Supporting Information for

Single nanowire-based fluorescence lifetime thermometer for simultaneous measurement of intra- and extracellular temperature

Yuan Wang,[ab] Qiaowen Zhao,[ab] Sen Liang,[ab] Mingliang Mei, [ab] Guangwei She,[a] Wensheng Shi, *[abc] and Lixuan Mu*[a]

[a] Key Laboratory of Photochemical Conversion and Optoelectronic Materials, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing 100190, China

[b] University of Chinese Academy of Sciences, Beijing 100049, China

[c] Ganjiang Innovation Academy, Chinese Academy of Sciences, Ganzhou 341000, China

E-mail: mulixuan@mail.ipc.ac.cn; shiws@mail.ipc.ac.cn.

EXPERIMENTAL SECTION

Chemicals and solvents

Silicon wafers were purchased from Tianjin Semiconductor Institute. Rhodamine B (RhB) and hydrofluoric acid (HF) were purchased from Beijing Inoke Technology Co., Ltd. (3-Aminopropyl)triethoxysilane (APTES) were purchased from Beijing Bailingwei Technology Co., Ltd. Mitoview Blue and cytoplasmic blue dye were purchased from Beijing Runzekang Biotechnology Co., Ltd. (3-chlorophenyl)carbonohydrazonoyl dicyanide (CCCP) was purchased from Shenzhen Wenle Biotechnology Co., Ltd. Cisplatin (Beyotime) was purchased from Shanghai Biyuntian Biotechnology Co., Ltd. Gold nanorods (80 nm in length, 20 nm in diameter) were purchased from Nanjing Dongna Biotechnology Co., Ltd. All reagents are of analytical grade unless otherwise specified.

Apparatus

The SEM images were captured by scanning electron microscope (Hitachi S-4800) and the TEM images were captured by using the transmission electron microscope (JEOL-2100F). The fluorescence images and fluorescence lifetime images were captured with laser scanning confocal microscopy (Nikon A1) equipped with PicoQuant PDL 828 Sepia two.

Fabrication of silicon nanowire

The silicon nanowire array (NWA) is obtained by the Ag+-assisted chemical etching method according to the previous report[1,2]. Then the NWA was put in the tube furnace. The tube furnace was heated to 900°C slowly and maintained for 10 - 200 min in oxygen atmosphere. After the tube furnace cooled to room temperature, the NWA was removed and immersed in the solution of H_2SO_4 (98%): 30% H_2O_2 (3:1, v:v) at 90°C for 1 h. After being washed with water thoroughly, the NWA was dipped into the solution of H_2O: H_2O_2: $NH_3 \cdot H_2O$ (5:1:1, v:v:v) for 3 h. Then the NWA was washed with water repeatedly and put into the vacuum oven for 12 h. The dried NWA was reacted with N-Methylaminopropyltrimethoxysilane in the distilled toluene at 90°C for 24 h to get the amide modified NWA. The amide modified NWA was washed with ethanol and put into the vacuum oven for at least 12 h.

Modification of NWA with RhB

The 300 μmol rhodamine B (RhB) was dissolved in 60 mL anhydrous 1,2-dichloroethane and 0.5 mL $POCl_3$ was added. The mixed solution was refluxed for 3 h. When the mixed solution was cooled to room temperature, the solvent was removed completely under vacuo. The residue was dissolved into the mix solution of 20 mL distilled acetonitrile and 15 mL distilled triethylamine. After the mixing solution was stirred for 30 min, the dried amide modified NWA was put into the mixing solution. The solution was refluxed for 24 h to obtain the RhB-modified NWA. The RhB-modified silicon nanowires were obtained from the RhB-modified NWA by the scalpel.

The anti-interference of the NWFLT experiment

In order to assess the anti-interference of the NWFLT, the ions abundantly in cells, such as Na^+, K^+, Ca^{2+}, and Mg^{2+}, were added into the test solution. The concentration of above agents is 10 mM. Bovine serum albumin (BSA) was used to simulate the intracellular proteins. The concentration of BSA is 600 μg/mL. After adding the interfence agents, the FL of the NWFLT was tested by the FLIM at 20°C.

The calculation of the fluorescence lifetime

According to the previous report[3,4], the average fluorescence lifetime is defined as follows：

$$\tau_{ave} = f_1\tau_1 + f_2\tau_2 \quad (1)$$

Where the f is the frictional contribution to the fluorescence lifetime.

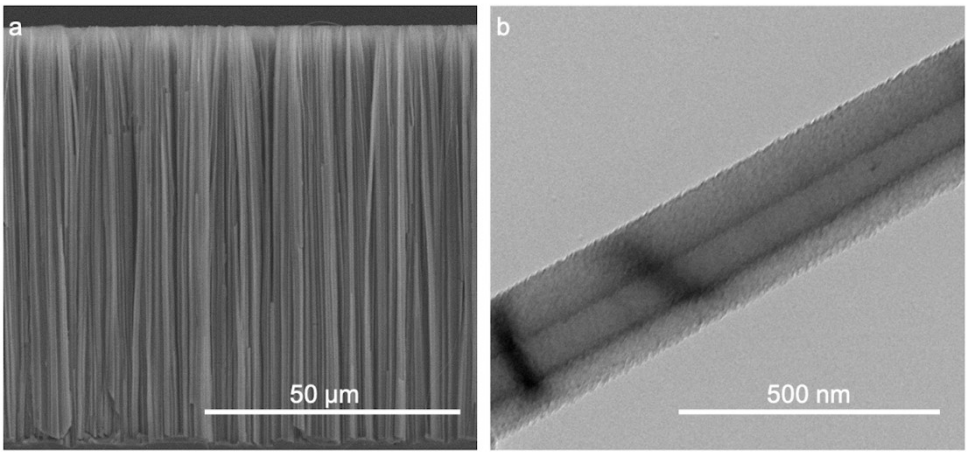

Fig. S1 a) SEM image of the nanowire array cross-section; b) the TEM image of the SiNW.

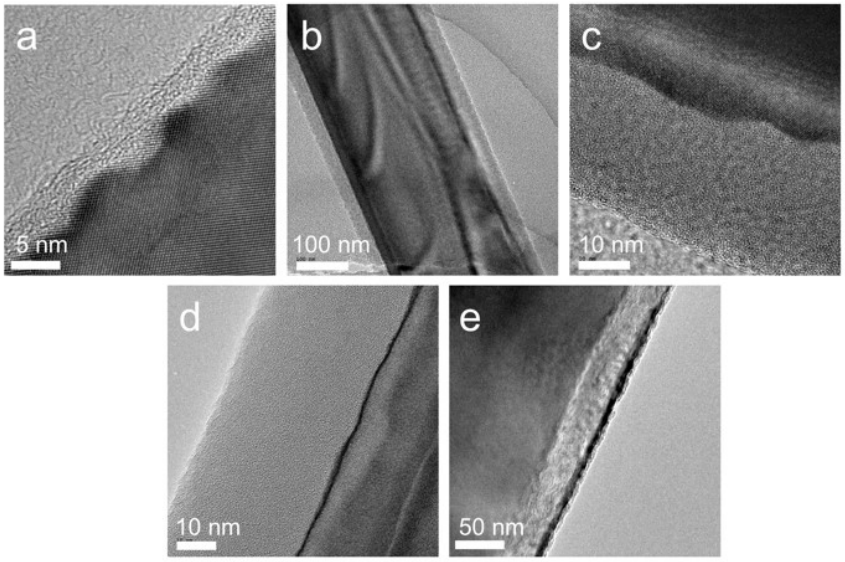

Fig. S2. The HRTEM of the single nanowire annealed at 900°C for 0 min (a), 25 min (b), 50 min (c), 80 min (d) and 200 min (e).

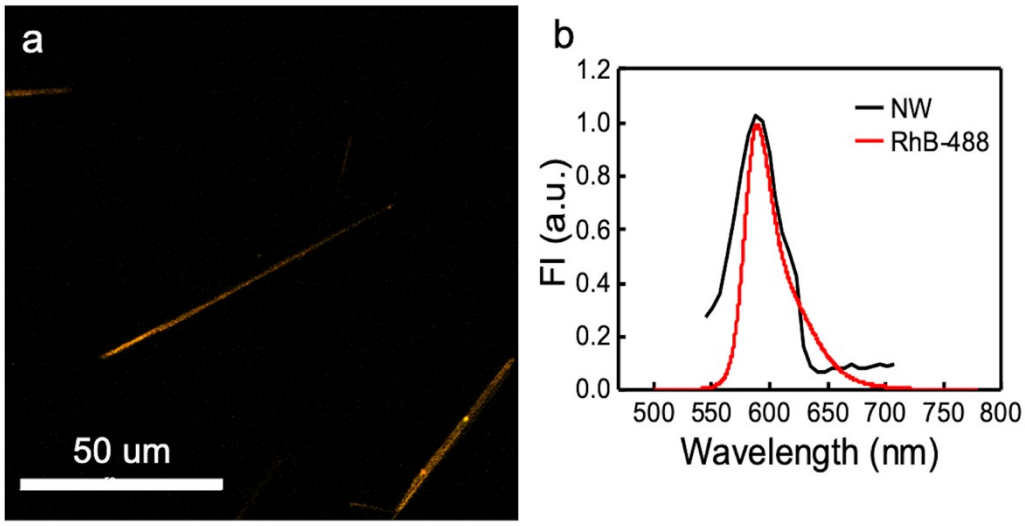

Fig. S3 a) the fluorescence image of the RhB-modified SiNW; d) the fluorescence spectrum of the RhB-modified SiNW and RhB solution.

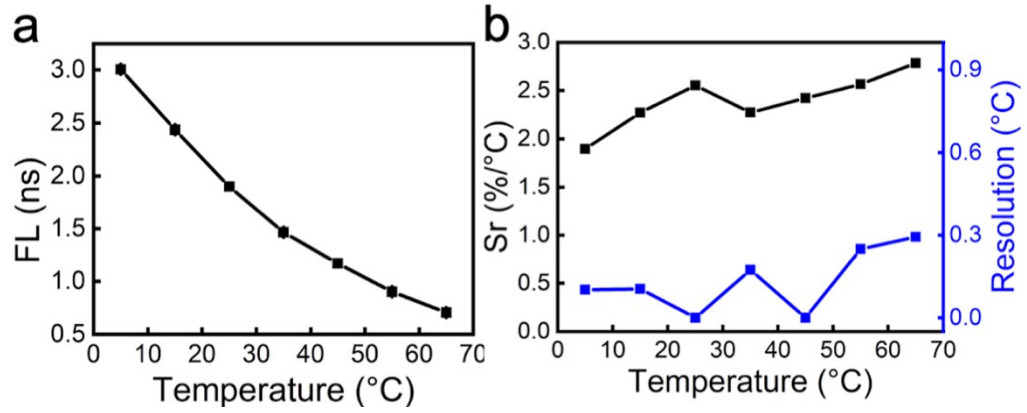

Fig. S4 (a) The fluorescence lifetime of the RhB solution *vs.* temperatures; (b) the relative sensitivity and resolution of the RhB to temperature.

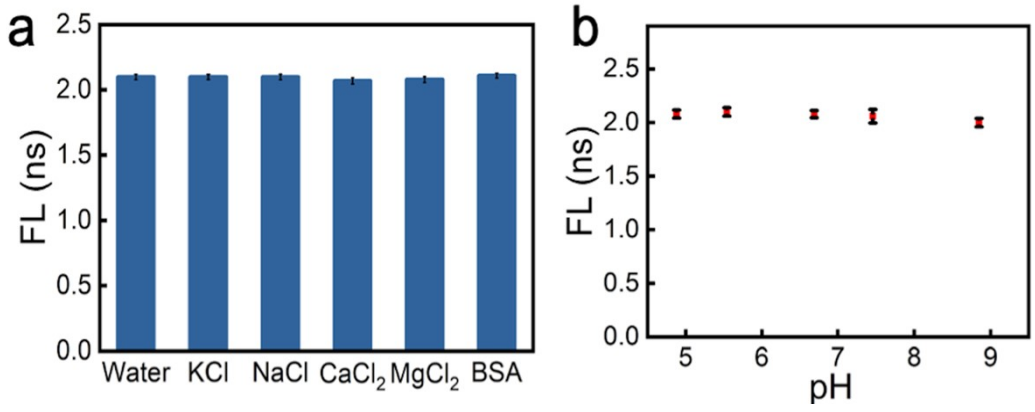

Fig. S5 a)The fluorescence lifetime of the NWFLT in water, solutions containing different cations and BSA solution at 20°C; b) the fluorescence lifetime of the NWFLT *vs.* pH (20°C).

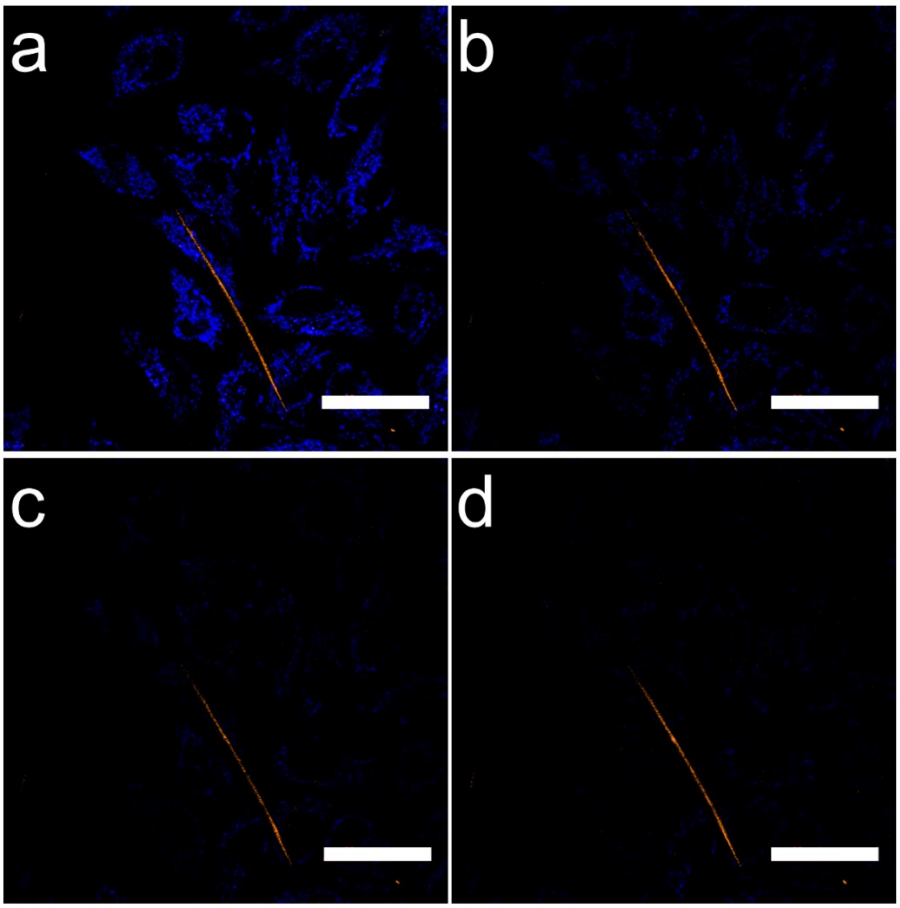

Fig. S6 The fluorescence intensity image of the NWFLT and the cells, the blue fluorescence is from mitochondria dye excited by 405 nm laser while the orange fluorescence is from the NWFLT excited by 488 nm laser. The irradiation time is 0 min (a), 10 min (b), 20 min (c), 30 min (d); the scale bars are 30 μm.

Table S1 The FL of NWFLT with different sample out and in the cell

Sample	FL(out the cell)/ns	FL(in the cell)/ns	Bis/ns
1	2.13	2.09	0.05
2	1.89	1.54	0.35
3	2.40	1.95	0.45

4	4.22	2.36	1.86
5	3.24	2.12	1.12
6	2.50	2.00	0.50
7	2.84	2.17	0.67

Table S2 The FL of NWFLT with different sample before and after add the CCCP

Sample	Before add CCCP		After add CCCP	
	FL(out the cell)/ns	FL(in the cell)/ns	FL(out the cell)/ns	FL(in the cell)/ns
1	1.80	1.80	1.76	1.73
2	2.63	2.11	2.60	1.61

Table S3 The FL of NWFLT with different sample before and after add the Ca^{2+}

Sample	Before add Ca^{2+}		After add Ca^{2+}	
	FL(out the cell)/ns	FL(in the cell)/ns	FL(out the cell)/ns	FL(in the cell)/ns
1	1.89	1.54	1.86	1.79
2	2.84	2.17	3.01	2.51

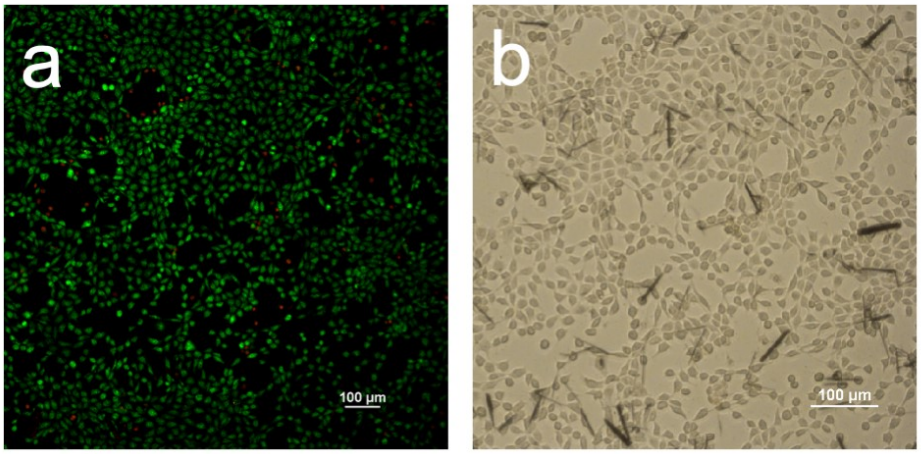

Fig. S7 The fluorescence intensity images (a) and bright images (b) of the L929 cells stained with AO and EB after incubation with silicon nanowire for 48 h.

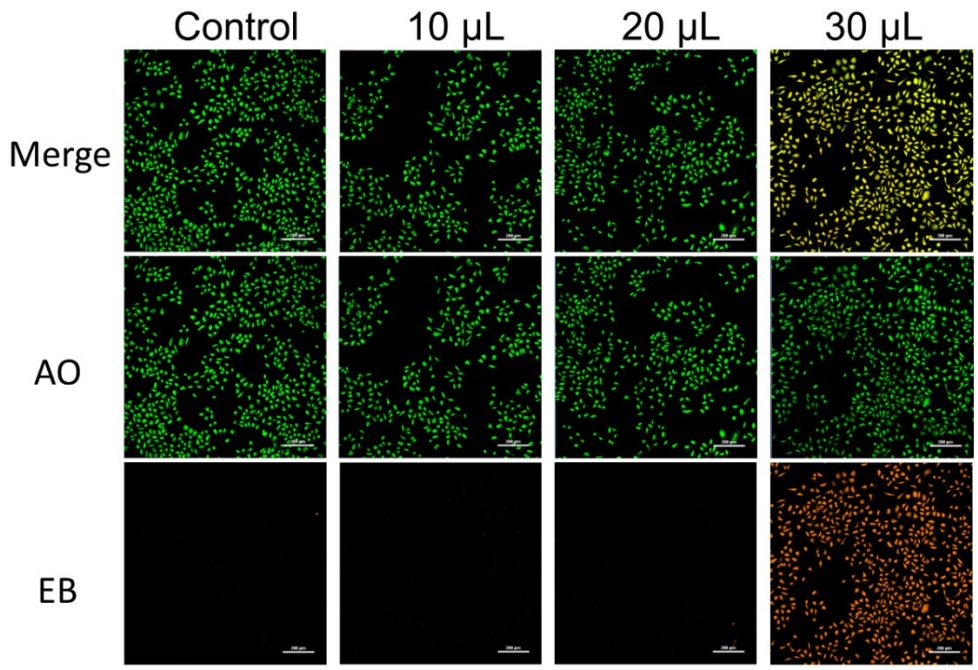

Fig. S8 The fluorescence intensity images of the L929 cells stained with AO and EB after adding different volumes of cisplatin (10 μL, 20 μL and 30 μL) for 5 h. The cisplatin solution is 5 mM.

References

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