**Supplementary information for**

# Oxide Formation on Biological Nanostructures via a Structure-Directing Agent: Towards an Understanding of Precise Transcription

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## Experimental Procedure

### Buffer Preparation:

One liter stock of 1x PBS buffer solution was prepared by dissolving 8.0 g NaCl, 0.2 g KCl, 1.44 g $Na_2HPO_4$ and 0.24 g $KH_2PO_4$ in 800 ml of distilled water, and adjusting pH to 7.0 or 7.4 with 0.1N HCl, finally topping up to 1 L. Phosphate buffer in the pH range pH = 8 to 11 were prepared according the reference (1).

### Engineering of bacteriophages

To get phage with the positive net surface charge, we genetically modified the major coat of *M13* phage by displaying a short peptide containing 4 positively charged arginines (*R4*) on the side wall of *M13* phage by following our previous publication (2). The recombinant phage was purified by precipitation with polyethylene glycol (PEG) twice. The virus concentrations were determined using spectrophotometry with an absorption coefficient of 3.84 $cm^2$/mg at 270 nm, the positive net charge was determined by zeta potential measurement which show positive charge in 1× PBS buffer (pH = 7.4).

### Cationic liposome preparation.

DOPC and DOTAP were purchased from Avanti Polar Lipids, Inc. (Alabaster, AL, USA) and used without further purification. Cationic liposome was prepared according to the protocol (http://www.avantilipids.com) without sizing.

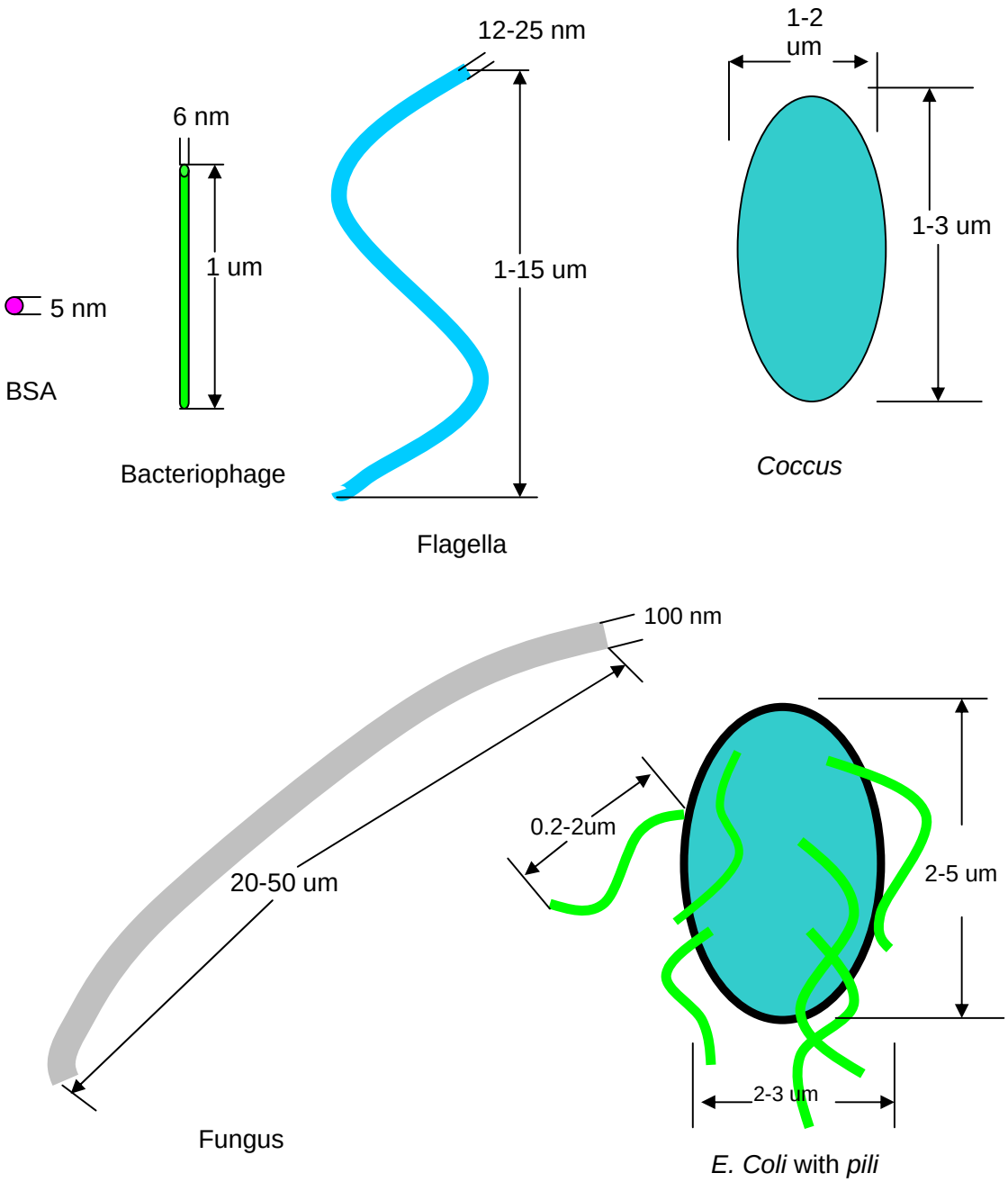



**Figure S1.** Cartoons of the available biotemplates that were used for silica preparation, together with their sizes. The cartoon was drawn in exact proportional scales.

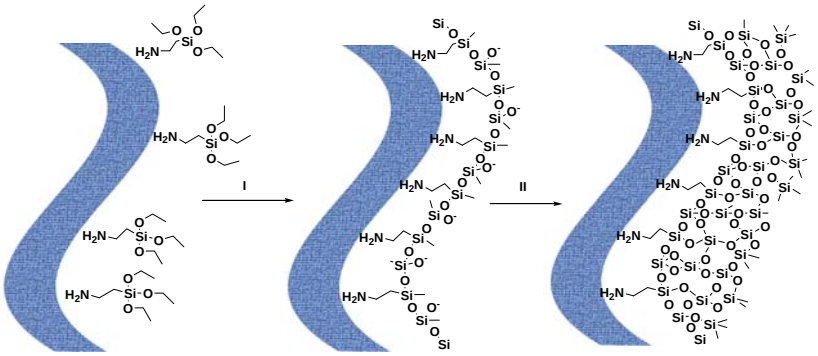



**Figure S2.** Schematic representation of the assembly and hydrolysis of APTES and subsequent silica growth at the chemical and biological interface. (I) The assembly of APTES on the surface of biotemplates via hydrogen-bonding and/or electrostatic interactions, together with its hydrolysis to form silica nuclei (silicic acid). (II) The polycondensation of silica on these pre-formed nuclei when TEOS was added.

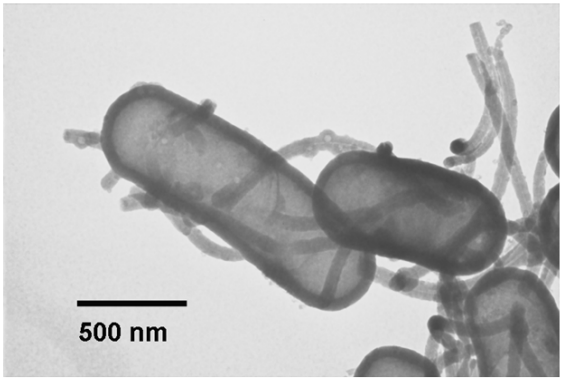



**Figure S3.** TEM images of 3D silica structures using the *E. coli* strain *TG1*as a template.

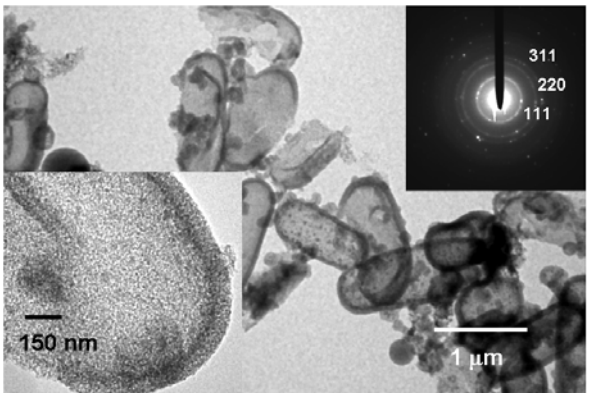



**Figure S4.** TEM images of the silicon replica after magnesiothermic conversion of the synthesized silica (using *E. coli* as templates). The insert shows the high magnification and corresponding selected area electron diffraction of the obtained silicon.

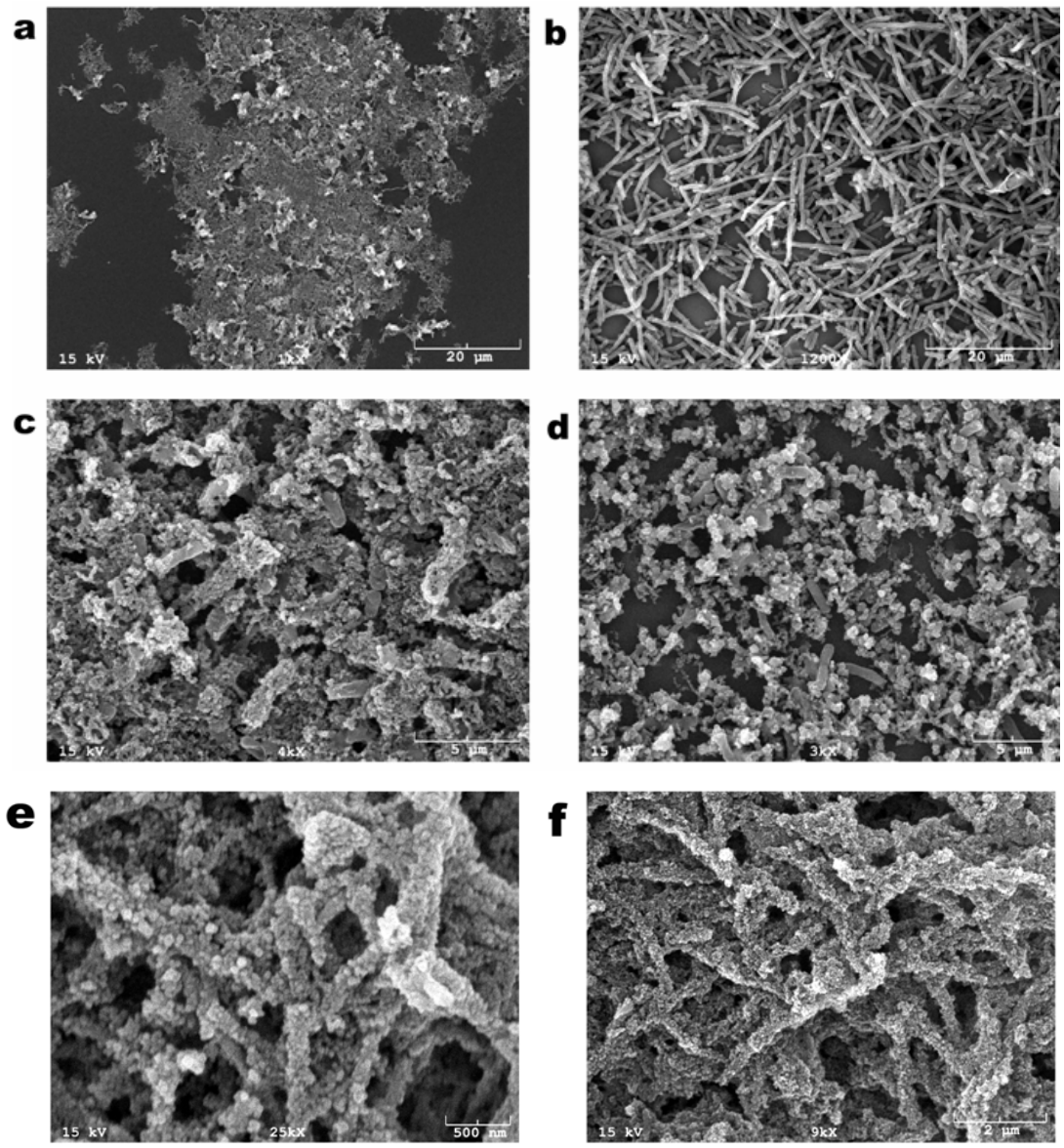



**Figure S5.** Control experiments. a, SEM images of the silica structure by hydrolysis of TEOS with $NH_4$.OH as a catalyst in the presence of the *E. Coli* strain *XL Blue* as a template; b, SEM images of the silica structure using APTES as a directing reagent together with TEOS in the presence of the *E. Coli* strain *XL Blue* as a template. c, SEM images of the silica structures formed by using a reverse addition order (TEOS then APTES) to the templates of *E. Coli* strain *XL Blue*. d, SEM images of the silica structures formed after simultaneous addition of APTES and TEOS to the templates of *E. Coli* strain *XL Blue*. e, SEM images of the silica structures formed by using a reverse addition order (TEOS then APTES) to the templates of wild type bacteriophage *M13*. d, SEM

images of the silica structures formed by simultaneous addition of APTES and TEOS to the templates of wild type bacteriophage *M13*.

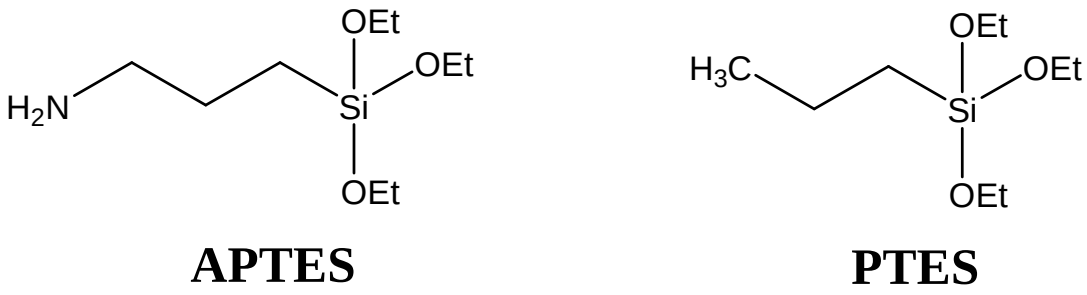



**Figure S6.** Chemical structures of APTES and PTES.

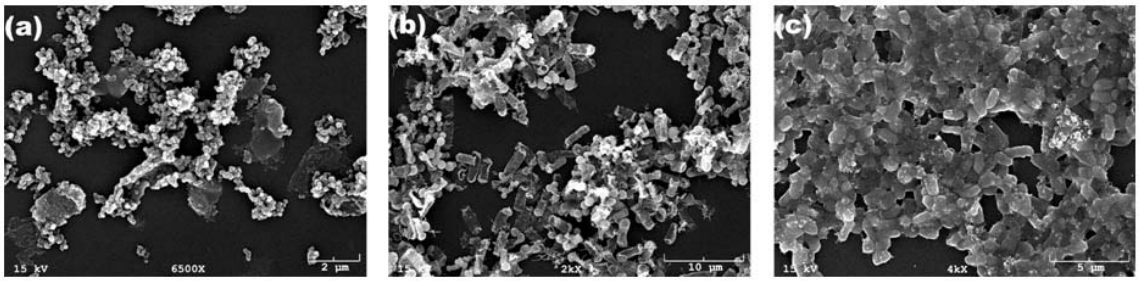
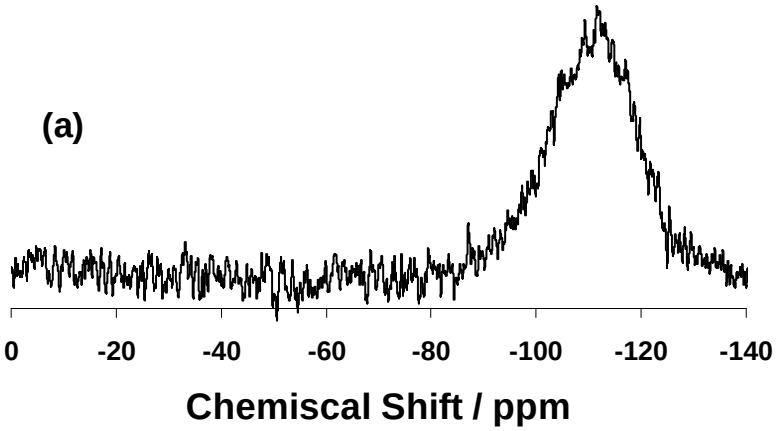



**Figure S7**. SEM images of the silica structure formed using APTES as a directing reagent together with TEOS in the presence of the *E. Coli* strain *XL Blue* as a template, at different buffer pH values: (a) pH = 11, (b) pH = 10, and (c) pH = 9.



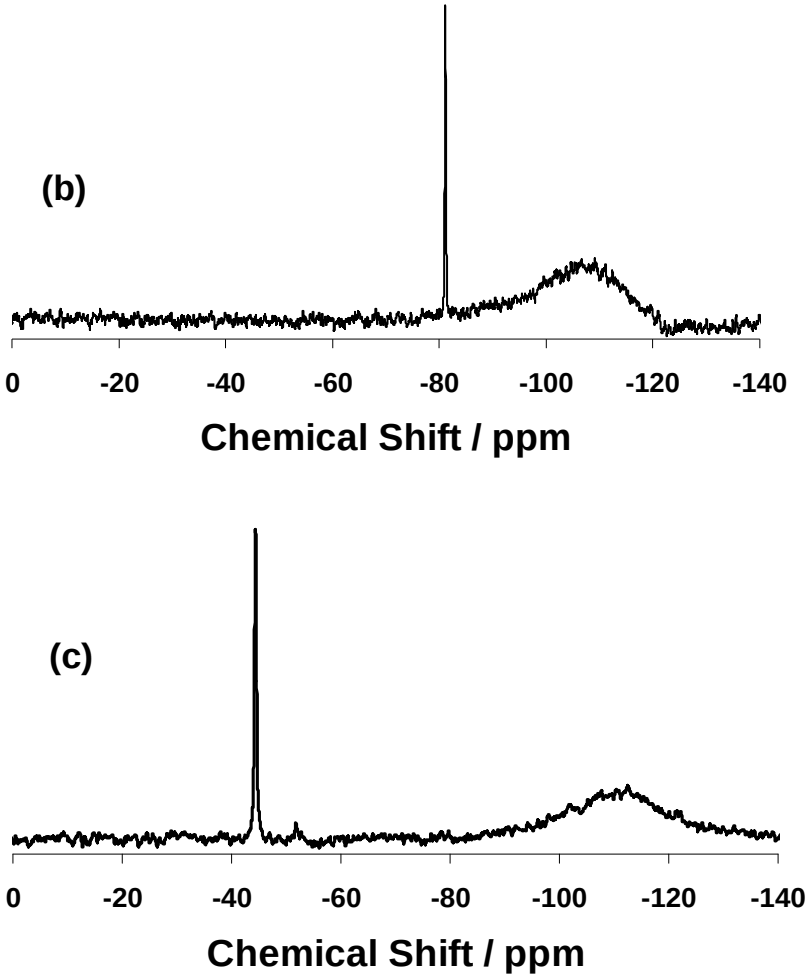
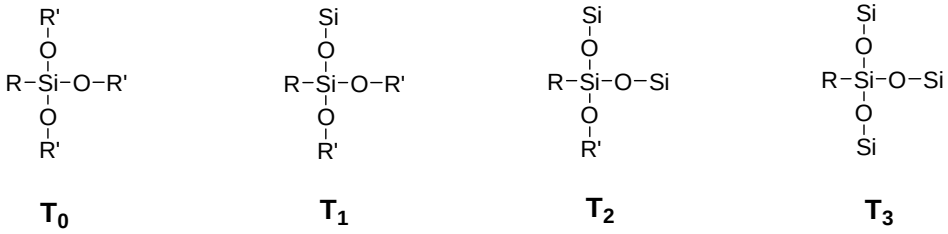



**Figure S8.** $^{29}$Si NMR spectra of (a) background (from glass), (b) pure TEOS, and (c) pure APTES.




**R= alkyl chain; R'= H or alkul chain**

**Figure S9.** The chemical structures of silicon species with T-structures.

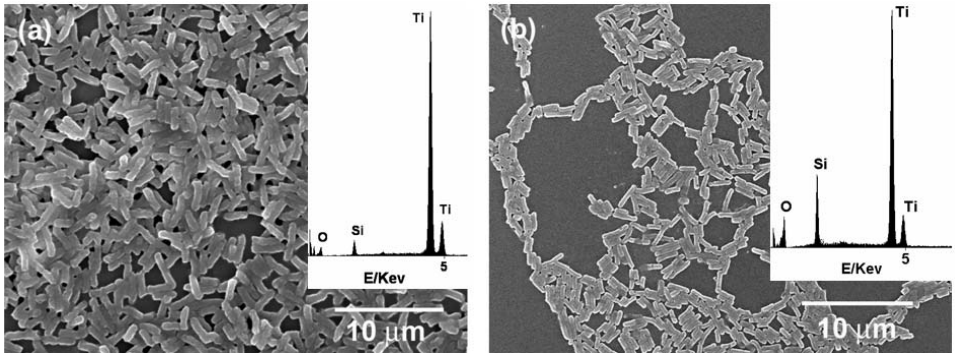



**Figure S10**. SEM and EDS spectra of a larger area of hybrid titania/silica encapsulated *E. coli*. (a) 10 mM APTES and 50 mM (Ti[BALDH]); (b) 10 mM APTES, 20 mM TEOS and 50 mM (Ti[BALDH]).

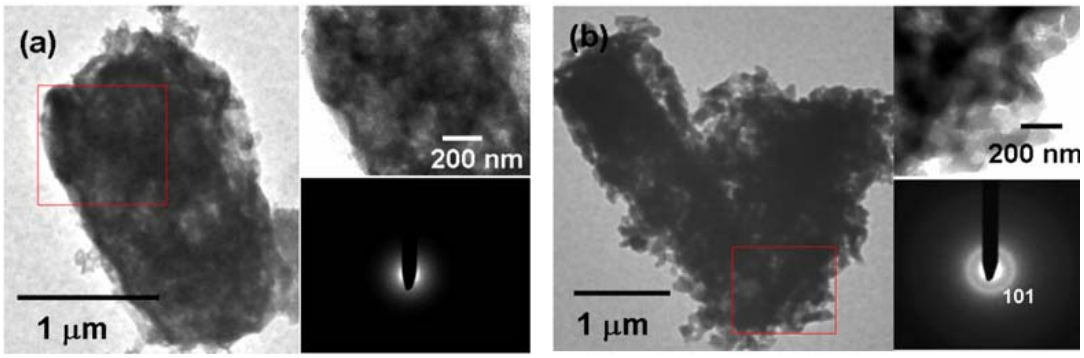



**Figure S11.** TEM images and corresponding selected area electron diffraction (SAED) patterns of the $SiO_2/TiO_2$ shell before (a) and after (b) calcinations. High magnification TEM images of the area highlighted by a red square are shown as insets.

## References

1. R. A. Robinson, R. H. Stokes, **Electrolyte Solutions**. 2nd ed., Butterworths, London, 1968.
2. A. Liu, G. Abbineni, C. B. Mao.. “Nanocomposite films assembled from genetically engineered filamentous viruses and gold nanoparticles: nanoarchitecture- and humidity-tunable surface plasmon resonance spectra." **Advanced Materials**, 2009, 21, 1001–1005.