

Supporting Information for

Controllable Synthesis of Multi-Layered Gold Spirangles

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Experimental Section

Polyethylene (100) stearyl ether ($(C_2H_4O)_{100}C_{18}H_{37}OH$, Brij 700, Sigma–Aldrich), hydrogen tetrachloroaurate trihydrate ($HAuCl_4 \cdot 3H_2O$, 99.9%, Sigma–Aldrich), and sodium hydroxide (NaOH, 98.0%, Sigma–Aldrich) were used as received. All stock solutions were freshly prepared before each reaction. Prior to use, all glassware was washed with Aqua Regia (3:1 ratio by volume of HCl and HNO_3 ; *Caution: Aqua Regia is highly toxic and corrosive and must be handled in fume hoods with proper personal protection equipment*) and rinsed thoroughly with nanopure water. In a typical experiment, Multy-layered gold spirangles were synthesized through the reduction of Au(III) ions ($HAuCl_4$) using Brij700 and NaOH in aqueous solution. Aqueous Brij700 (1 mL; 5 wt%) was well mixed with NaOH (aq) (100 μ L; 10 mM) by shaking for 30 seconds. After mixing, $HAuCl_4$ (aq) (100 μ L; 10 mM) was added, and the reaction mixture was shaken vigorously for more than 1 minute. The pale yellow reaction mixture was then placed in a 50 °C water bath for 6 hours. The mixture was then purified by centrifugation (2 min, at 2300 g), and redispersed three times in nanopure water, and imaged. For temperature-dependent synthesis of gold crystals, the temperature of water bath was controlled to 25 °C (single-layered gold plates) and 90 °C (gold rings), and reaction mixture (Brij700 (1 mL; 5 wt%) + NaOH (aq) (100 μ L; 10 mM) + $HAuCl_4$ (aq) (100 μ L; 10 mM)) was placed for 6 hours. The resulting nanocrystals were imaged using a FEI 400F scanning electron microscope (SEM), and JEOL JEM-2010 Luminography (Fuji FDL-5000) Ultramicrotome (CRX) transmission electron microscope (TEM). TEM samples were prepared by concentrating the nanocrystal mixture using centrifugation (centrifuged twice for 1 min at 8000 rpm and resuspending pellets in 100 μ L of nanopure water) and immobilizing 10 μ L of the solution on a Formvar-coated Cu grid.

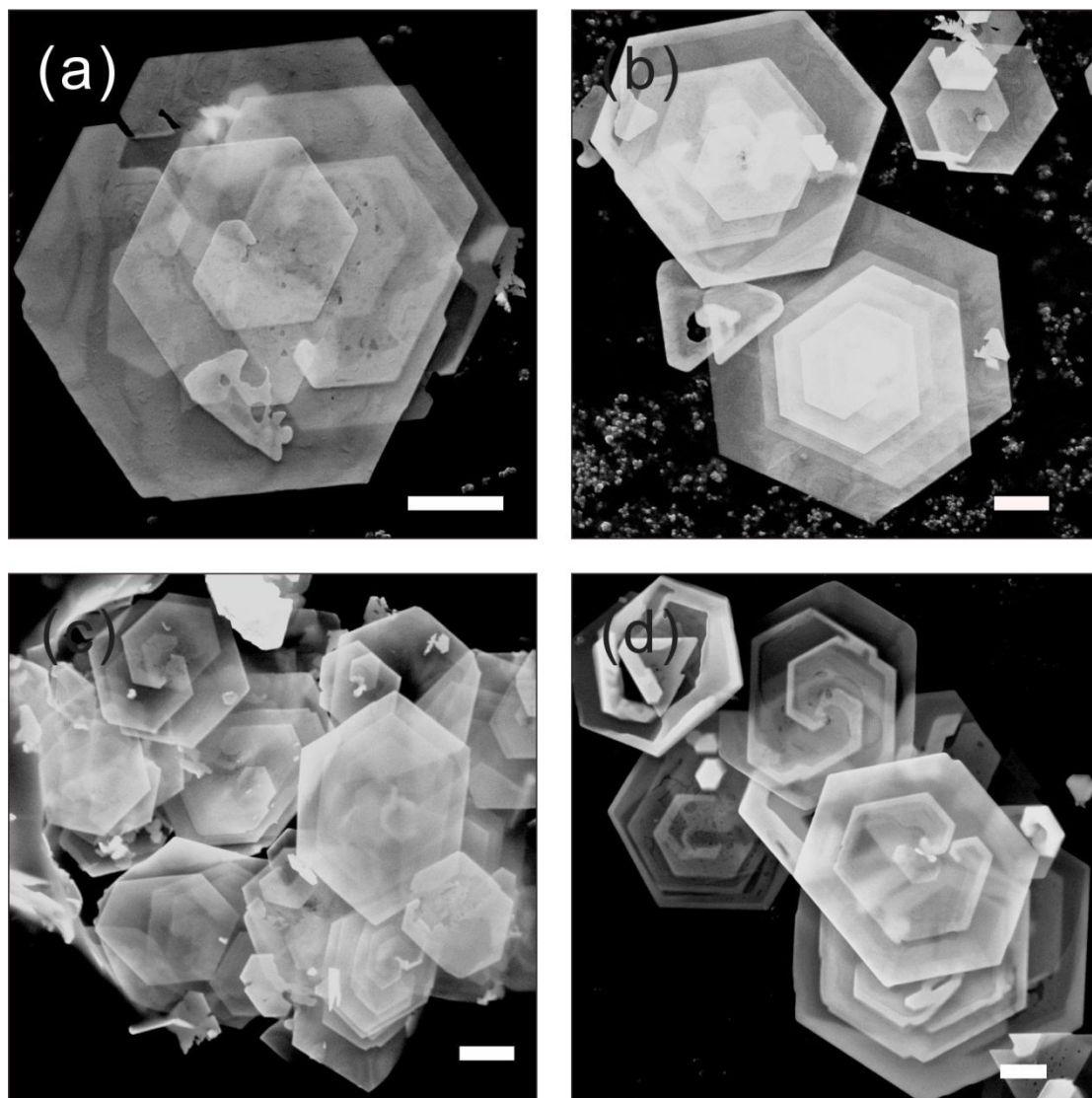


Figure S1. Scanning electron microscopy (SEM) images of gold spirangles synthesized from a mixture of 1 mL of Brij 700 aqueous solution (5 wt%), 0.1 mL of 10 mM NaOH (aq), and 0.1 mL of 10 mM HAuCl₄ (aq) after 6 h heating at 50 °C. Scale bars represent: 1 μm in (a), (b), and (d), and 2 μm in (c).

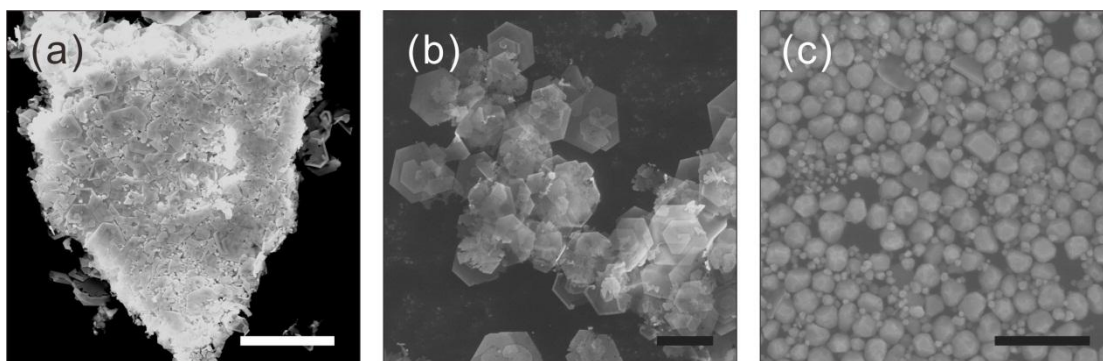


Figure S2. Scanning electron microscopy (SEM) Images of gold crystals synthesized after 6 h heating at 50 °C from a mixture of 0.1 mL of 10 mM HAuCl₄ (aq), 0.1 mL of 10 mM NaOH (aq), and 1 mL of (a) 2 wt%; (b) 5 wt%; (c) 10 wt% Brij 700 aqueous solution. Scale bars represent: 10 μm in (a), 5 μm in (b), and 1 μm in (c).

Temperature	NaOH	Brij	Main Shape of Gold Particle
90 °C	0.1 mL	10 wt%	Pseudo spherical particle
		5 wt%	Ring
		2 wt%	Ring and Plate
50 °C	0.1 mL	10 wt%	Pseudo spherical particle
		5 wt%	Spirange
		2 wt%	Spirange and Plate

Table S1. The summary of synthesized gold particle structures through the change of brij concentration (after 6 h heating at each temperature from a mixture of 0.1 mL of 10 mM HAuCl₄ (aq), 0.1 mL of 10 mM NaOH (aq), and 1 mL of each concentration of Brij 700 aqueous solution. cf. plate: single-layered plate)

Temperature	Brij	NaOH	Main Shapes of Gold Particle
90 °C	5 wt%	0.2 mL	Sickle
		0.1 mL	Ring
		0.05 mL	Ring, Plate, and pseudo spherical particle
		0.02 mL	Ring, Plate, and pseudo spherical particle
		0	Pseudo spherical particle
50 °C	5 wt%	0.2 mL	Sickle
		0.1 mL	Spirangle
		0.05 mL	Spirangles and Plate
		0.02 mL	Plates and Pseudo spherical particle
		0	Plates and Pseudo spherical particle
25 °C	5 wt%	0.1 mL	Plate

Table S2. The summary of gold particle structures through the change of temperature and the amount of NaOH. (synthesized from a mixture of 1 mL of Brij 700 aqueous solution (5 wt%), each amount of 10 mM NaOH (aq), and 0.1 mL of 10 mM HAuCl₄ (aq) after 6 h heating at each temperature, cf. plate: single-layered plate)