Electronic Supplementary Material (ESI) for Nanoscale.

Supporting Information

We confirmed the experimental results of Joule heated metal nanowire by finite element method (FEM) calculation with COMSOL Multiphysics 4.2a. The material properties used in the calculation were from the library available in the simulation software except for the thermal conductivity of ZnO nanowire, which was from the literature[1], because the thermal conductivity of ZnO nanowire is significantly different from that of bulk ZnO. We simulated the nanowire heater with the same dimensions of the fabricated device such as length, width and thickness of nanowire (4 um, 100 nm and 10 nm (Cr) and 60 nm (Au), respectively), thickness of SiO_2 (330 nm) and thickness of Si_3N_4 (300 nm). Joule heating, thermal conductive heat transfer and fluidic heat transfer models were utilized for the simulation of Joule heating of nanowire, heat dissipation through SiO_2, Si substrate, silicon nitride and ZnO, and heat dissipation through air or water. Also we compared temperature distribution around nanowire heater before and after the growth of ZnO nanostructures. Since the accurate model for ZnO nanostructure was too complicated for computation, we simplified the ZnO nanostructure as a rectangular parallelepiped of ZnO to observe the effect of heat conduction through the ZnO nanostructure surrounding the nanowire heater. The ZnO parallelepipeds of 0.6 μm x 1.2 μm x 3 μm and 0.8 μm x 1.6 μm x 3 μm (height x width x length) were used for the modeling of ZnO nanowire bundles with lengths of 0.6 μm and 0.8 μm.

Figure S1 shows the simulation results of the nanowire heating in air and water environments. As expected, temperature in the water environment is lower than that in the air due to higher thermal conductivity of water than that of air. The simulation result shows that the temperature on the top of silicon nitride surface is over 90 ˚C, which is the synthesis temperature for ZnO nanowires. The isothermal line has an elliptical shape which is similar to the ZnO nanostructure grown on the nanowire heater. The temperature after the synthesis of the ZnO nanostructure is lower than that before the synthesis. Also, the temperature further decreases as the synthesized ZnO nanostructures become longer as shown in Figures S1 (c) and (d). After the nanostructure synthesis, the surface area is increased and thermal conductivity of the surrounding environment is also increased due to higher thermal conductivity of the ZnO than that of water. Therefore, more heat can be dissipated from the nanowire heater to the environment and the temperature of the nanowire heater is decreased. The synthesis of the ZnO nanowire could be self-limited because the temperature on the ZnO nanostructure surface is decreased below the synthesis temperature when the length of ZnO nanostructures exceeds a certain threshold value.

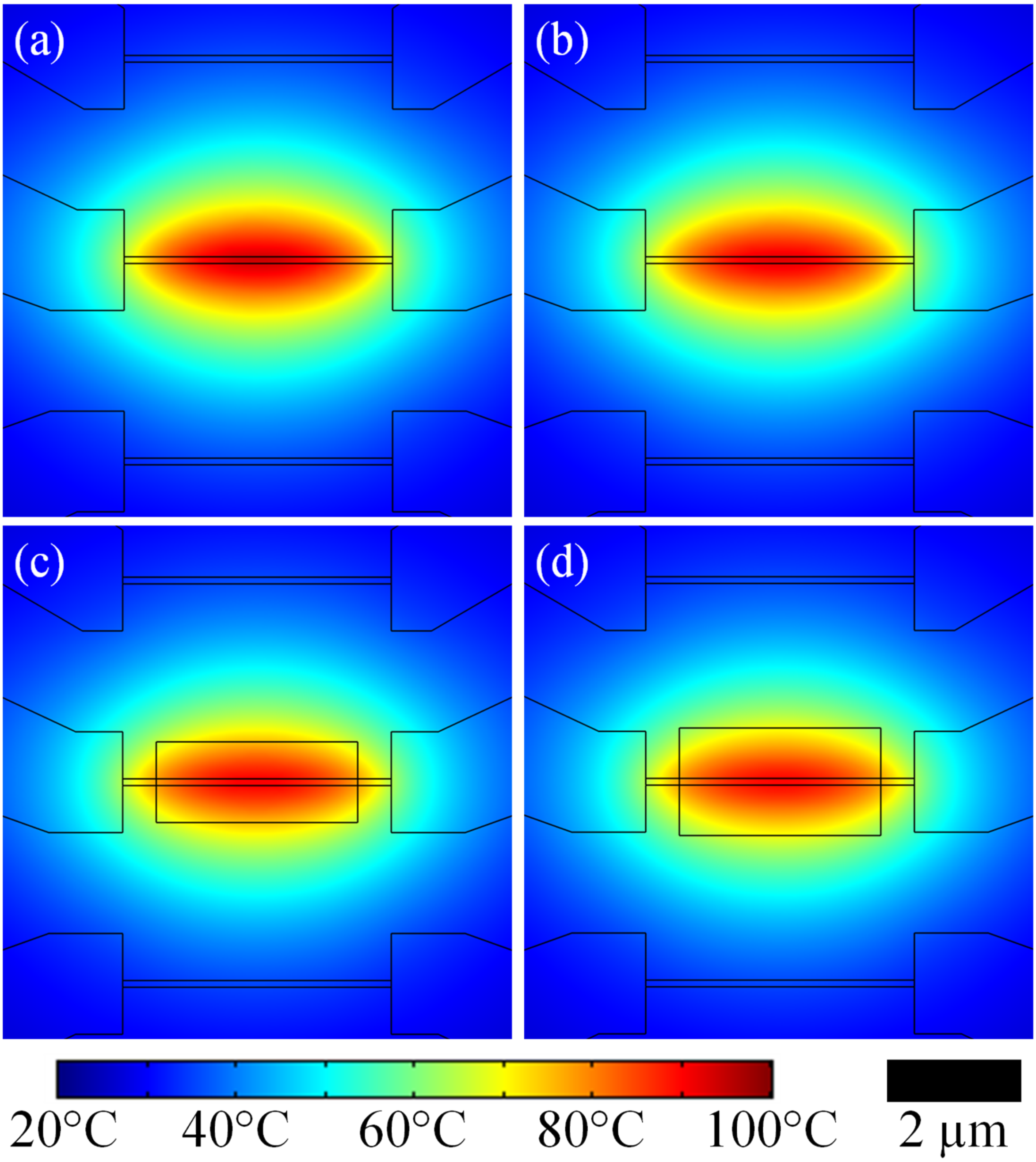

Figure S1. Simulation results of a nanowire heater array: temperature distribution on the top surface of the silicon nitride layer (a) in air environment, (b) in water environment, (c) after the synthesis of 0.6 μm long ZnO nanowires from the center and (d) after the synthesis of 0.8 μm long ZnO nanowires (in water environment).

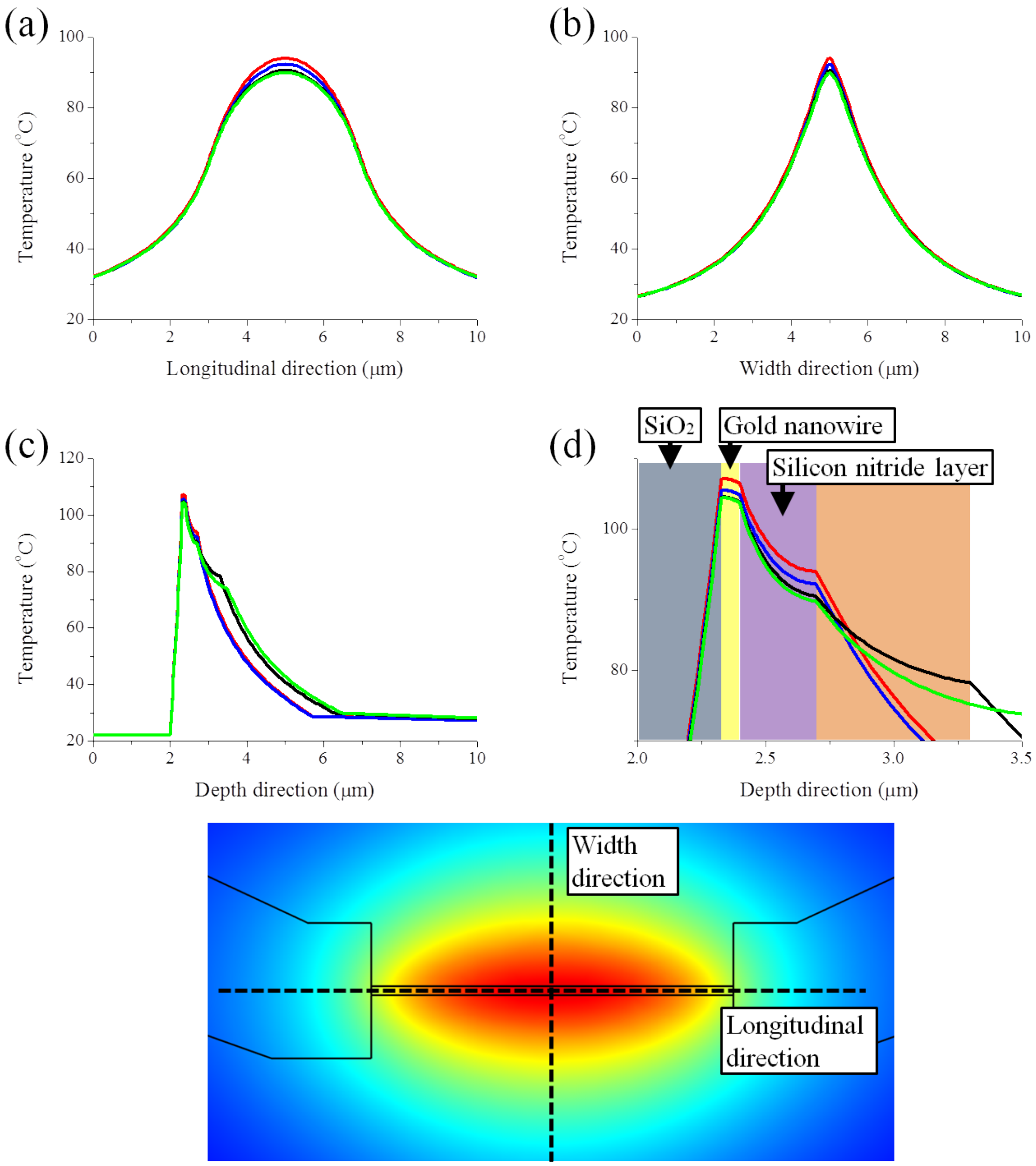

Figure S2. Temperature profile around nanowire heater by numerical simulation: (a) longitudinal direction, (b) lateral direction and (c) vertical direction through the center of nanowire heater (d: magnified view of (c)); red curve = in air, before nanowire synthesis / blue curve = in water, before nanowire synthesis / black curve= in water, 0.6 μm long ZnO nanowire / green curve= in water, 0.8 μm long ZnO nanowire

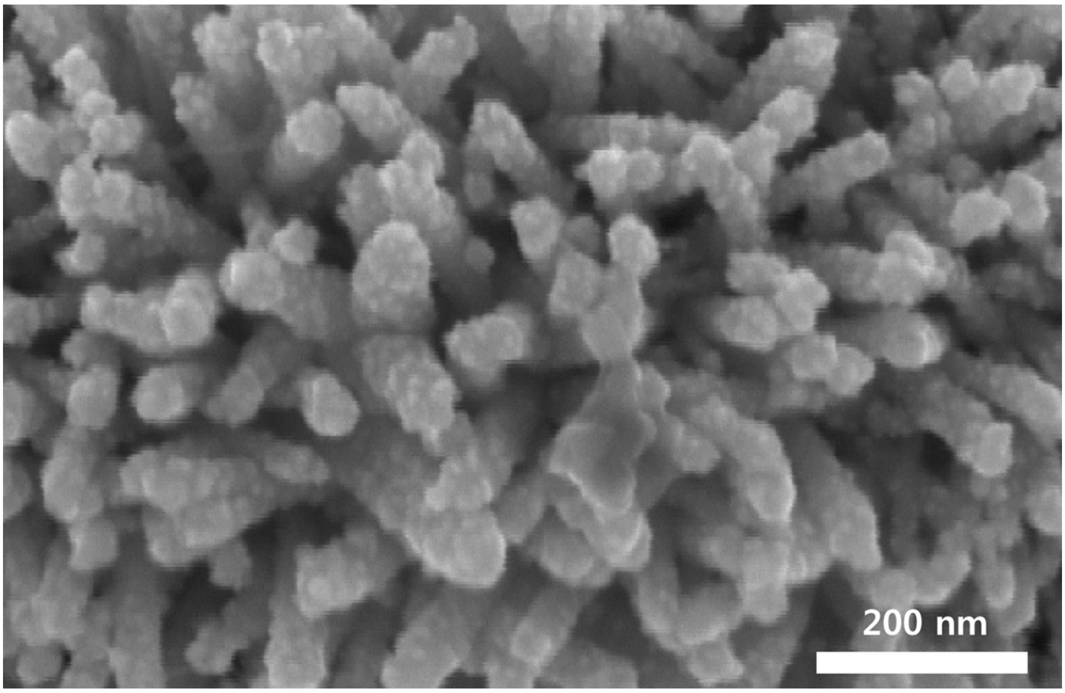

Figure S3. High resolution SEM image of ZnO nanowires decorated with Au nanoparticles by applying an electrical bias of 0.50 V for 60 sec.

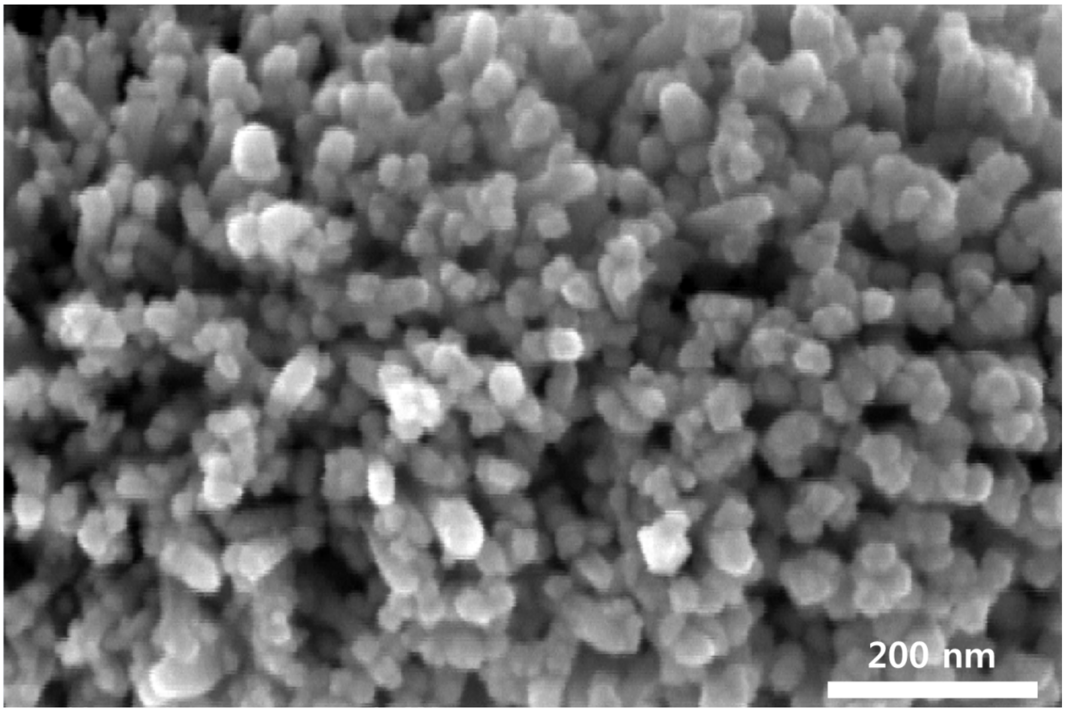

Figure S4. High resolution SEM image of ZnO nanowires decorated with Au nanoparticles by applying an electrical bias of 0.50 V for 120 sec.

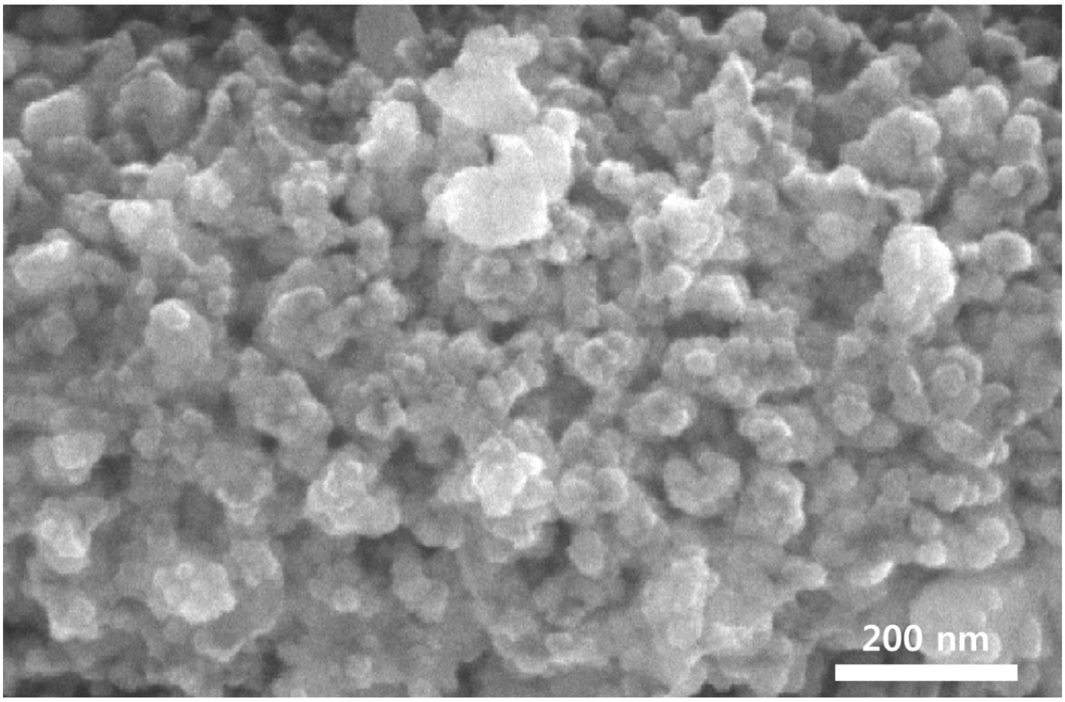

Figure S5. High resolution SEM image of ZnO nanowires decorated with Pd nanoparticles by applying an electrical bias of 0.53 V for 60 sec.

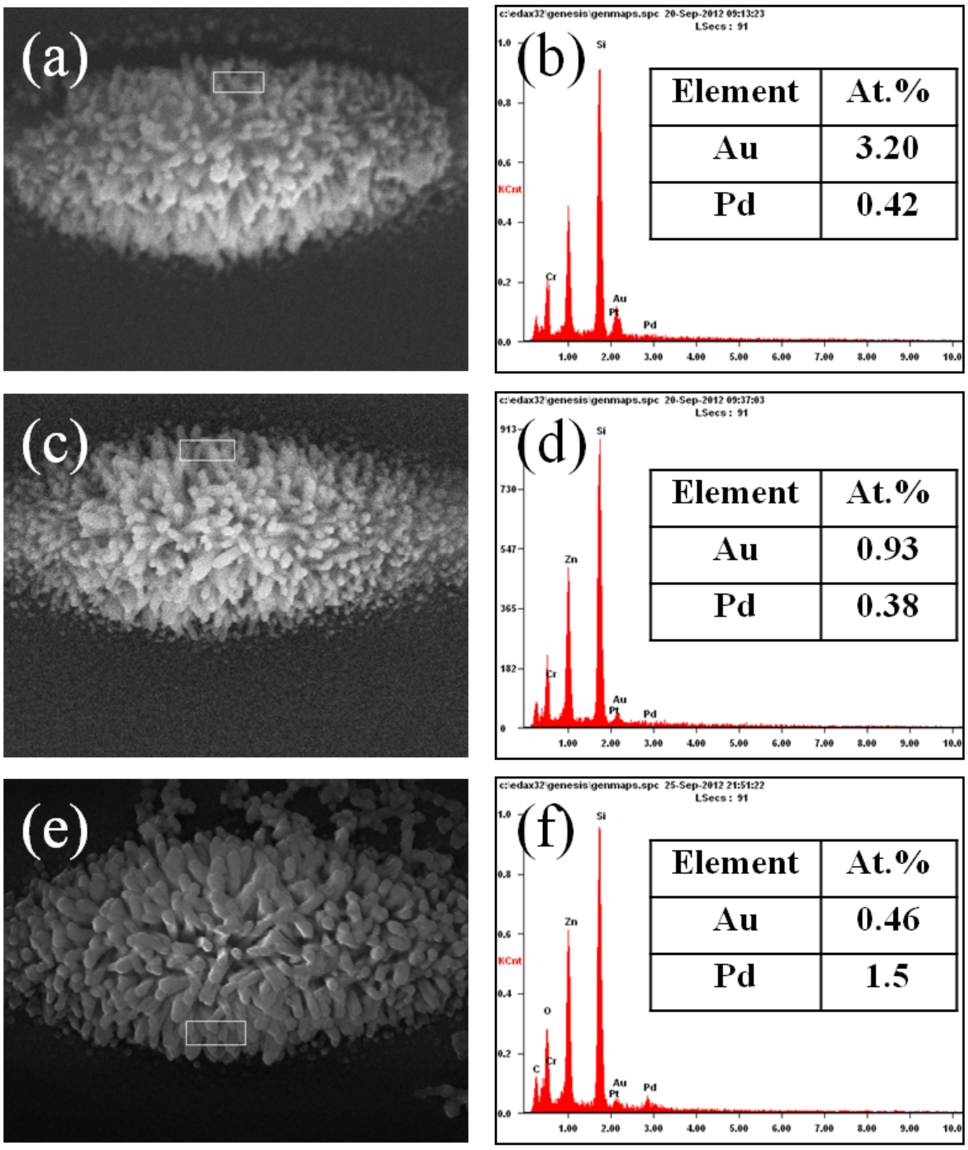

Figure S6. SEM images and EDS results of array of Au coated ZnO nanowires and Pd coated ZnO nanowires as shown in Fig. 5 (a) in main text: (a, b), (c, d) and (e, f) correspond to (ii), (iii) and (iv) in Fig. 5 (a), respectively. (a, c, e) SEM images of EDS scanning area, (b, d, f) EDS results of whole peaks with notations.

1 C. T. Bui, R. Xie, M. Zheng, Q. Zhang, C. H. Sow, B. Li, and J. T. L. Thong, *Small*, 2012, **8**, 738-745.