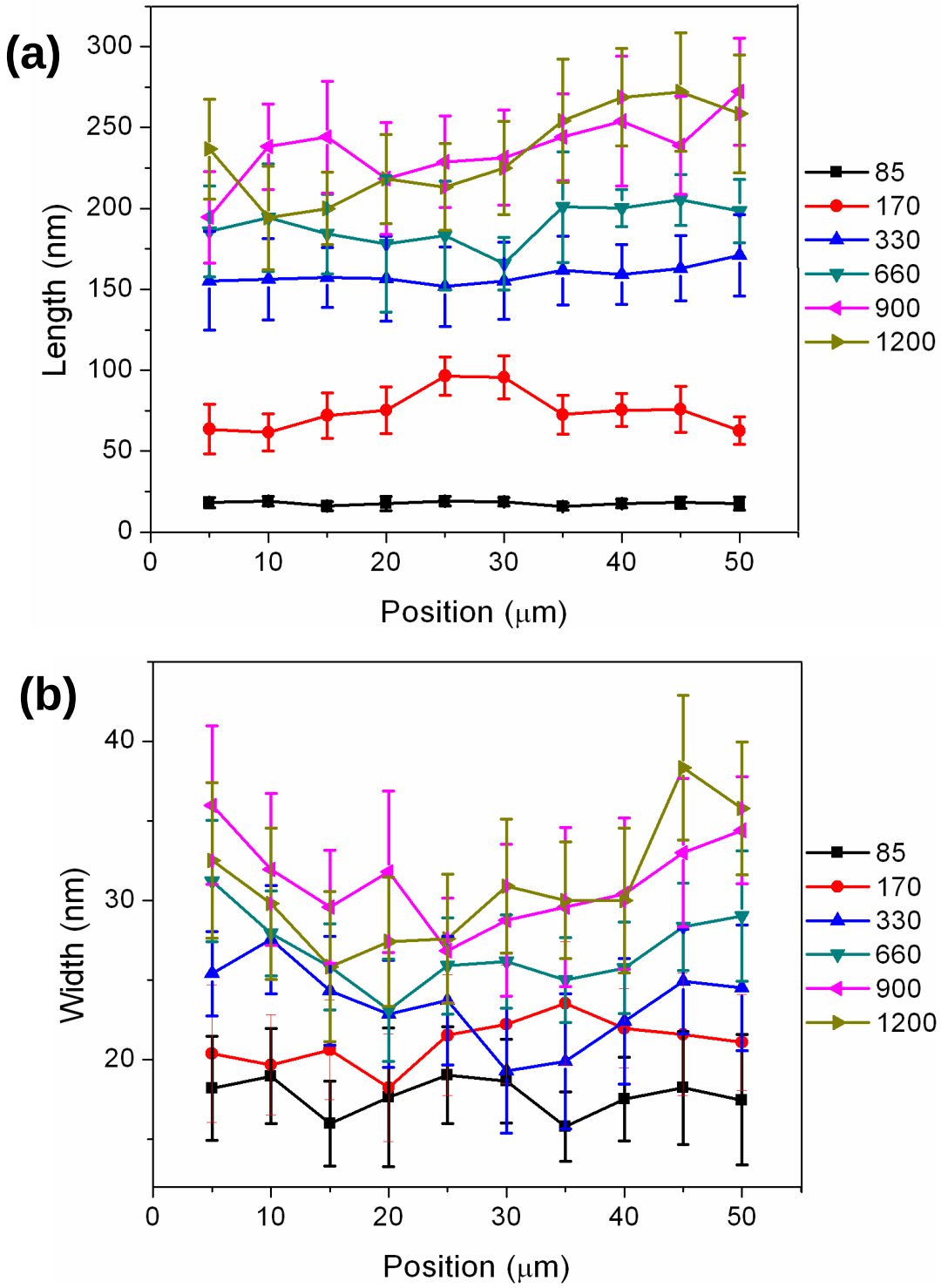

**S1. (a)** SEM image of the cross-section of the AAO template. (**b)** SEM image of the bottom portion of the AAO template, where the AAO channels become a little narrower and channel bifurcation or termination appears. In general, the AAO templates are ~53-54 µm long. The channels in the AAO template are ~250 nm in diameter. The average aspect ratio of the AAO channels is ~200.



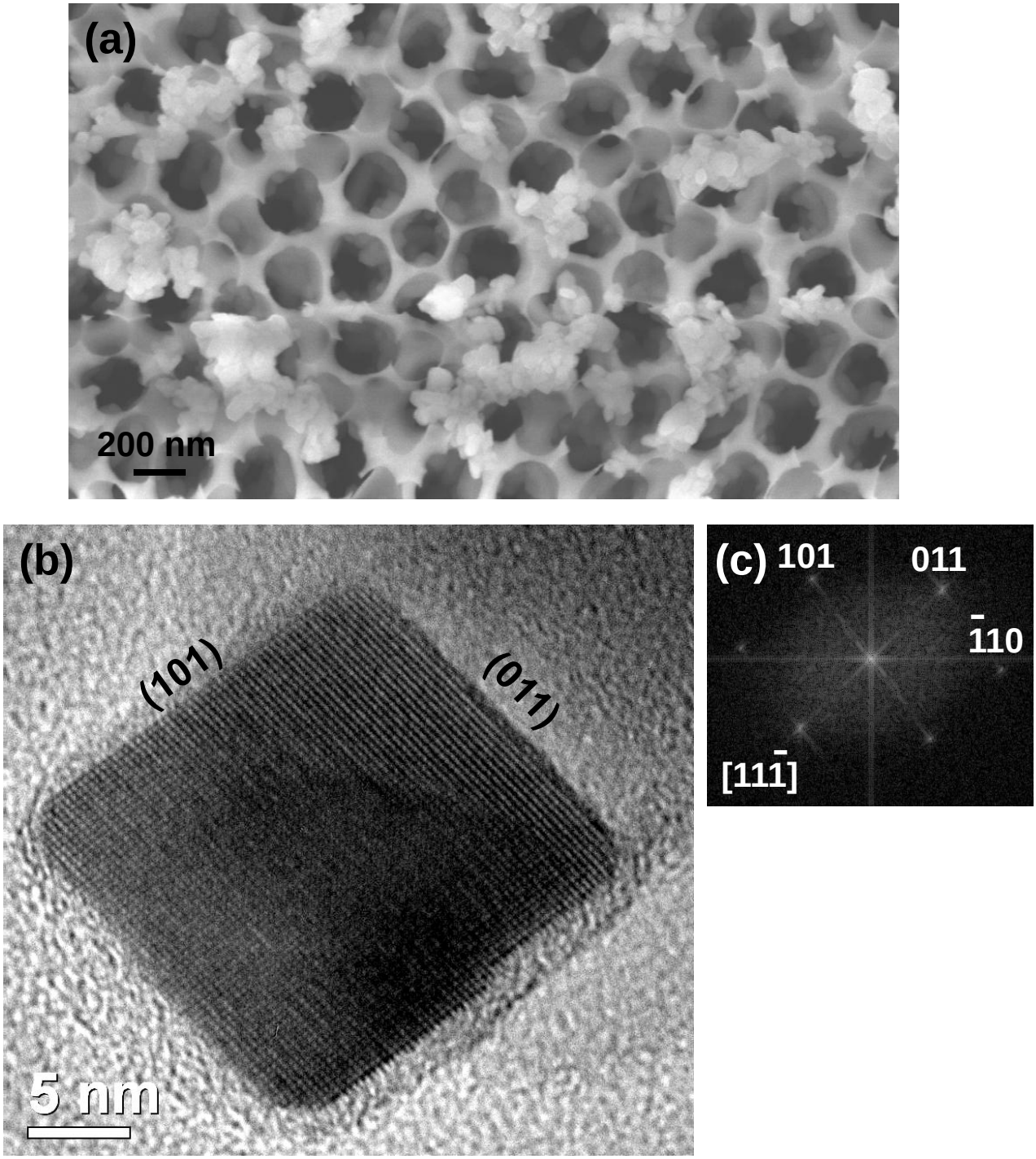

**S2:** Length and width distribution of the $TiO_2$ nanorods along the AAO channel. The data were collected from the $TiO_2$ nanorods grown by 660 cycles.



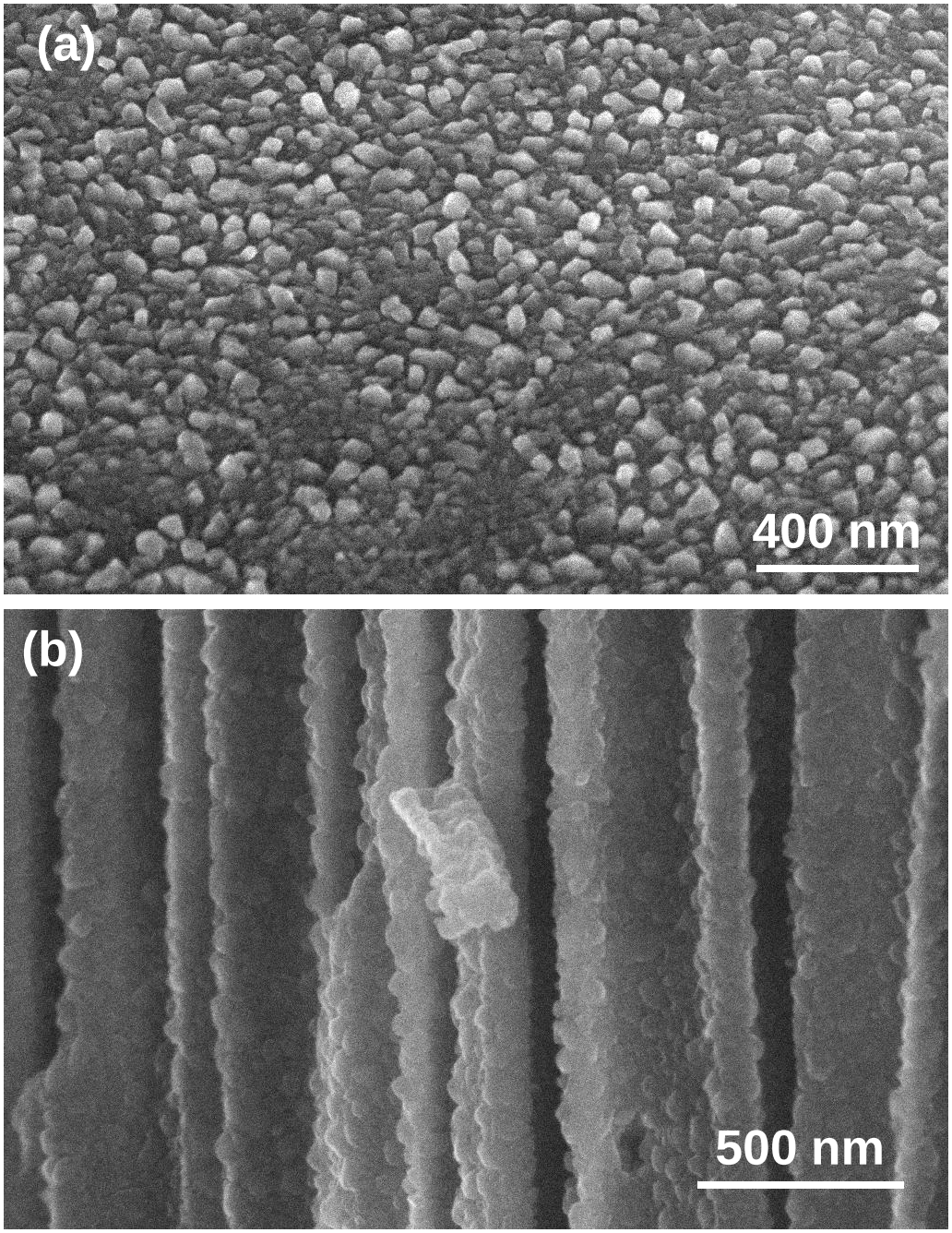

**S3:** (**a)** XRD spectrum of the $TiO_2$ nanorods grown in AAO template. (**b)** EDS spectrum of the $TiO_2$ nanorods.



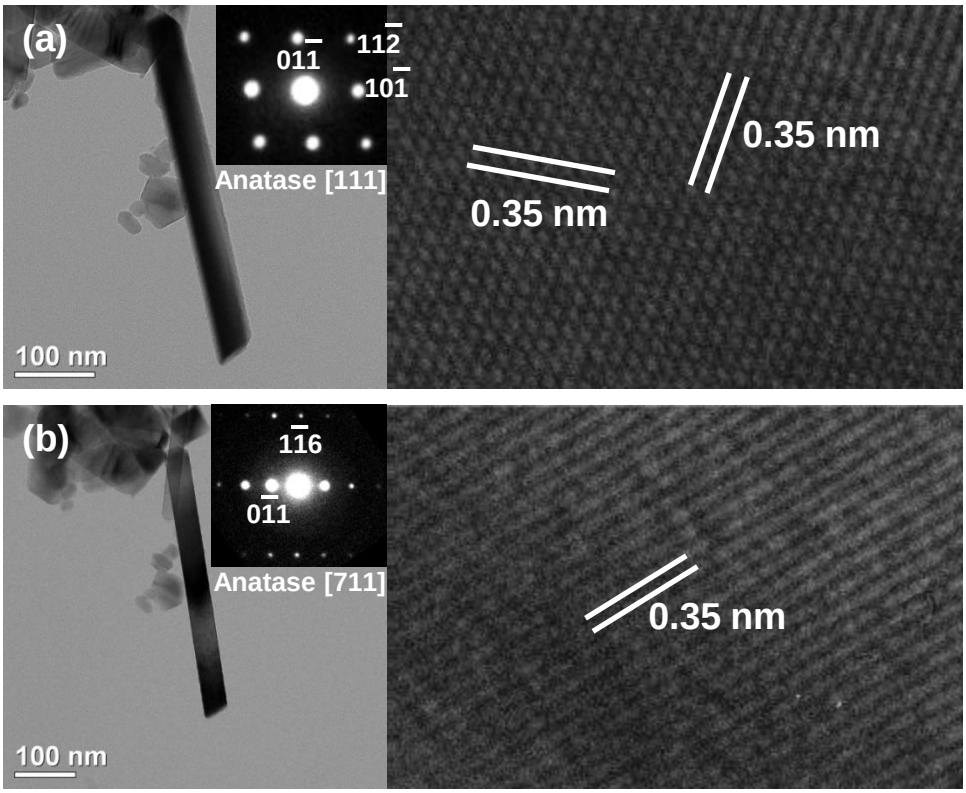

**S4. (a)** Length and **(b)** width analysis of the $TiO_2$ nanorods grown by different cycles. Both length and width exhibit a uniform distribution along the entire AAO channel and are rarely dependent on the positions. This is a distinguishing merits comparing to other nanostructure growth techniques.



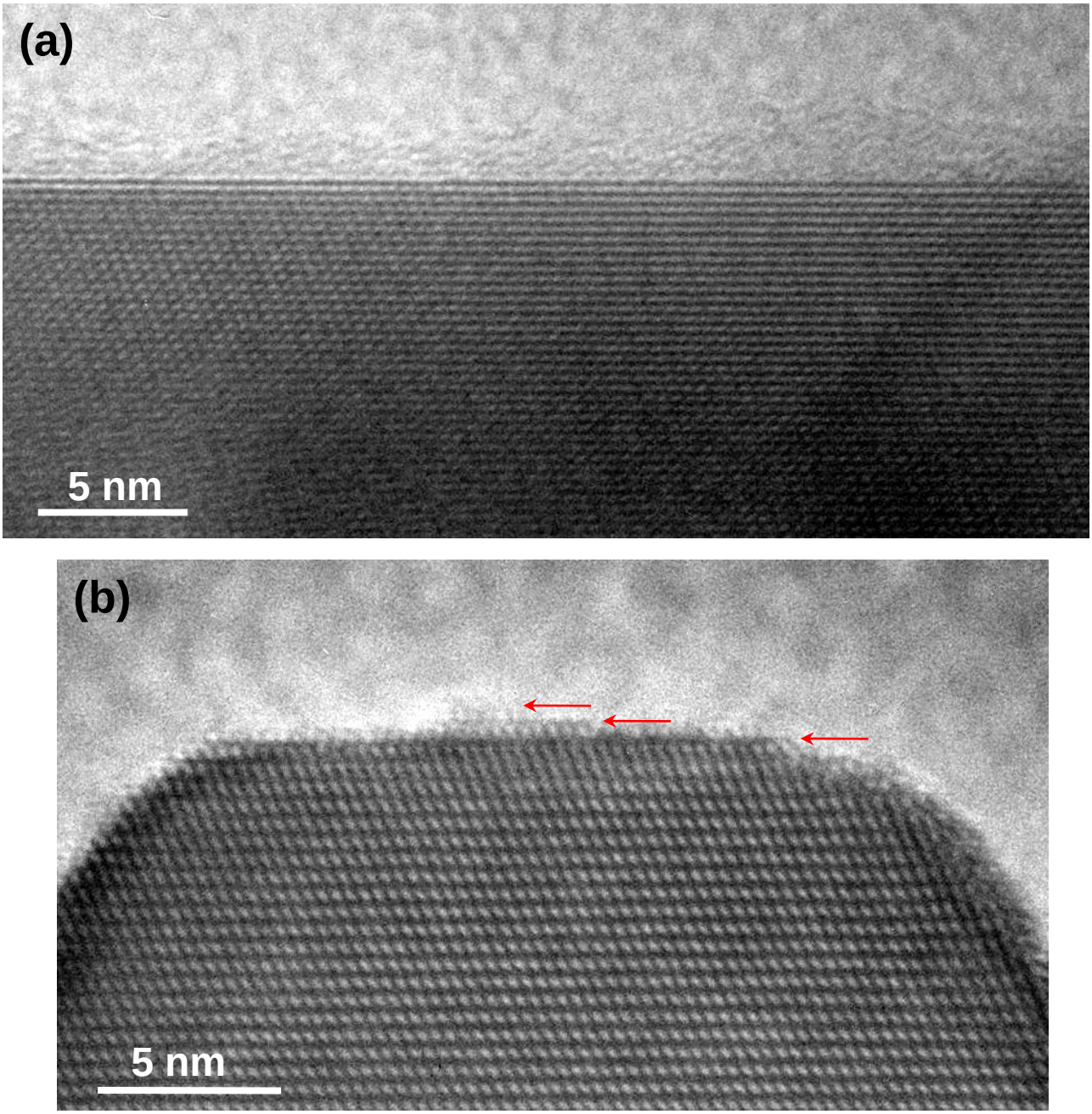

**S5:** Anatase $TiO_2$ nanoparticles. (**a)** SEM image of the top surface of an AAO template after 900 cycles. Pulse and purge time are 1.5 s and 60 s, respectively. No nanorod morphology was observed on the top surface but only nanoparticles. (**b)** HRTEM image of an $TiO_2$ nanoparticle obtained from the top surface. It is surrounded by {011} side surfaces. (**c)** Fourier transformation image of the HRTEM in (b) confirms the orientation and the anatase phase.



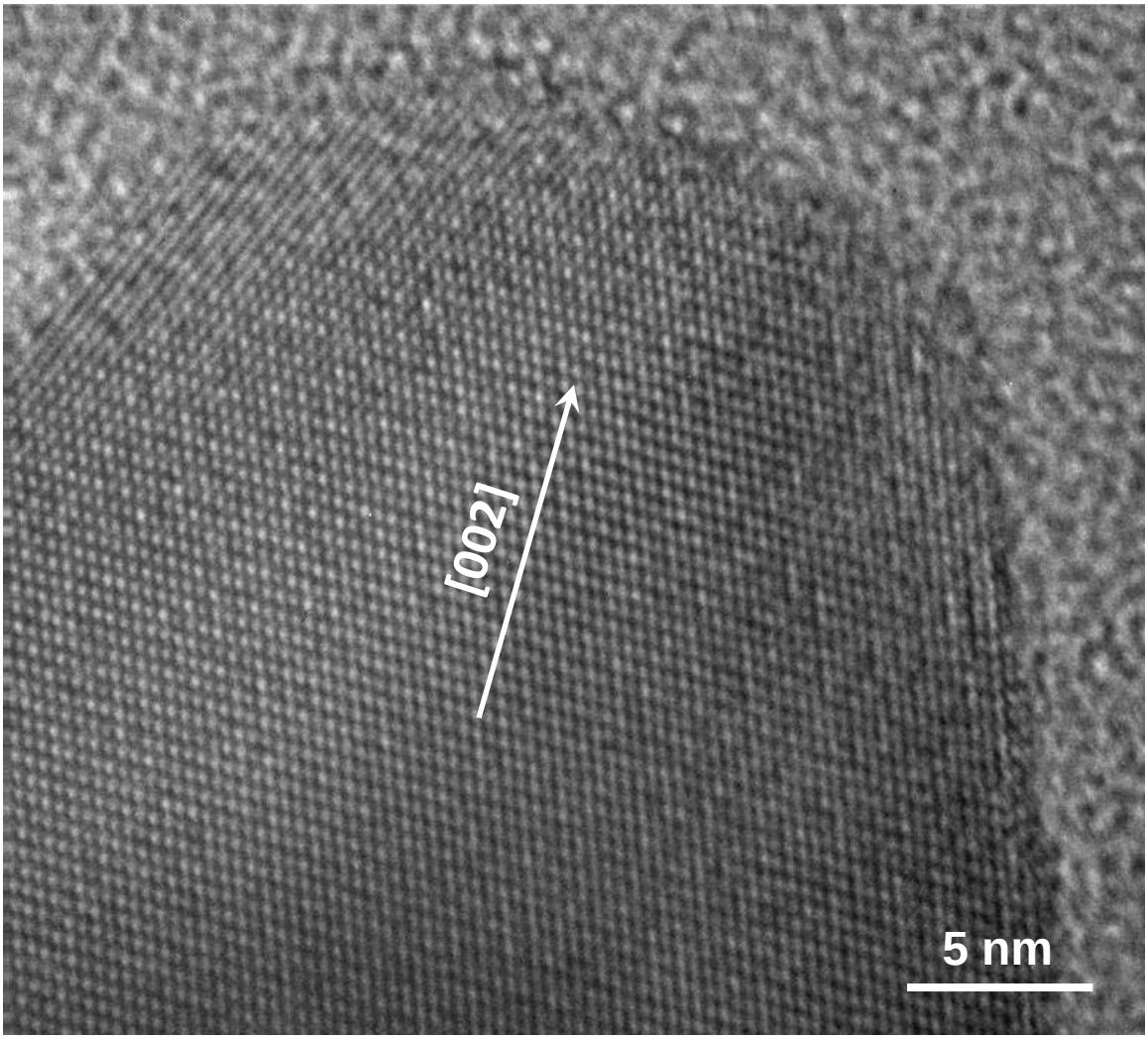

**S6:** SEM images of anatase $TiO_2$ grown via the same pulsed CVD procedure (660 cycles at 600°C). (**a)** On a flat polycrystalline $Al_2O_3$ substrate. (**b)** On an open AAO channel surface. Nanoparticle became the dominating morphology indicating confined space is favorable for nanorod formation.



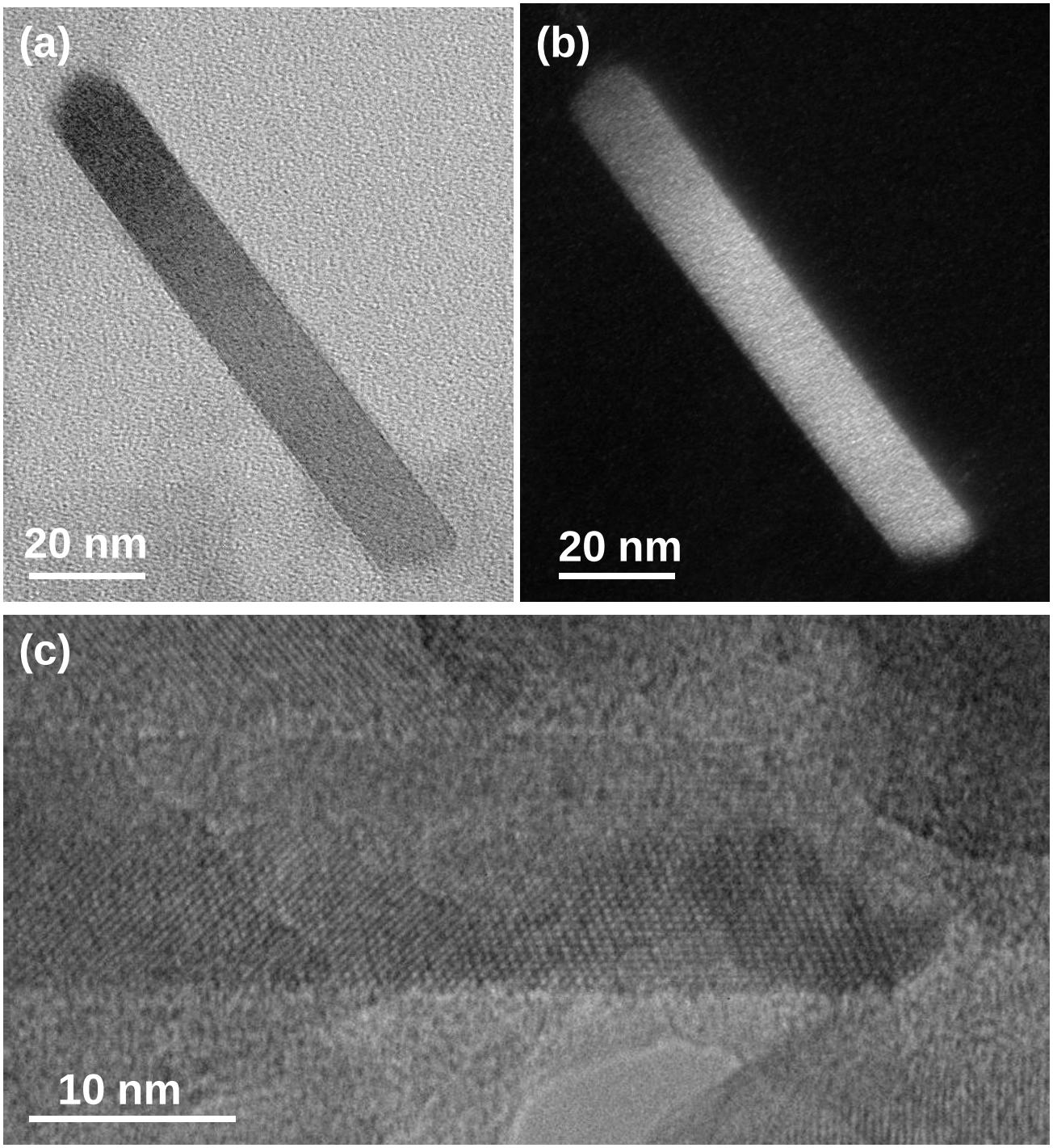

**S7**: Confirmation of the anatase phase of the $TiO_2$ NRs with diffraction patterns and high-resolution images from two different zone axes of the same NR. (a) The NR aligned along the [111] zone axis. (b) The same nanorod aligned along the [711] zone axis. Both diffraction patterns and the high-resolution lattice images match well with the standard anatase $TiO_2$ crystal.



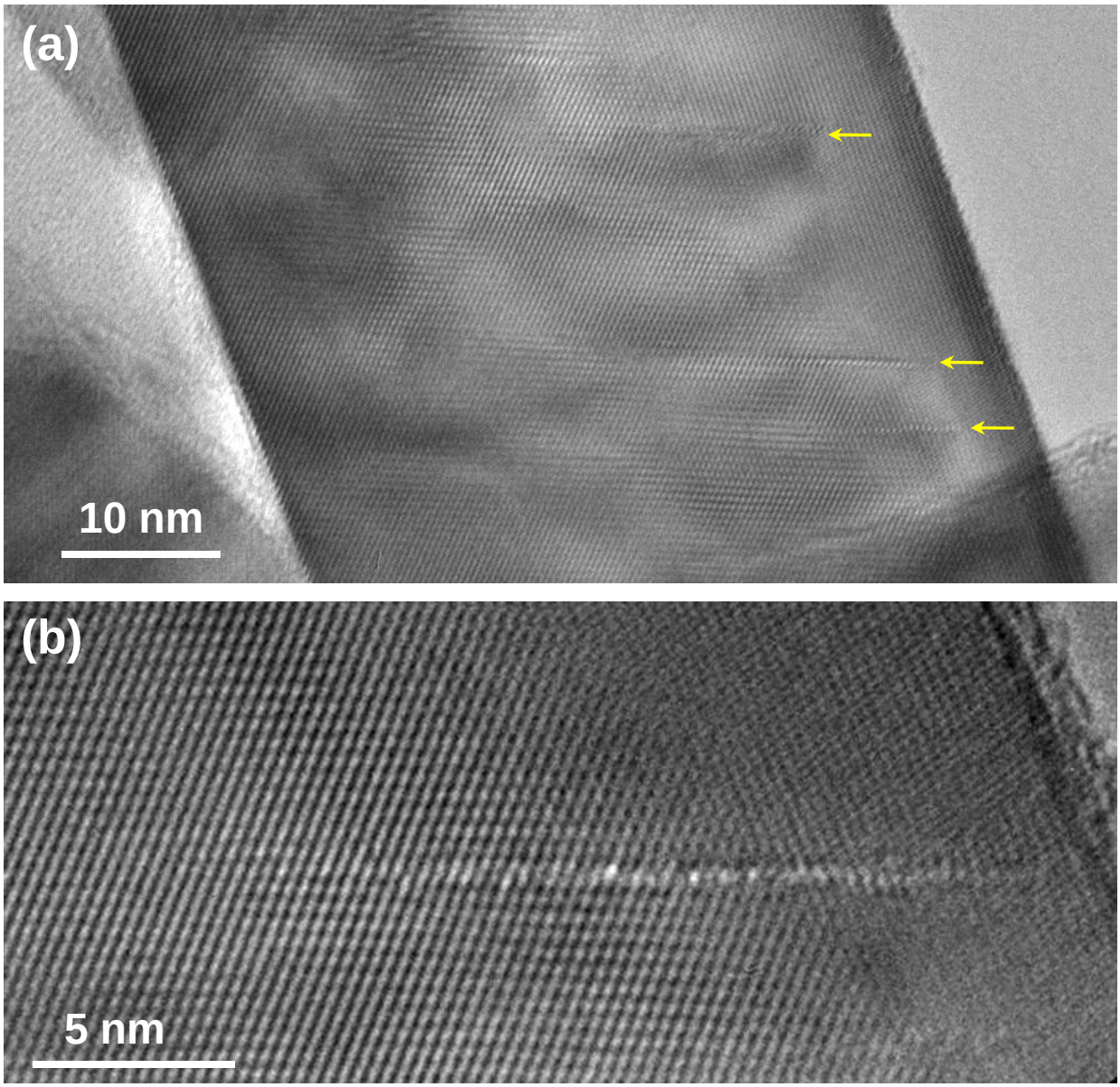

**S8:** HRTEM images of the side and tip of an anatase $TiO_2$ nanorod. (**a)** Side surface showing flat and stepless (011) atomic plane. (**b)** Tip surface showing multiple steps on the (001) atomic plane.




**S9:** HRTEM images of an anatase $TiO_2$ nanorod tip. The line fringes on the top-left corner of the nanorod tip indicates different thickness comparing to other region of the tip, where a 2D lattice can be clearly observed. This image suggests that the unevenness also appears along the [100] direction, which is the direction perpendicular to the image plane.




**S10: (a)** Bright field and (**b)** dark field TEM images of a $TiO_2$ nanorod growth by 330 cycles ; where the tips are not well facetted. (**c)** HRTEM image of a $TiO_2$ nanorod growth by 170 cycles . It exhibits a non-facet growth front of but well defined side surfaces.




**S11:** Planar defects observed on an anatase $TiO_2$ nanorod. (**a)** TEM image showing several planar defects along the (001) plane, as indicated by the arrows. (**b)** HRTEM image of one planar defect. The formation of such planar defects was a very rare case. Most NRs observed under TEM did not show such dislocations.