Electronic Supplementary Information

A Plasmonic Nano-antenna With Controllable Resonance Frequency: $Cu_{1.94}S$-ZnS Dimeric Nanoheterostructure Synthesized in Solution

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1. Detailed calculation of *R* and *L* values

To figure out the value of *R* and *L*, following constants for $Cu_{1.94}S$ is obtained from references [1-3]

$$\upsilon_h = 1.06\times10^{15}s^{-1},\ m_h = 0.8m_0 = 7.2\times10^{-31}kg$$
$$h = 1.6\times10^{-19}C,\ N_h = 1.0\times10^{27}m^{-3}$$

Considering that the $Cu_{1.94}S$ nanospheres have mean diameter of δ～18 nm, the values of *R* and *L* can be figured out as following:

$$R = \frac{m_h v_h}{h^2 \delta N_h} = 1.46k\Omega$$

$$L = \frac{m_h}{h^2 \delta N_h} = 1.56pH$$

2. Detailed deviation of equation (5) in the main text

Light absorbance measurements are carried out by detecting the intensity of light that transmits through the colloid solution containing the $Cu_{1.94}S$-ZnS nanoheterostructure, as demonstrated in Figure S1. The absorption coefficient *A* is determined by the following equation:

$$\frac{I}{I_0} = exp(-A)$$

where I_0 and *I* represent intensity of the incident and transmitted light respectively. Following Lambert's law, the absorption coefficient *A* could be described as:

$$A = \alpha nd$$

where α is the extinction cross-section of an individual nanoparticle, *n* the concentration of nanoparticles, *d* the transmission distance. In present work, α is the sum of scattering cross-section (s_0) and absorption cross-section (h_0) of an individual nano-antenna, i.e., $\alpha = s_0 + h_0$. Since the concentration of colloid is low and the interactions between nanoparticles are therefore week, h_0 could be regarded proportional to the frequency dependent response *H* of the nano-antenna, i.e., $h_0 \propto H(\lambda)$, while s_0 is a constant. Hence, the absorption coefficient A is wavelength λ dependent, and Equation (6) is converted to:

$$A(\lambda) = \alpha nd = s_0 nd + h_0 nd = S + NH(\lambda)$$

$$A(\lambda) = S + \frac{NR^2}{R^2 + (\frac{2\pi c_0}{\lambda} L - \frac{\lambda}{2\pi c_0 C})^2}$$

where N represents a parameter related to the amount of nano-antennas and S denotes the scattering loss of nanoheterostructure in solution.

3. Figure S1-S5

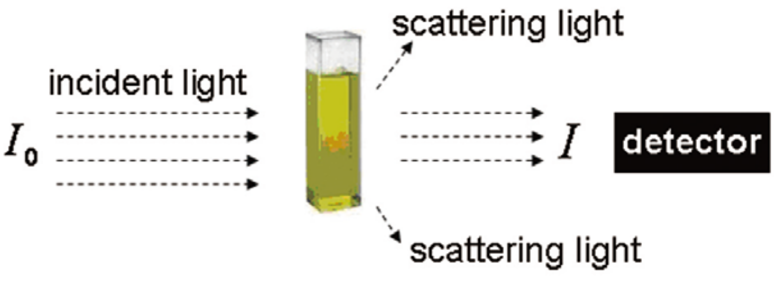

Figure S1 Schematic illustration of light absorbance measurement.

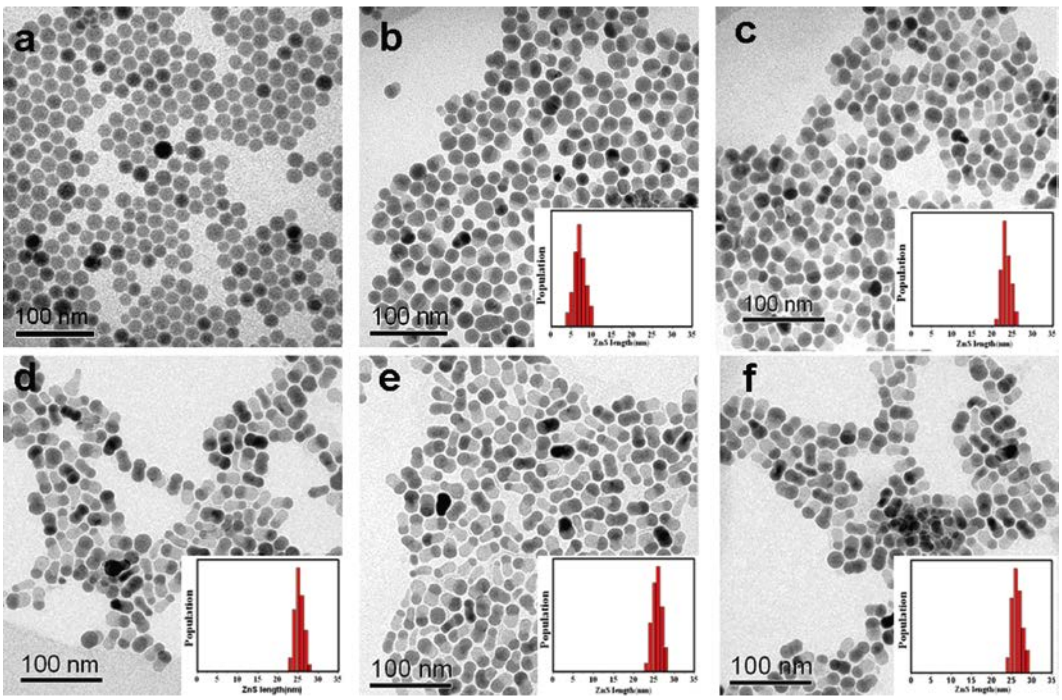

Figure S2 TEM micrographs of $Cu_{1.94}S$ nanosphere precursors (a), and $Cu_{1.94}S$-ZnS nanoheterostructures having reacted for 5 min (b), 15 min (c), 20 min (d), 25 min (e), and 30 min (f) respectively; insets are the histograms showing ZnS length distributions by measuring 100 nanoheterostructures lying horizontally.

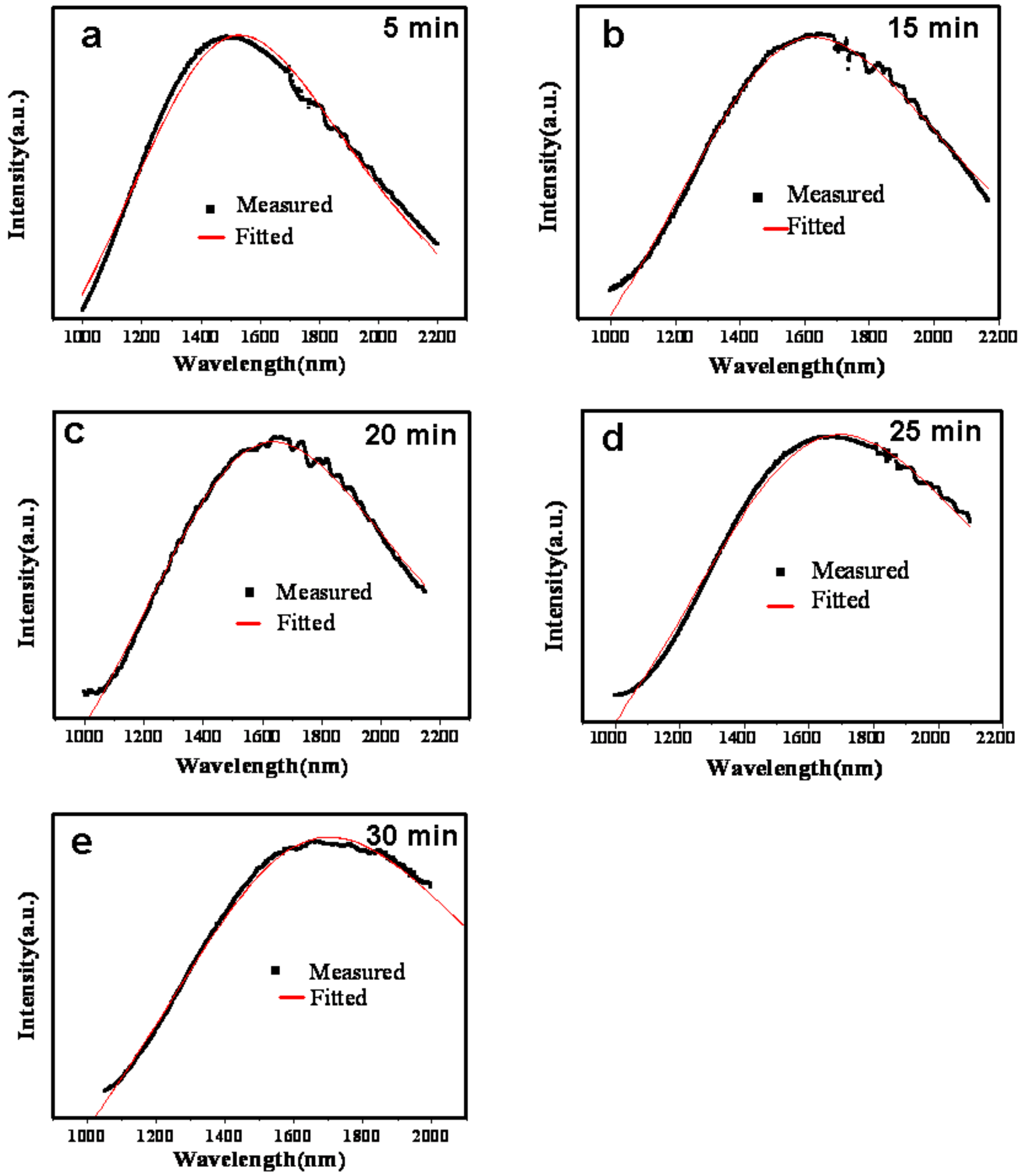

Figure S3 Measured and fitted LSPR absorption spectra of $Cu_{1.94}S$-ZnS nanoheterostructures having reacted for 5 min (a), 15 min (b), 20 min (c), 25 min (d), and 30 min (e), respectively.

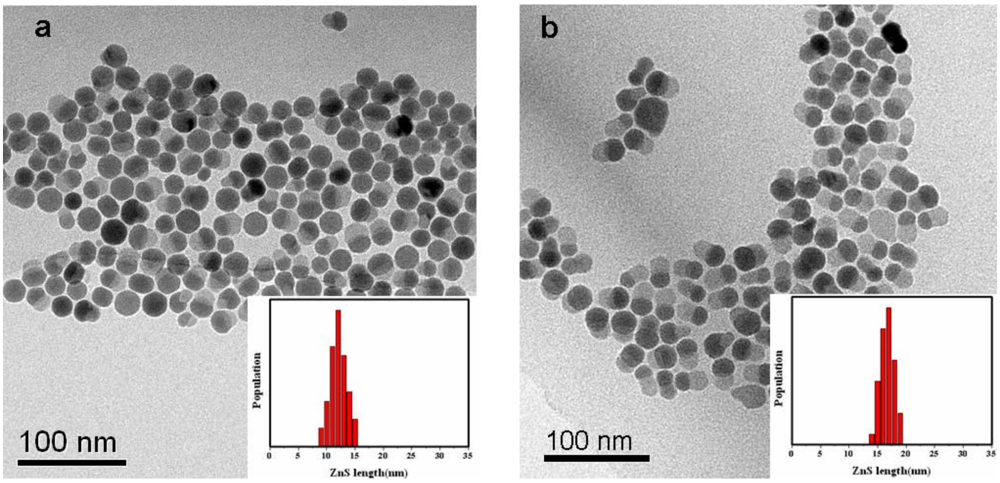

Figure S4 TEM micrographs of the $Cu_{1.94}S$-ZnS nanoheterostructures having reacted for 8 min (a), and 12 min (b) respectively; insets are the histograms showing ZnS length distributions by measuring 100 nanoheterostructures lying horizontally.

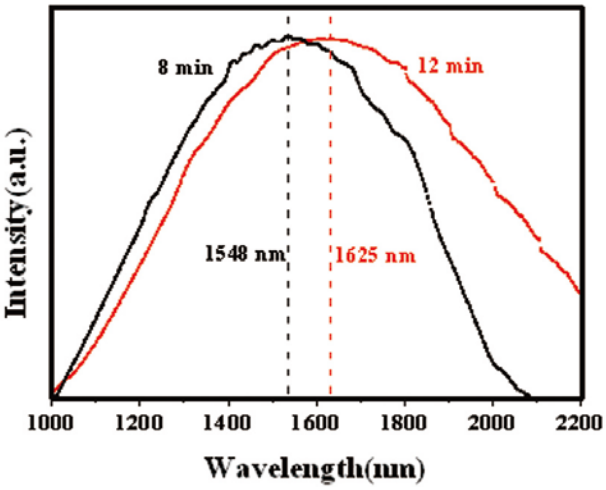

Figure S5 Absorption spectra of the $Cu_{1.94}S$-ZnS nanoheterostructures having reacted for 8 min and 12 min respectively.

References:

1. Y. B. He, A. Polity, I. O. sterreicher, D. Pfisterer, R. Gregor, B.K. Meyera, M. Hardt, *Physica B* 2001 308–310, 1069–1073

2. Y. Choi, D. Choi, L.P. Lee, *Adv. Mater.* 2010, 22, 1754–1758

3. J. M. Luther, P. K. Jain, T. Ewers, A. P. Alivisatos, *Nat. Mater.* **2011**, *11*, 361–366.