Supporting Information

Shearing-Induced Formation of Au Nanowires

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Experimental

Instruments: SEM images were collected on a Gemini 450 Analytical Field Emission Scanning Electron Microscope operated at 3 kV. TEM images were collected on a Hitachi HT7800 model operated at 100 kV. High-resolution TEM images were collected on a FEI Talos F200X G2 model operated at 120 kV.

Chemicals: Hydrogen tetrachloroaurate(III) trihydrate ($HAuCl_4 \cdot 3H_2O$, 99.9%), C_{16}TAB (≥ 99%), L-ascorbic acid (≥ 99%), L-cysteine (99%, Energy), sodium borohydride ($NaBH_4$, ≥ 97%), sodium citrate ($C_6H_5O_7Na_3$, ≥ 99%), sodium hydroxide (NaOH, ≥ 97%), potassium iodide (≥ 99%), trimethylpropyl ammonium bromide (C_3TAB, ≥ 98%), hexyltrimethylammonium Bromide (C_6TAB, ≥ 98%), octadecyl-trimethylammonium bromide (C_{18}TAB, ≥ 98%) hexadecyl-trimethylammonium chloride (≥ 98%), benzyldimethyl-hexadecylammonium chloride (≥ 98%) were purchased from Sigma-Aldrich. Dodecyl-trimethylammonium bromide (C_{12}TAB, ≥ 98%) was purchased from Aladdin. Tetradecyl-trimethylammonium bromide (C_{14}TAB, ≥ 98%) was purchased from TCI Chemicals (Japan). D-glutathione (≥ 98%) was purchased from GL Biochem., Ltd. (Shanghai, China). Milli-Q water (resistivity 18.2 MΩ·cm at 25 °C) was used in all experiments.

Triangular Au nanoplates with an edge length of 150 nm[1] and Au decahedra[2] were synthesized following literature. The as-synthesized seeds were washed 2 times with water

and re-dispersed as aqueous solution with no concentration variation before added in the nanowire syntheses.

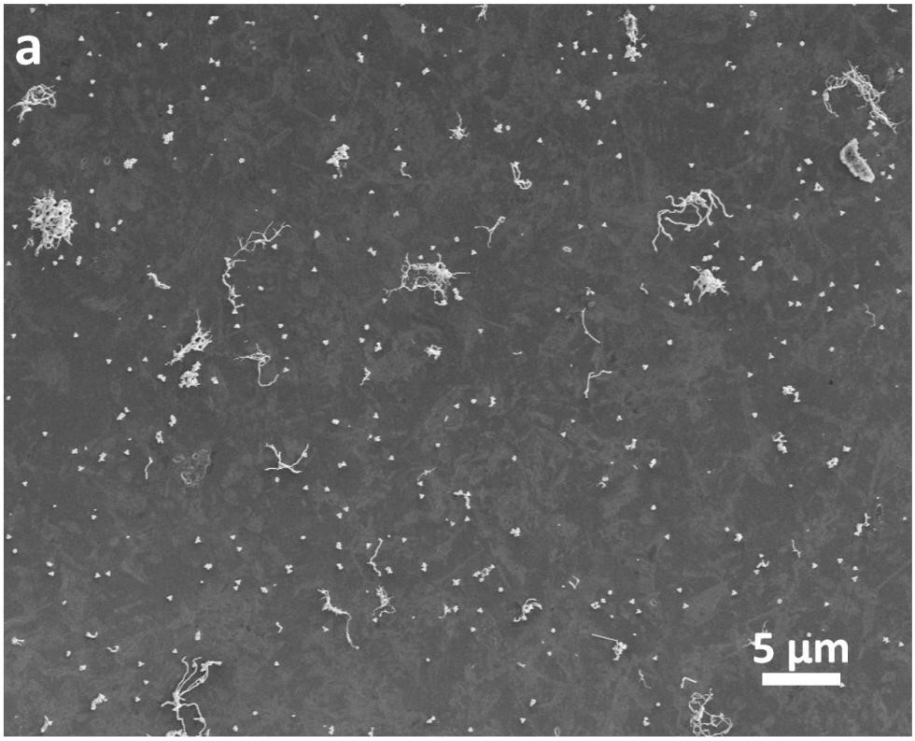
Shear-induced synthesis of Au nanowires (for nano-bowls): The whole process was performed at 60 °C. CTAB (50 mM, 1 mL) and H_2O (4 mL) were placed into a 15 ml vial and heated to 60 °C, followed by addition of $HAuCl_4$ (20 mM, 37.5 μL), L-ascorbic acid (100 mM, 16.5 μL) and L-cysteine (0.01 mM, 40 μL) quickly. Next, 40 μL triangular Au nanoplates solution was quickly added under vigorous vortexing. The mixture was shaken at 60 °C for 30 min in a 300 rpm orbital shaker. The product was purified with centrifugation and subjected to characterizations.

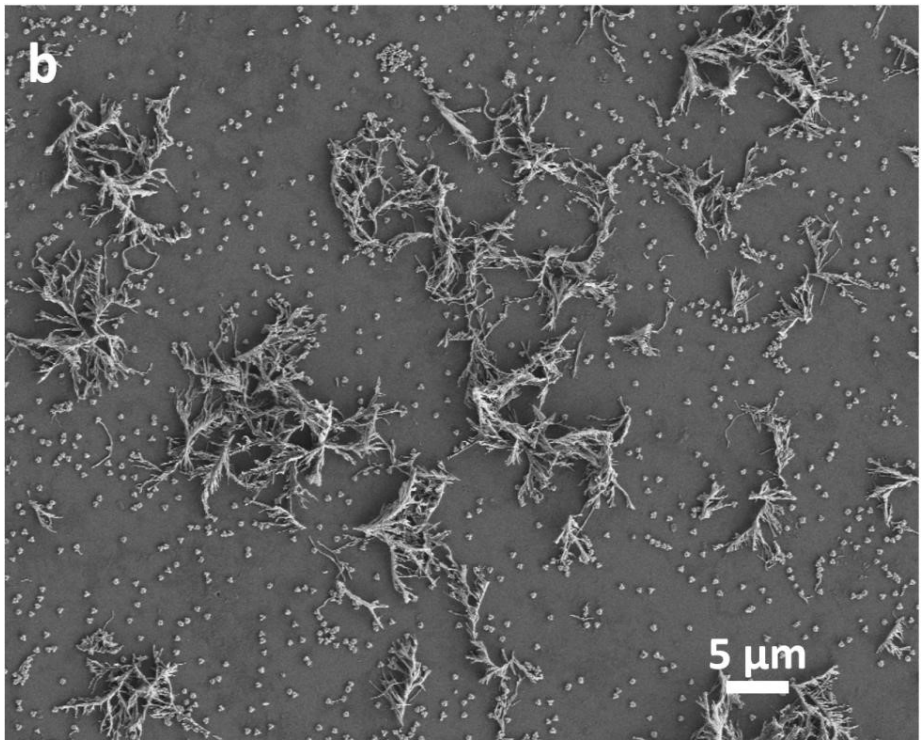
Shear-induced synthesis of Au nanowires (for nano-badges): The whole process was performed at room temperature. CTAB (100 mM, 0.8 mL), $HAuCl_4$ (10 mM, 0.2 mL) and H_2O (3.95 mL) were placed into a 15 ml vial. Then 100 mM, 0.475 mL AA were added to the above solution quickly. Then 40 μL fresh prepared D-glutathione solution (0.15 mg/mL) and 100 μL triangular Au nanoplates were added to the above solution. The mixture was shaken at 30 °C for 60 min in a 300 rpm orbital shaker. The product was purified with centrifugation and subjected to characterizations.

Shear-induced synthesis of Au nanowires (for nano-propellers): The whole process was performed at room temperature. CTAB (100 mM, 0.8 mL), $HAuCl_4$ (10 mM, 0.2 mL) and H_2O (3.95 mL) were placed into a 15 ml vial. Then 100 mM, 0.475 mL AA were added to the above solution quickly. Then 40 μL fresh prepared D-glutathione solution (0.15 mg/mL) and 1 μL Au decahedra were added to the above solution. The mixture was shaken at 30 °C for

60 min in a 300 rpm orbital shaker. The product was purified with centrifugation and subjected to characterizations.

Supplementary Figures





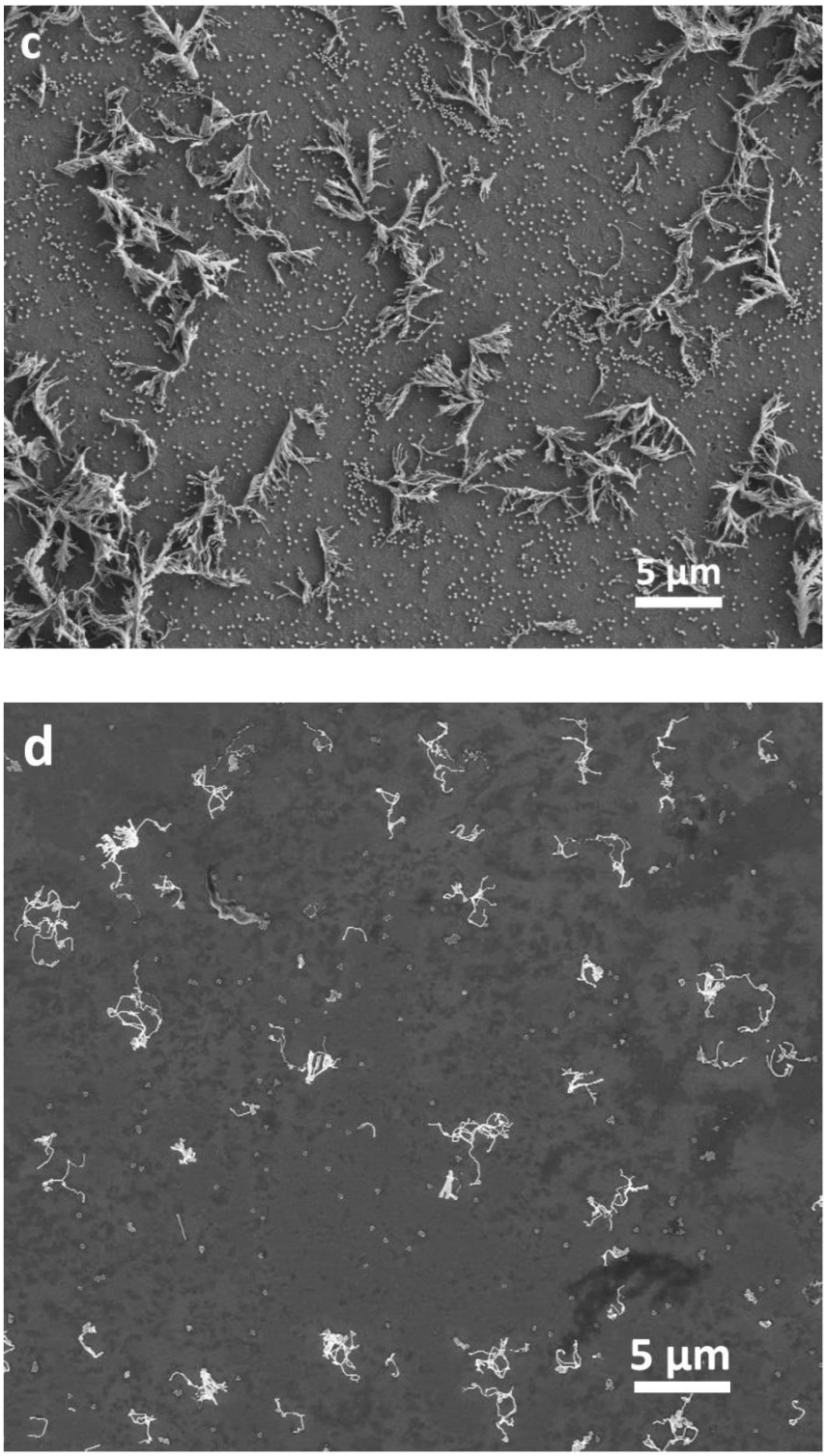


Fig. S1 SEM images of the Au nanowires when shear-force was applied during the synthesis of: (a) nano-bowls, (b) nano-badges, (c) nano-propellers, and (d) in the absence of any thiol-based ligands.

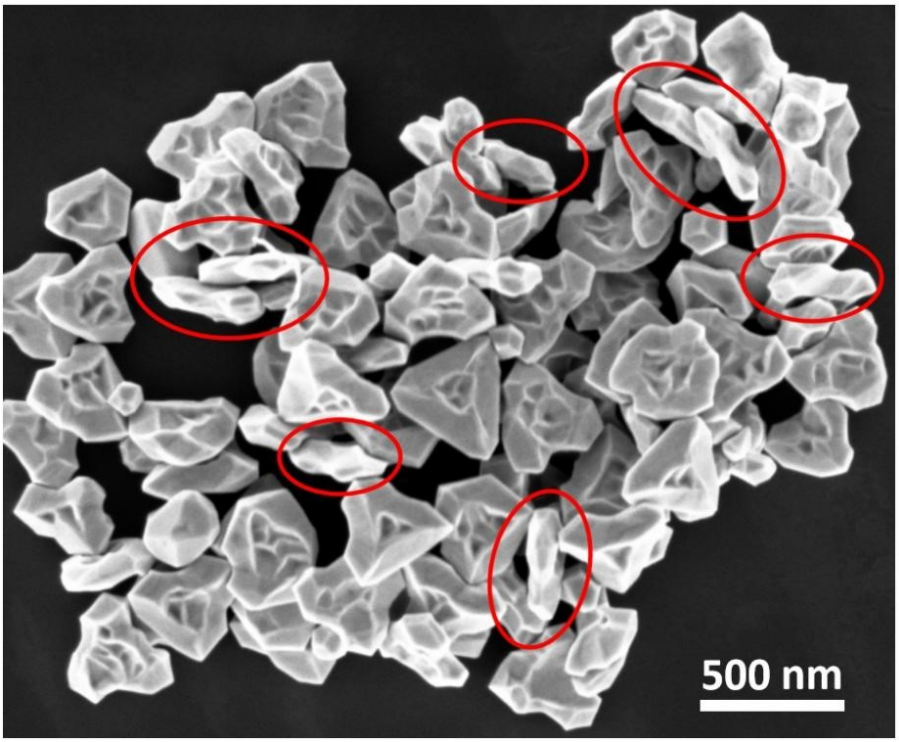


Fig. S2 SEM image of the tilted hexagonal particles after shaking the growth solution for 30 min.

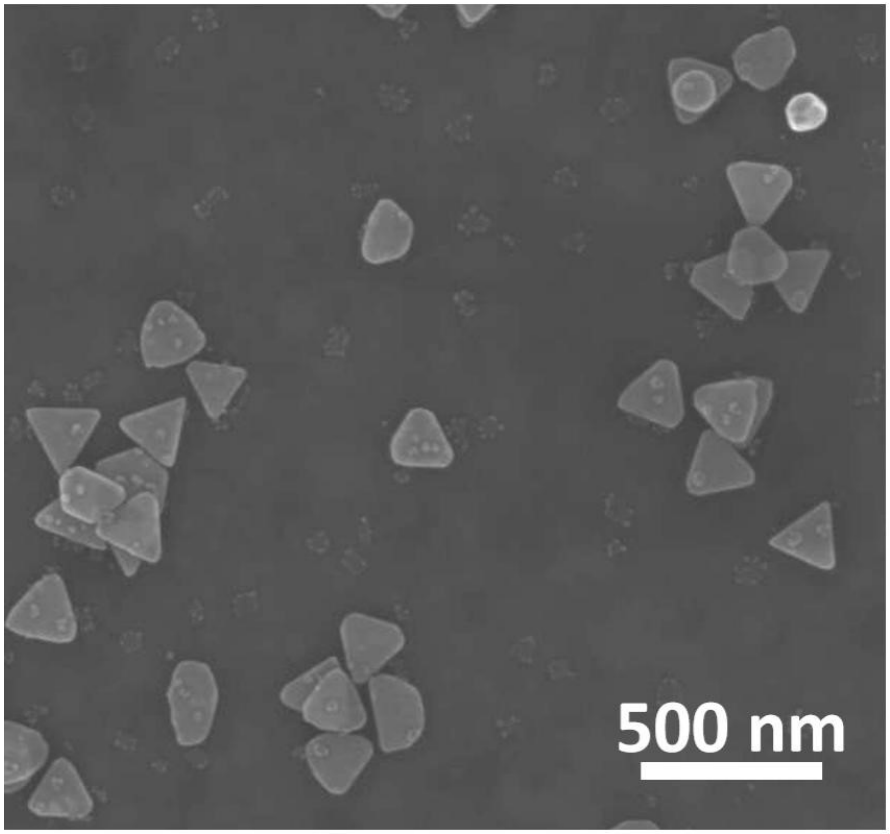


Fig. S3 SEM image of the triangular Au nanoplate seeds.

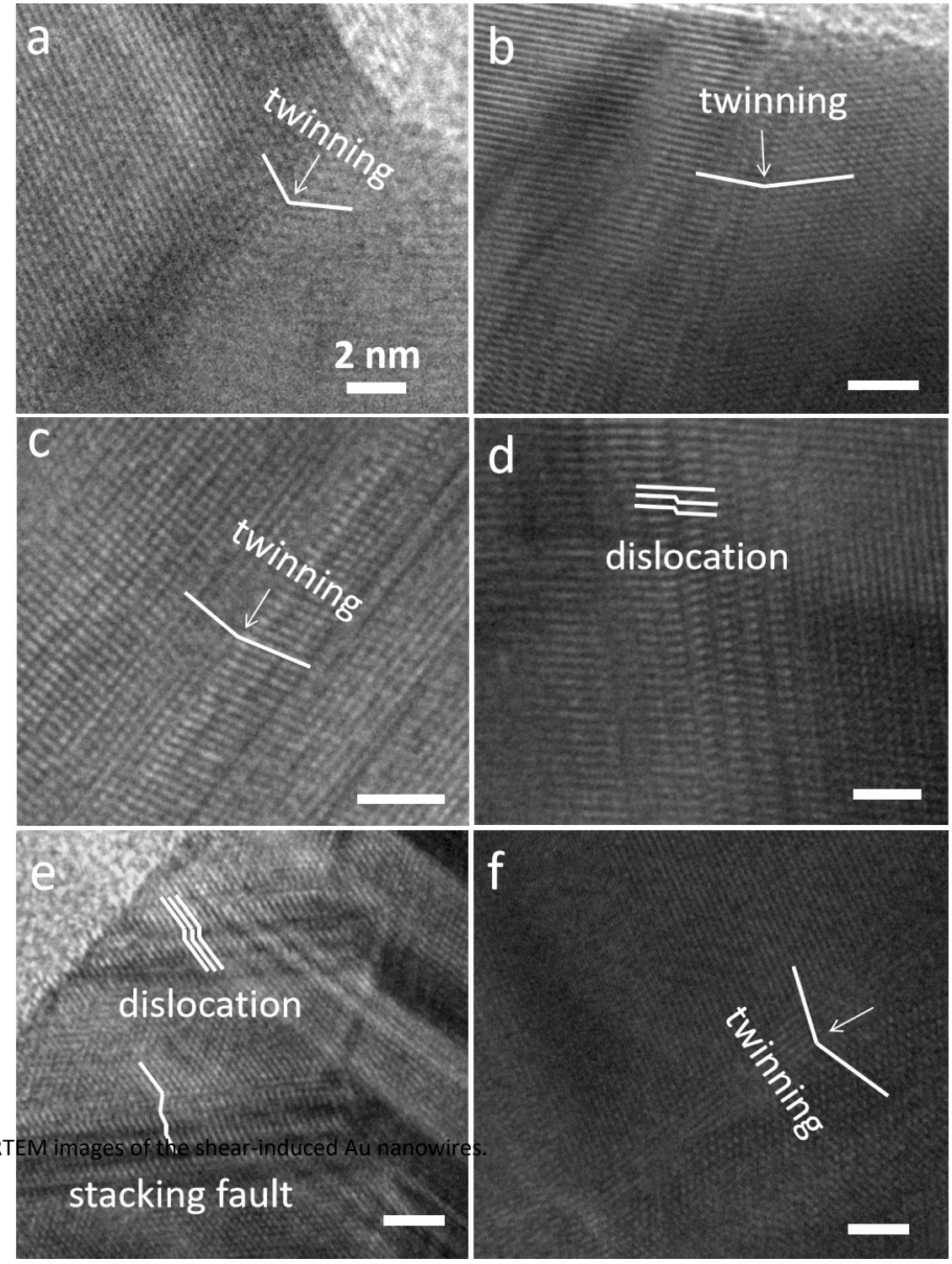


Fig. S4 (a-f) HRTEM images of the shear-induced Au nanowires.

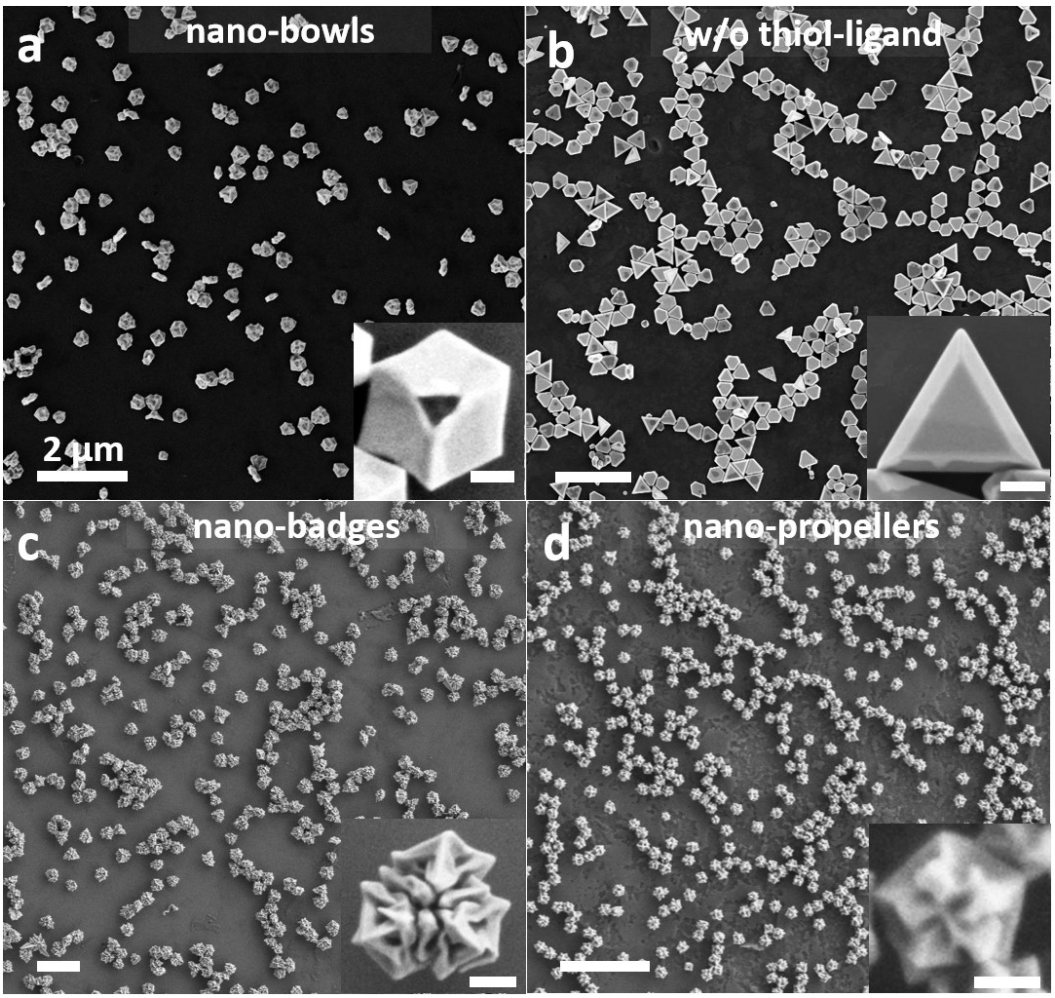


Fig. S5 SEM images of the (a) nano-bowls, (b) enlarged triangular nanoplates (with all condition the same as (a) except no thiol-ligands), (c) nano-badges and (d) nano-propellers synthesized in static solutions. (All the inset scale bars are 100 nm)

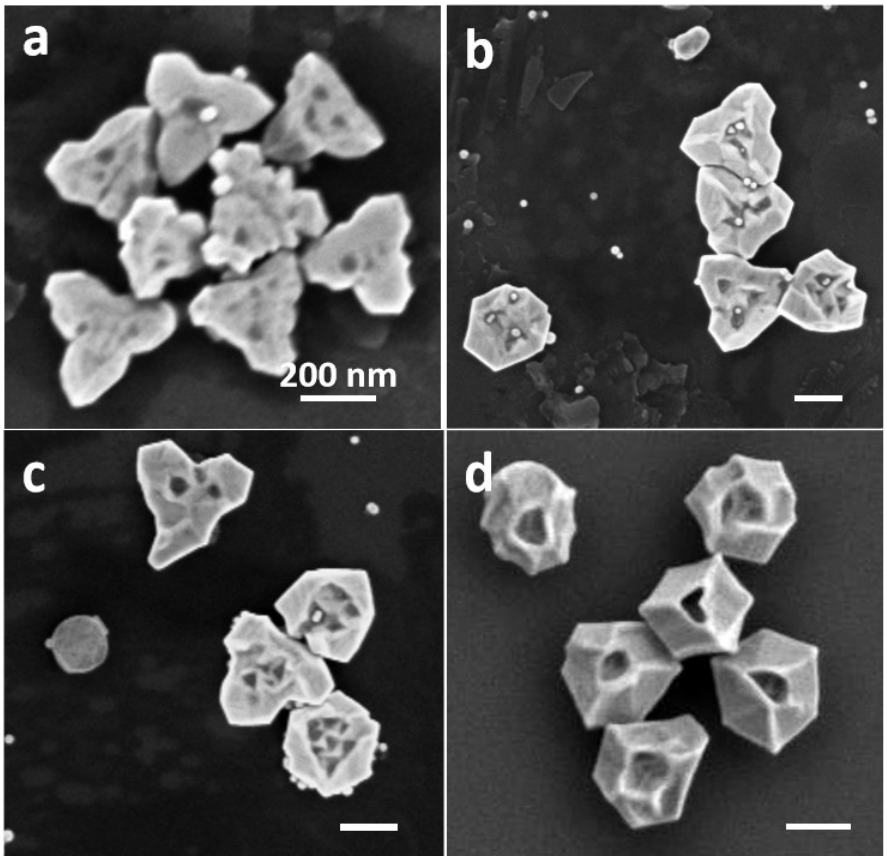


Fig. S6 SEM images of nanostructures/nano-bowls obtained at (a) 1 min, (b) 5 min, (c) 10 min, and (d) 30 min reaction time in static solutions.

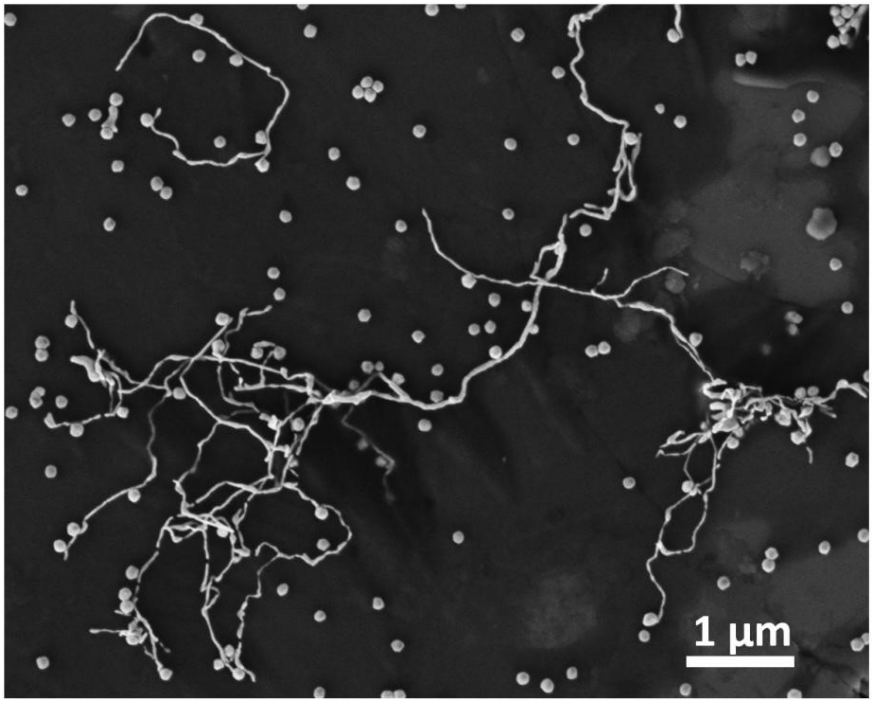


Fig. S7 SEM image of the shear-induced Au nanowires with the 60 nm Au nanoparticles as the seeds.

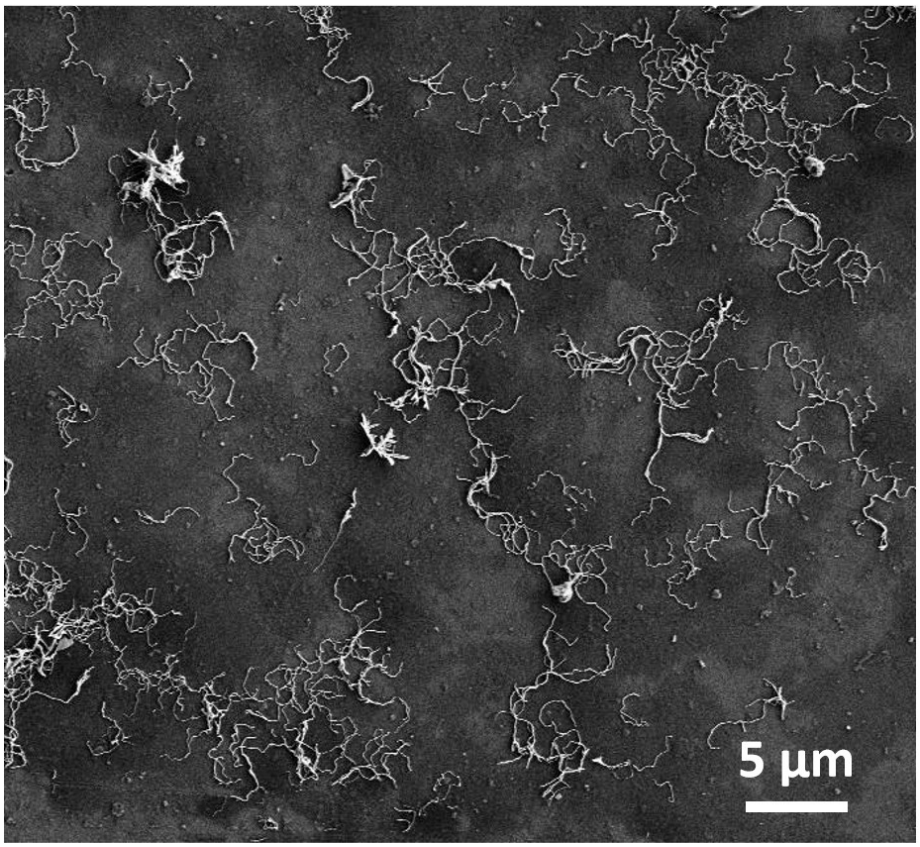


Fig. S8 SEM image of the shear-induced Au nanowires obtained without any seeds.

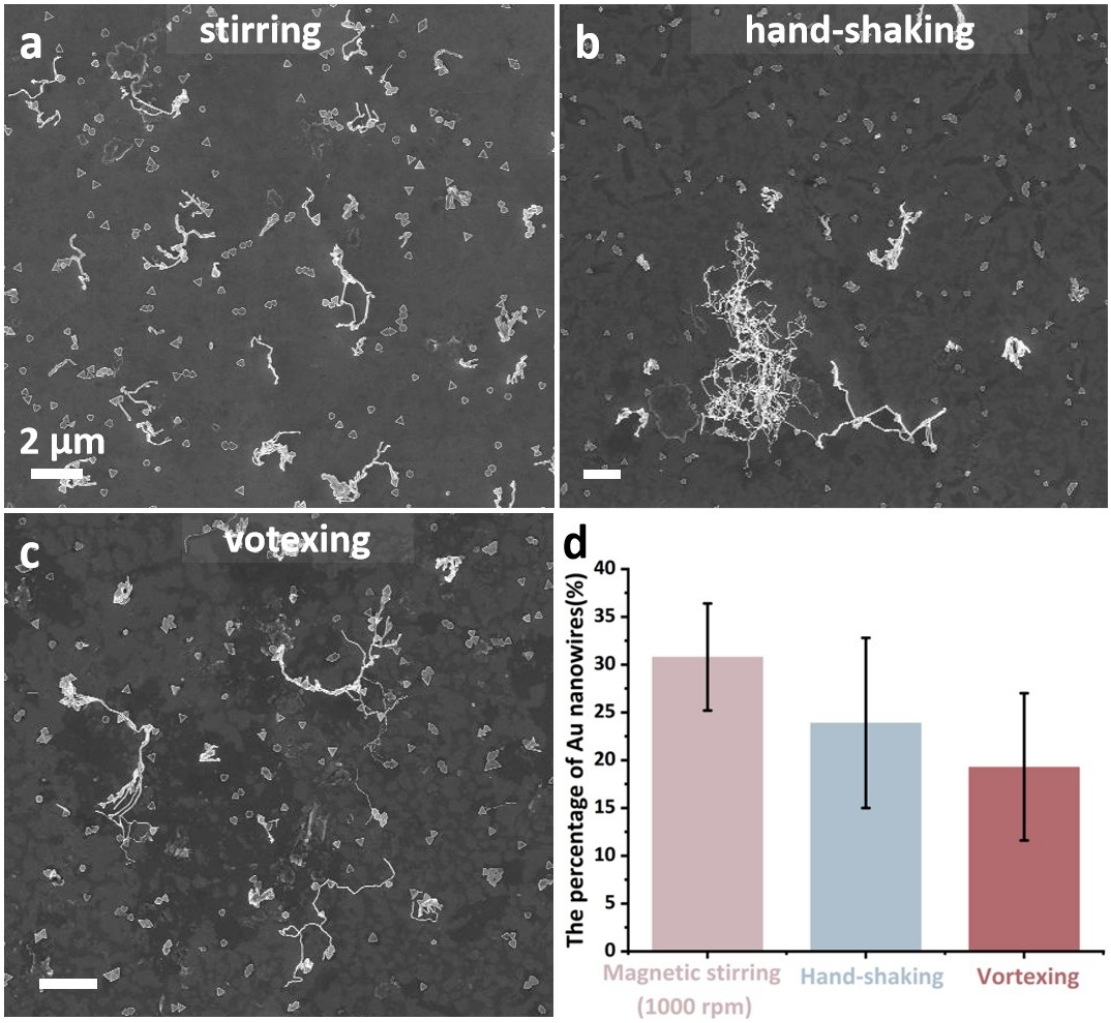


Fig. S9 SEM images of the shear-induced Au nanowires with the shear-force applied via (a) magnetic stirring (1000 rpm), (b) hand-shaking, and (c) vortexing. (d) The histogram of the percentage of Au nanowires among all nanostructures in (a), (b) and (c).

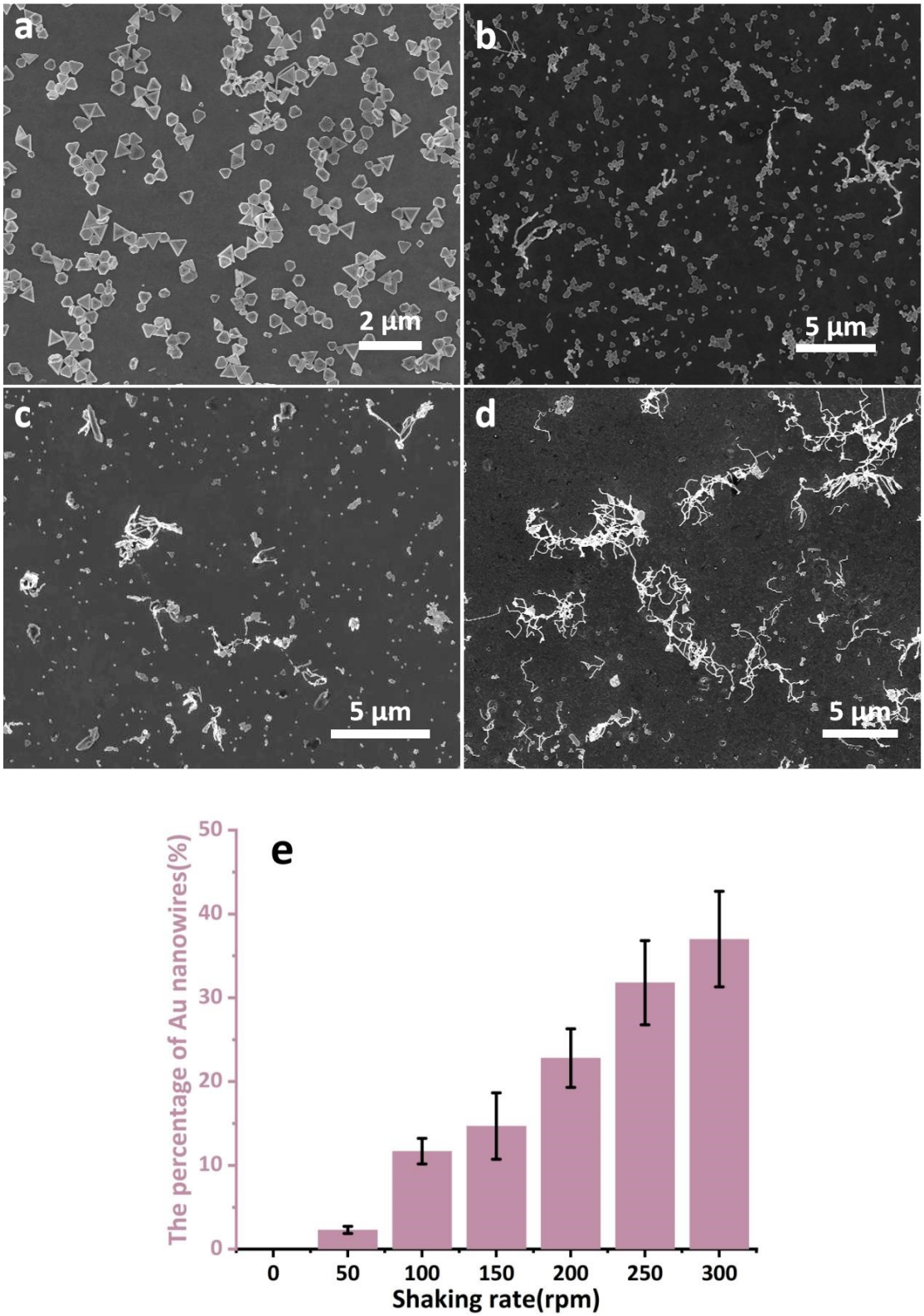


Fig. S10 SEM images of the shear-induced Au nanowires obtained with (a) 50 rpm; (b) 100 rpm; (c) 200 rpm and (d) 300 rpm orbital shaking. (e) The histogram of the percentage of the nanowires obtained at different orbital shaking rates.

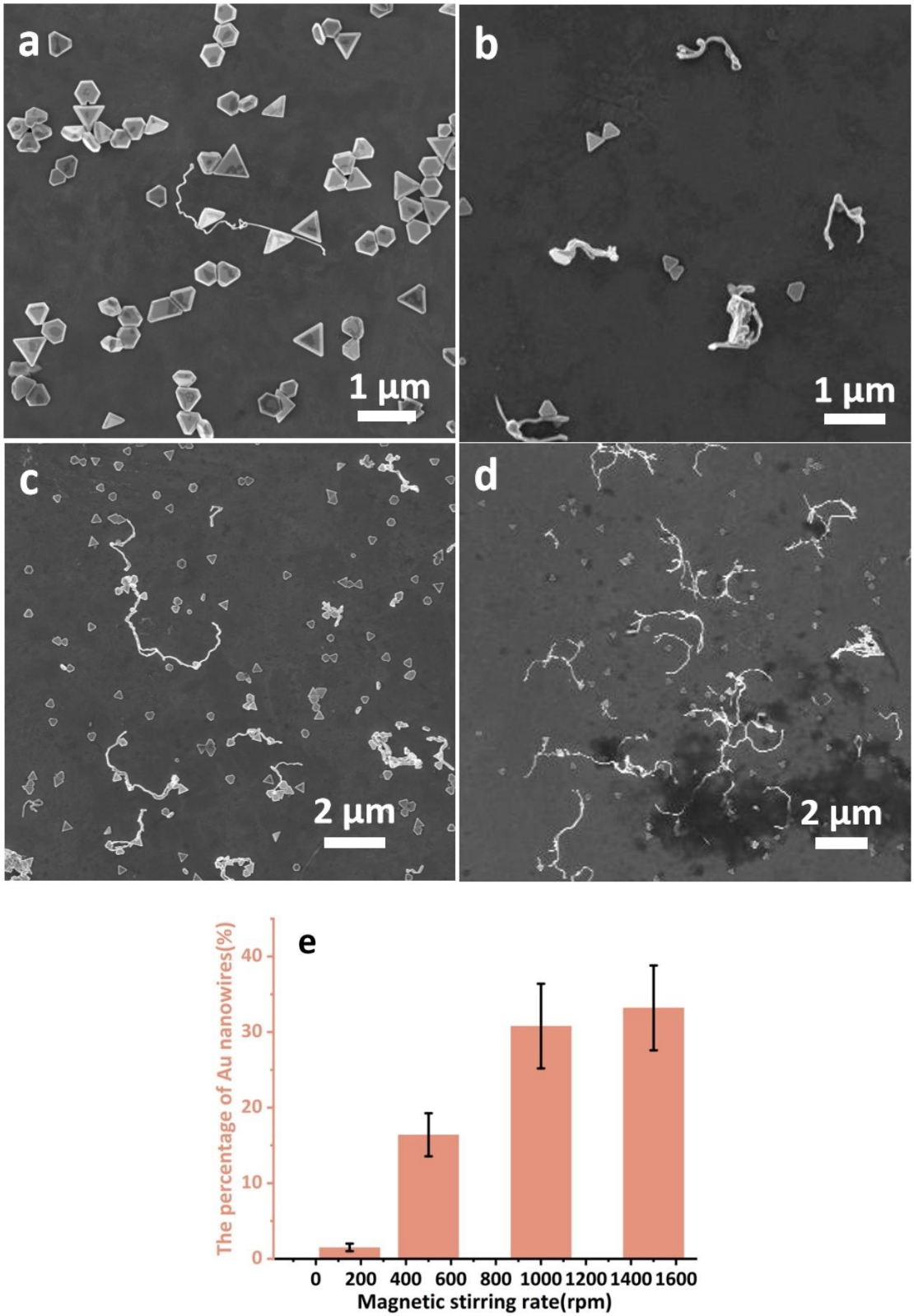


Fig. S11 SEM images of the Au nanowires obtained with (a) 150 rpm; (b) 500 rpm; (c) 1000 rpm and (d) 1500 rpm magnetic stirring. (e) The histogram of the percentage of the nanowires at various magnetic stirring rate.

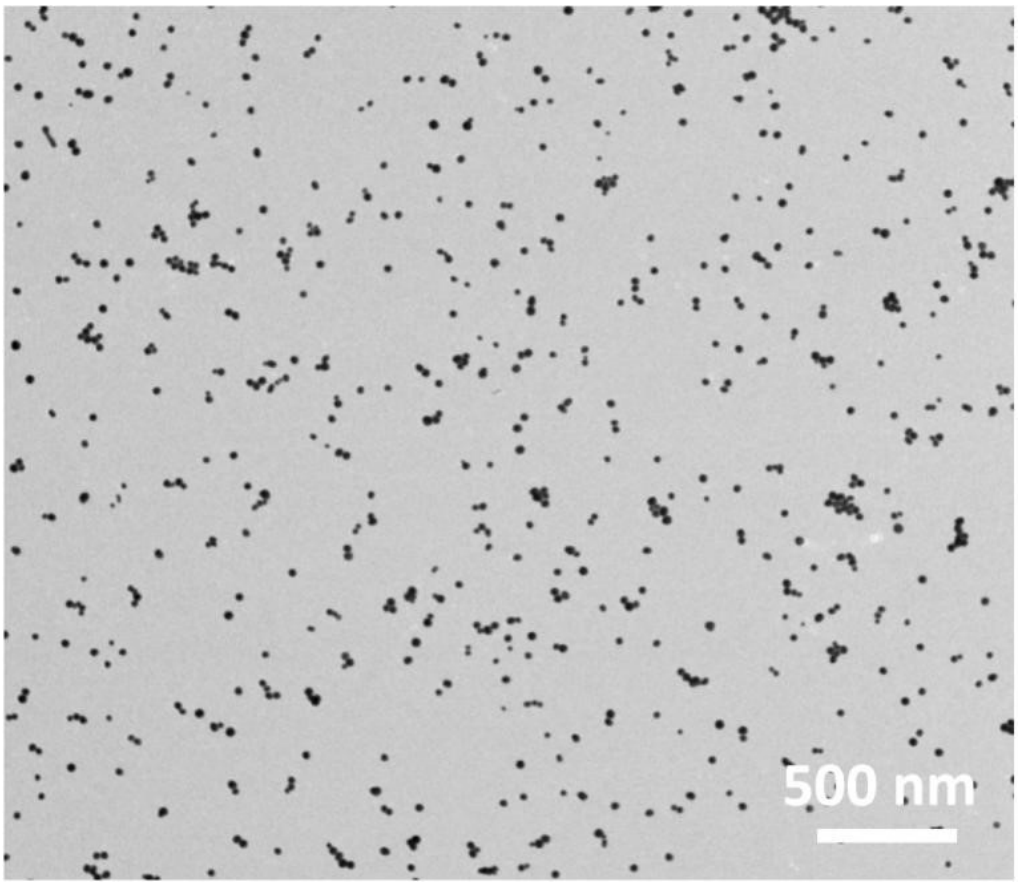


Fig. S12 TEM image of the Au nanoparticles formed in the absence of CTAB, with all other conditions unchanged.

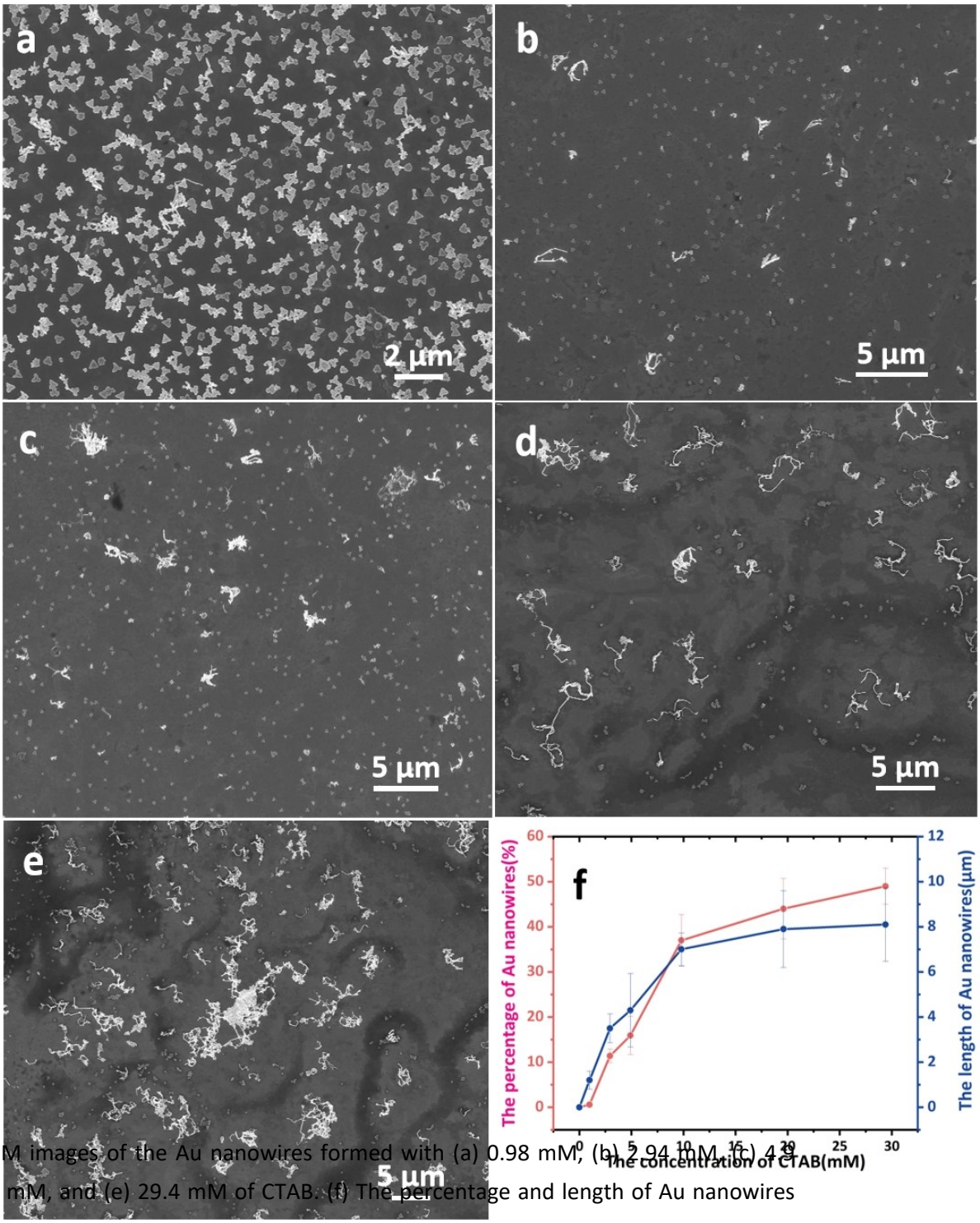


Fig. S13 SEM images of the Au nanowires formed with (a) 0.98 mM, (b) 2.94 mM, (c) 4.9 mM, (d) 9.8 mM, and (e) 29.4 mM of CTAB. (f) The percentage and length of Au nanowires against the CTAB concentrations.

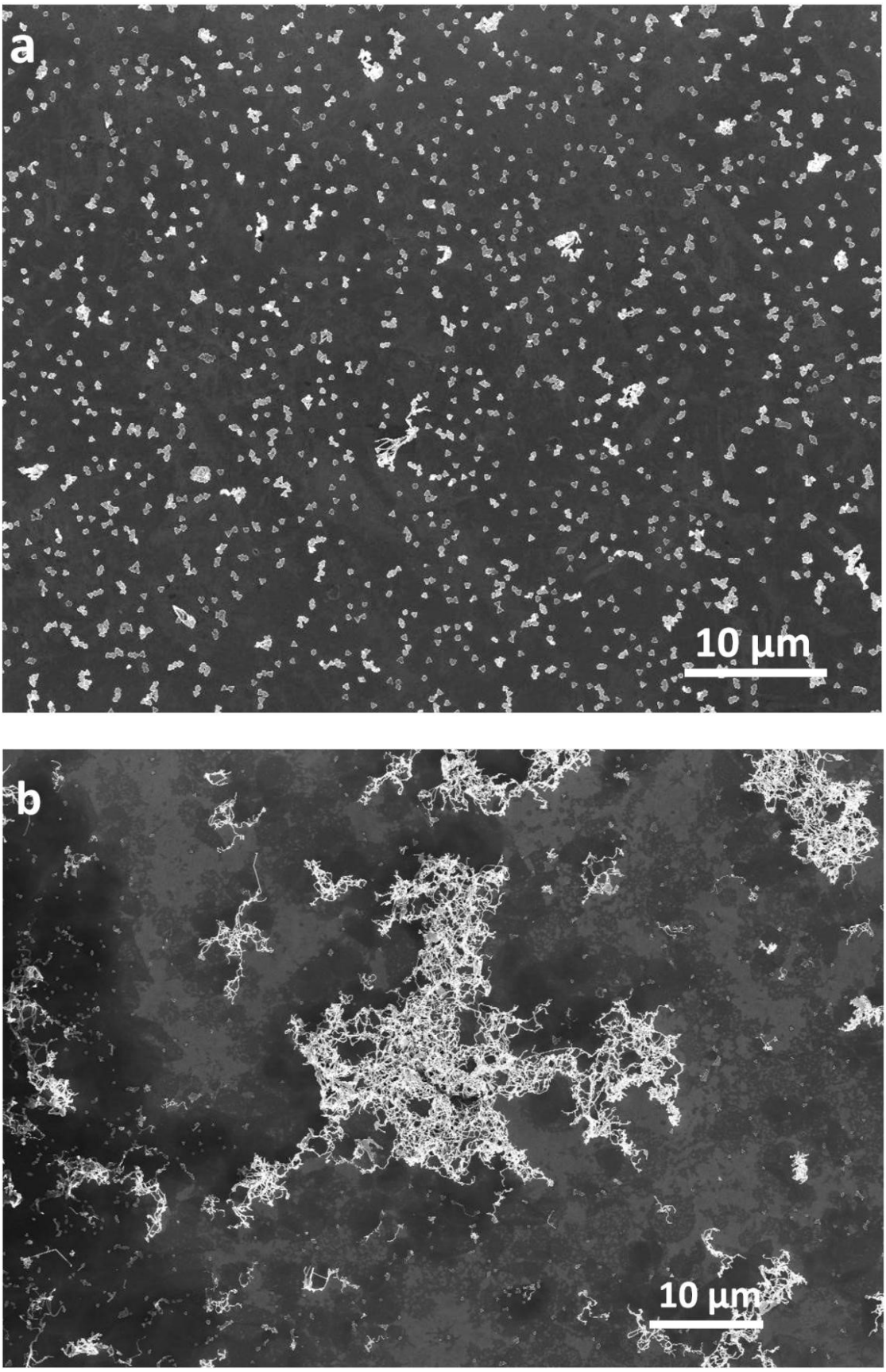


Fig. S14 SEM images of the shear-induced Au nanowires obtained by replacing the C_{16}TAB with (a) C_{14}TAB and (b) C_{18}TAB as the ligand.

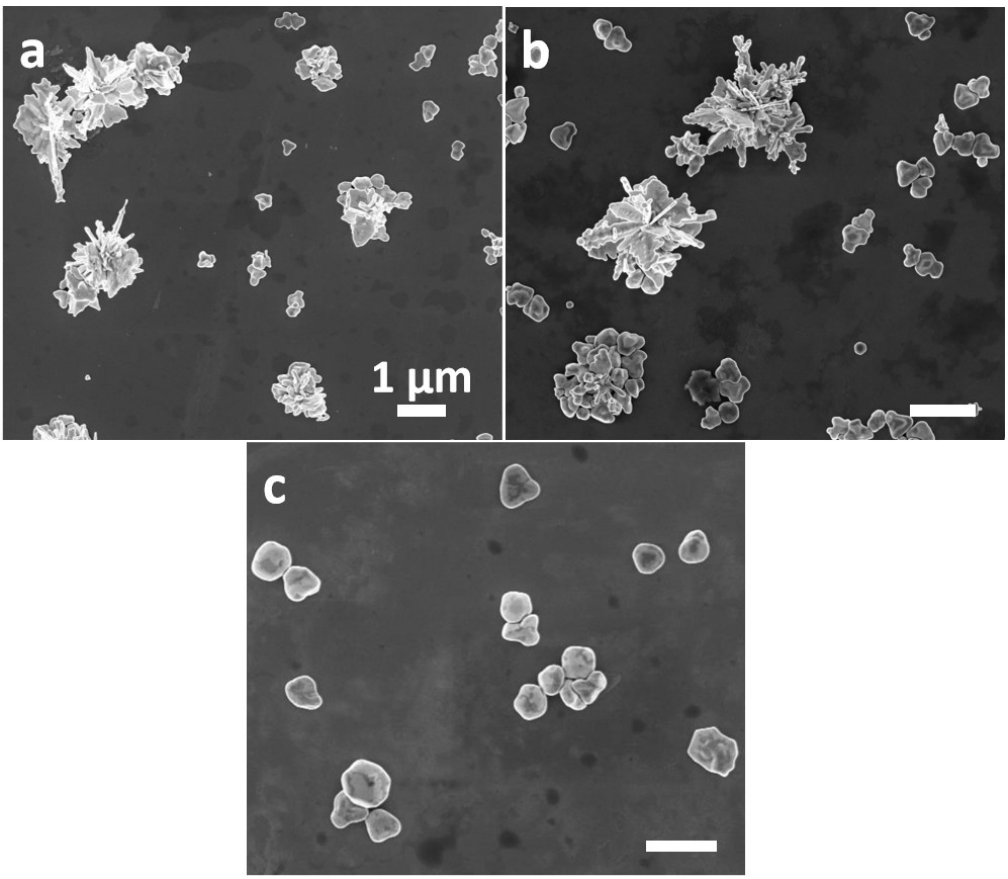


Fig. S15 SEM images of the irregular Au nanostructures obtained by replacing the C_{16}TAB with (a) C_3TAB, (b) C_6TAB and (c) C_{12}TAB as the ligand.

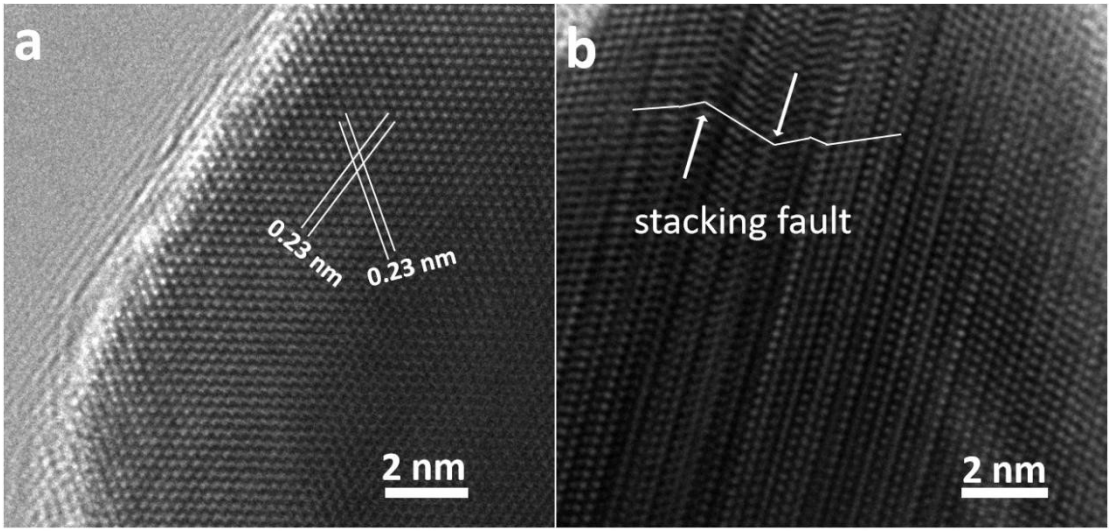


Fig. S16 HRTEM images showing the lattice structure of (a) the ridge and (b) the tail segments of the nano-badges.

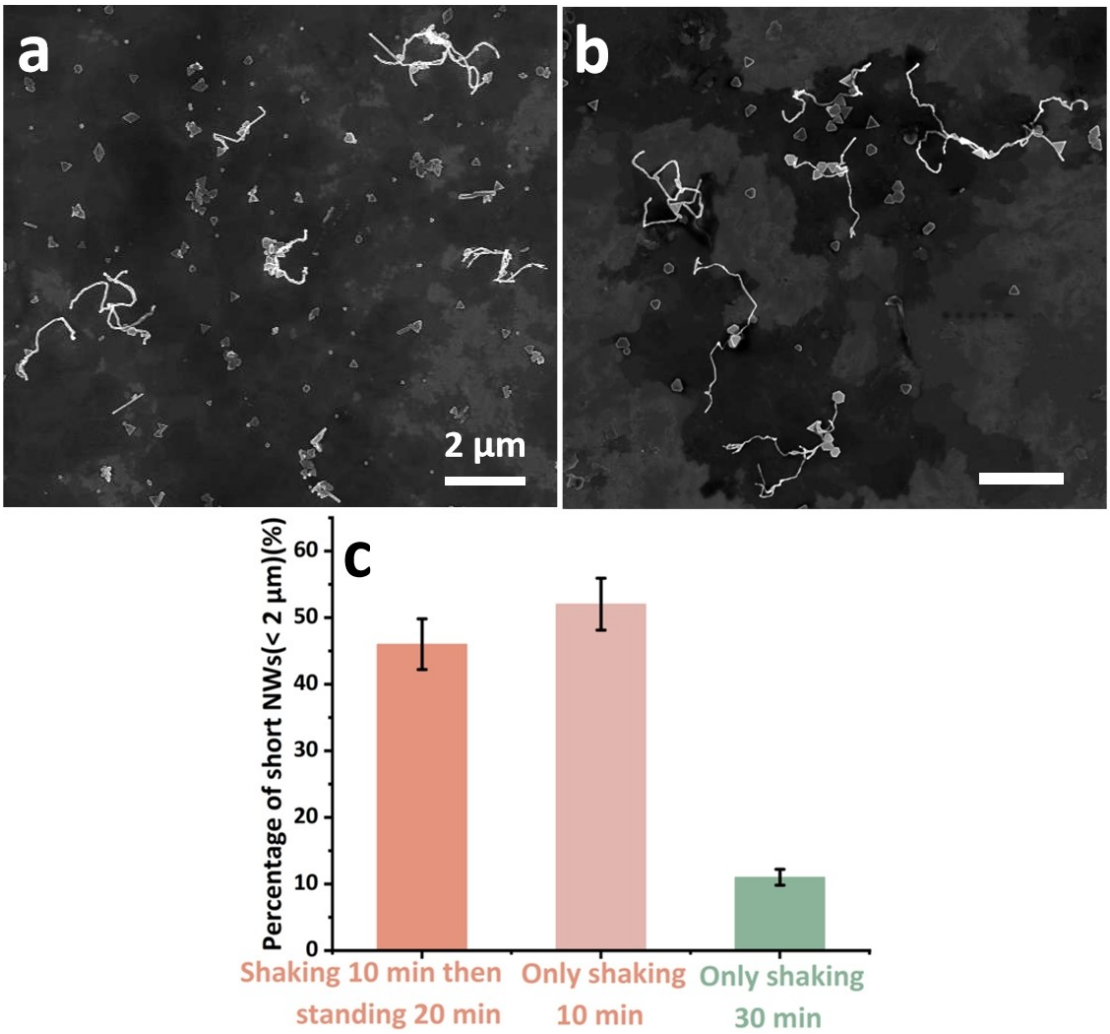


Fig. S17 SEM images of the Au nanowires when the reaction mixture was (a) firstly shaken for 10 min and then subjected to un-disturbed incubation at 60 °C for 20 min; and (b) shaken for 10 min. (c) The histogram comparing the percentage of short Au nanowires (< 2 µm) in condition (a) and (b) with the typical case (30 min orbital shaking).

If the reaction mixture was firstly shaken for 10 min and then subjected to un-disturbed incubation at 60 °C for 20 min, the short nanowires (< 2 µm) percentage was 46%, almost the same as the reaction trapped after 10 min shaking (Fig. S17b) This indicates that shaking is essential for maintaining the linear elongation of the nanowires.

Notes and references

1 Y. Huang, A. R. Ferhan, Y. Gao, A. Dandapat and D.-H. Kim, High-yield synthesis of triangular gold nanoplates with improved shape uniformity, tunable edge length and thickness, *Nanoscale*, 2014, **6**, 6496-6500.

2 A. Sánchez-Iglesias, N. Winckelmans, T. Altantzis, S. Bals, M. Grzelczak and L. M. Liz-Marzán, High-Yield Seeded Growth of Monodisperse Pentatwinned Gold Nanoparticles through Thermally Induced Seed Twinning, *J. Am. Chem. Soc.*, 2016, **139**, 107-110.