Electronic Supplementary Material (ESI) for Physical Chemistry Chemical Physics.

Supplementary Information

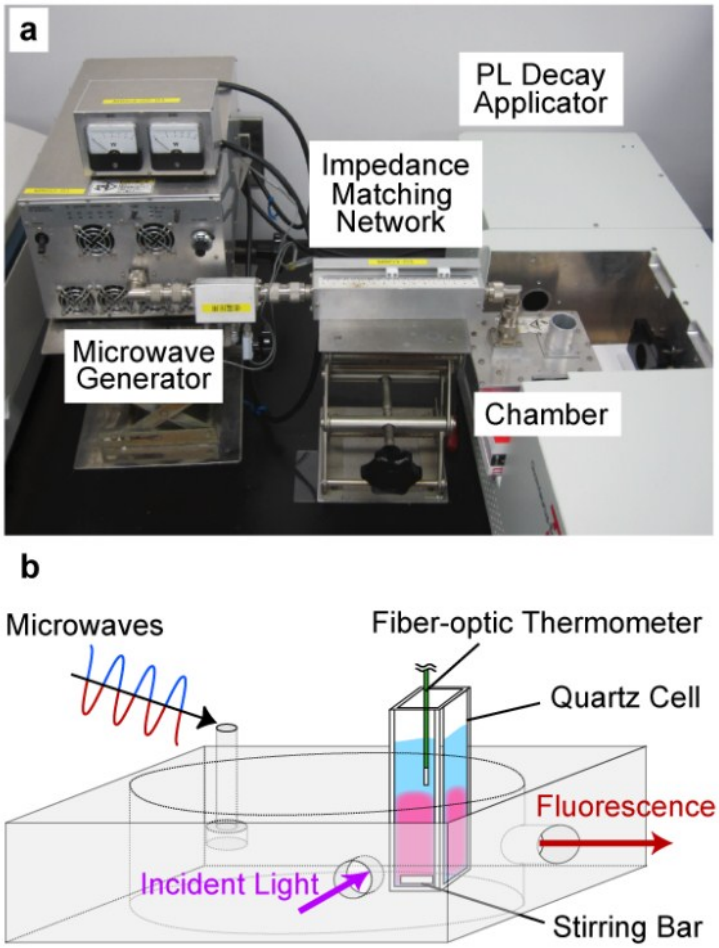
In situ temperature measurements of reaction spaces under microwaves using photoluminescent probes

Taishi Ano,[a] Fuminao Kishimoto,[a,b] Ryo Sasaki,[a] Shuntaro Tsubaki, *[a] Masato M. Maitani,‡[a] Eiichi Suzuki,[a] Yuji Wada,*[a]

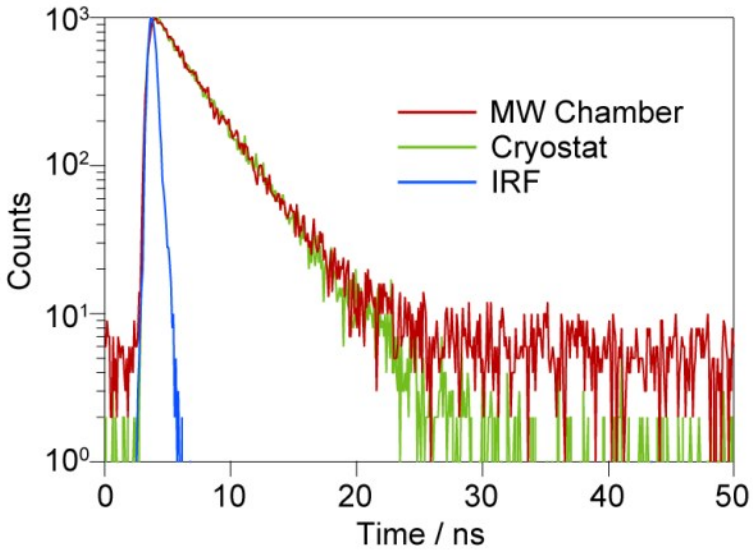
[a.] *Department of Applied Chemistry, Tokyo Institute of Technology, 2-12 Ookayama, Meguro, Tokyo 152-8552, Japan. Fax: +81-3-5734-2879; Tel: +81-3-5734-2879; E-mail: yuji-w@apc.titech.ac.jp, tsubaki.s.aa@m.titech.ac.jp*

[b.] *Research Fellow of Japan Society for the Promotion of Science.*

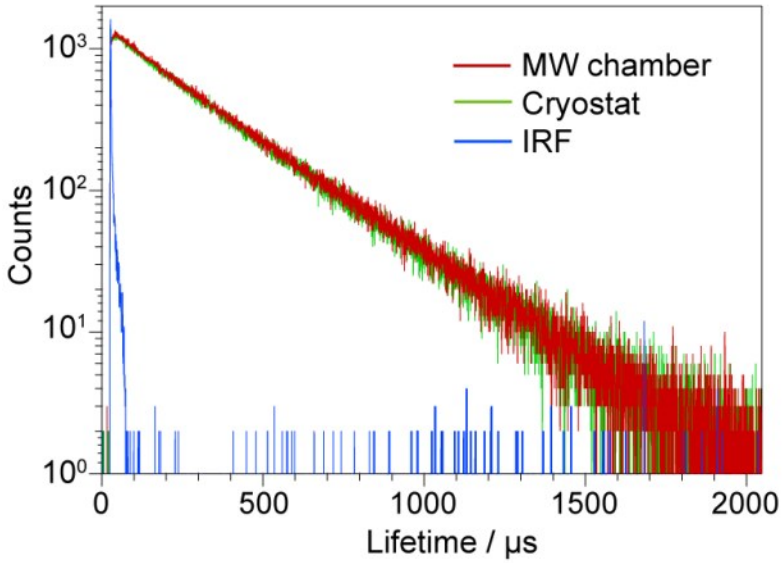
‡ *Present address: Research Center for Advanced Science and Technology (RCAST), The University of Tokyo, 4-6-1, Komaba, Meguro, Tokyo 153-8904, Japan.*



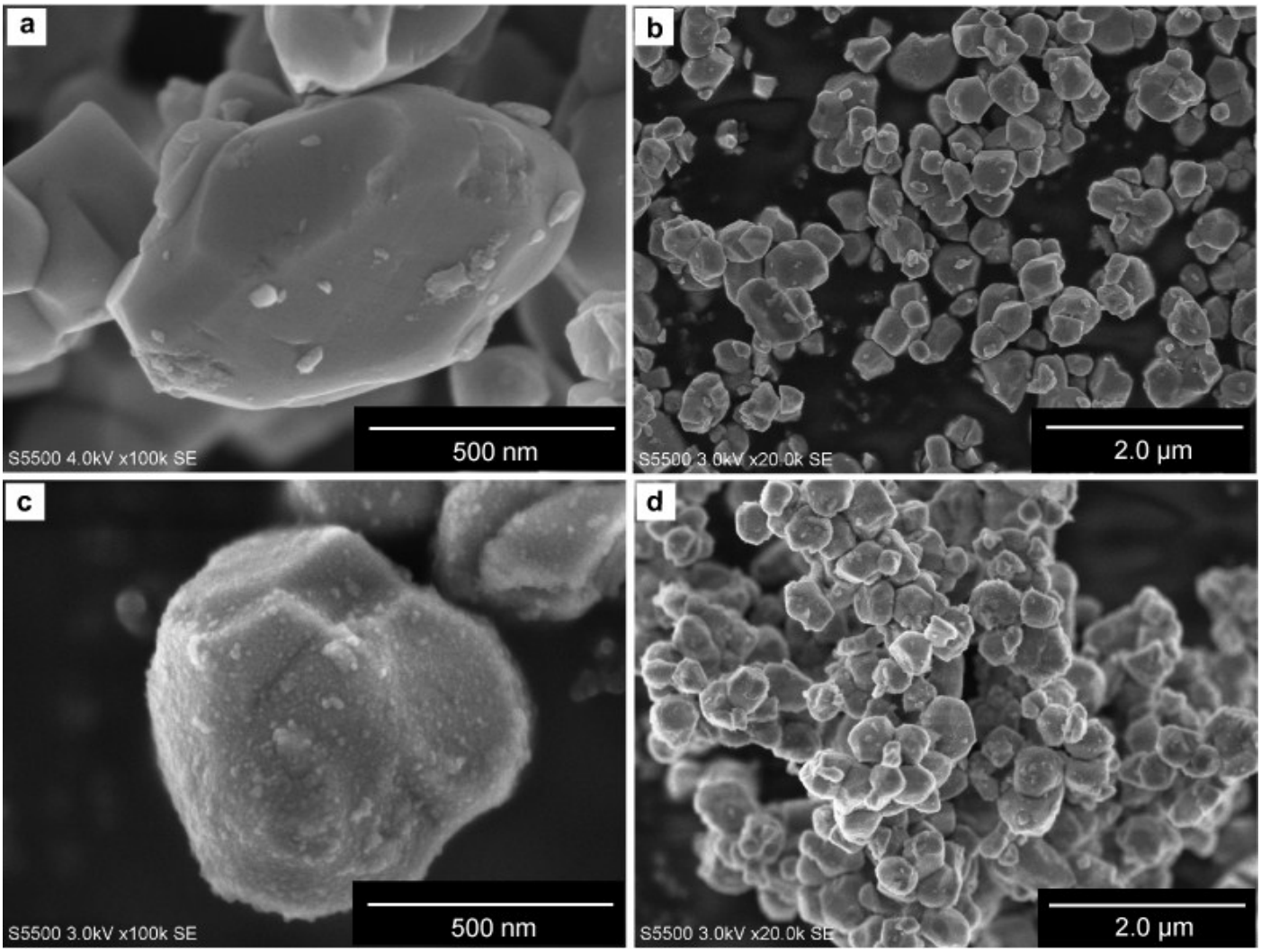
Supplementary Figure 1 | In situ PL decay measurement system under microwaves (Kishimoto et al) [18]**.** (a) An ellipsoid microwave applicator (Chronix Ltd.) and a PL lifetime applicator, Quantaurus-Tau (Hamamatsu Photonics K.K.) were assembled to form the in situ measurement system. (b) The microwave chamber was drilled to permit a PL path. Quartz cell was used as a container of the samples.



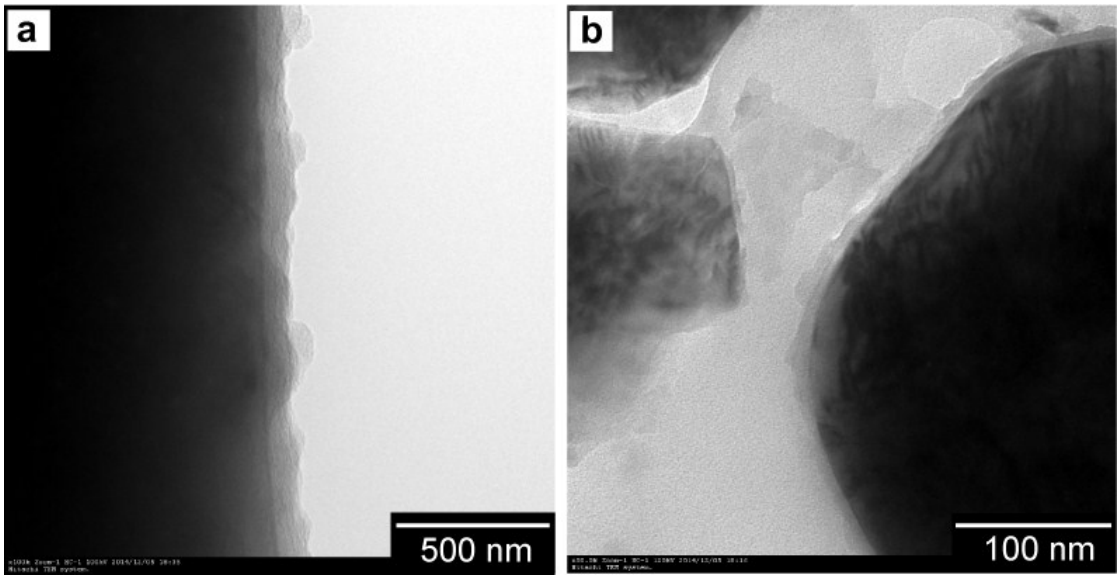
Supplementary Figure 2 | Comparing PL decay of the $BaTiO_3$-RhB@SiO_2 in the microwave chamber with that in the cryostat. The PL decay of the microwave chamber was the same as that of the cryostat in a PL lifetime range from 3.6 ns to 10.1 ns.



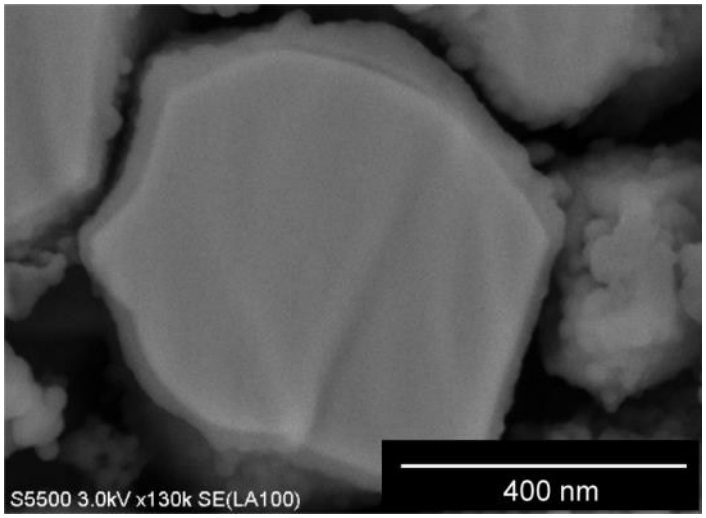
Supplementary Figure 3 | Comparing PL decays of $C_{16}N$-W_2O_7-Eu^{3+} in the microwave chamber with that in the cryostat. The PL decay of the microwave chamber was the same as that of the cryostat in a PL lifetime range from 100 µs to 502 µs range.



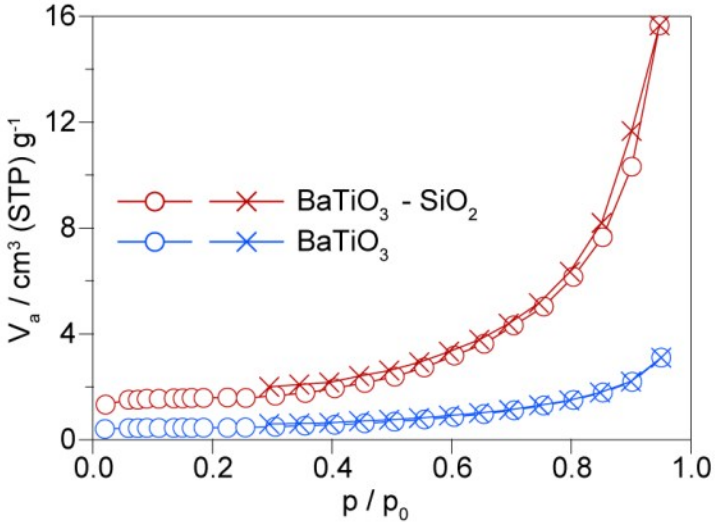
Supplementary Figure 4 | SEM images of $BaTiO_3$ and $BaTiO_3$-SiO_2. (a)(b) $BaTiO_3$ **(c)(d)** $BaTiO_3$-SiO_2. The particle structures were not changed thorough the Stober method [30].



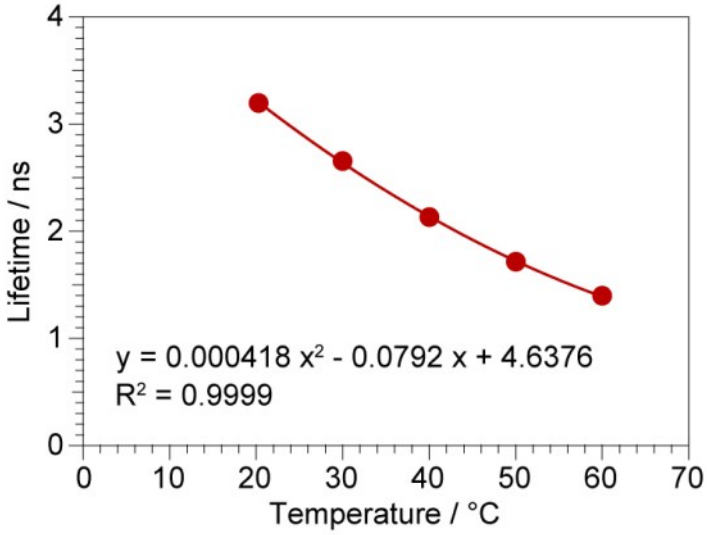
Supplementary Figure 5 | Cross-section TEM images of $BaTiO_3$-SiO_2.



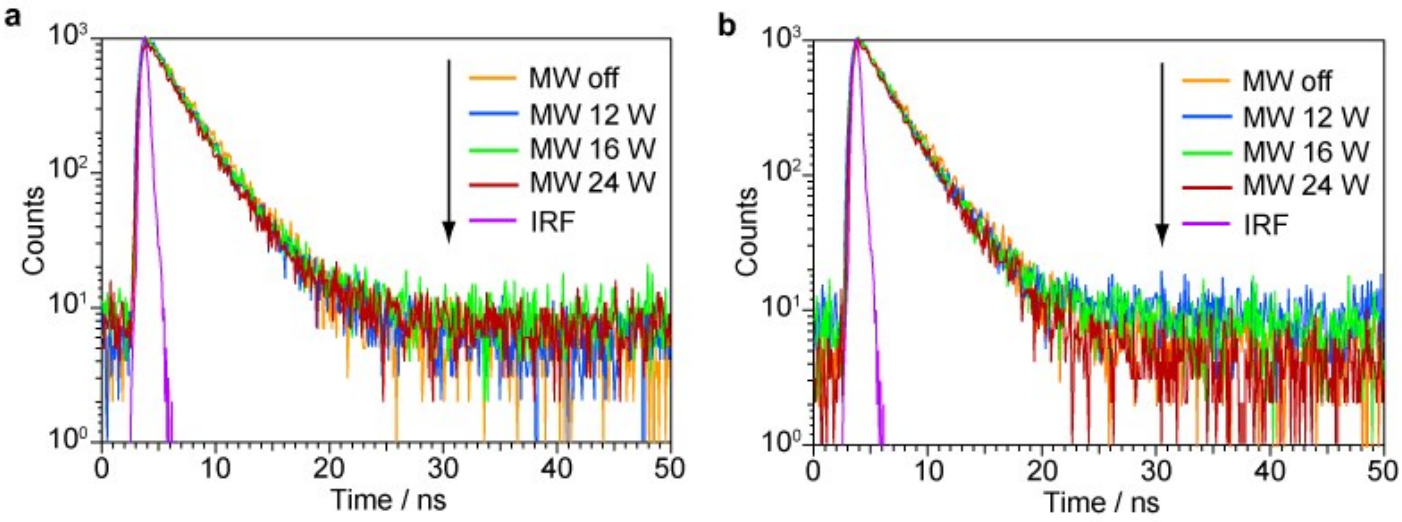
Supplementary Figure 6 | Cross-section SEM image of $BaTiO_3$-SiO_2.



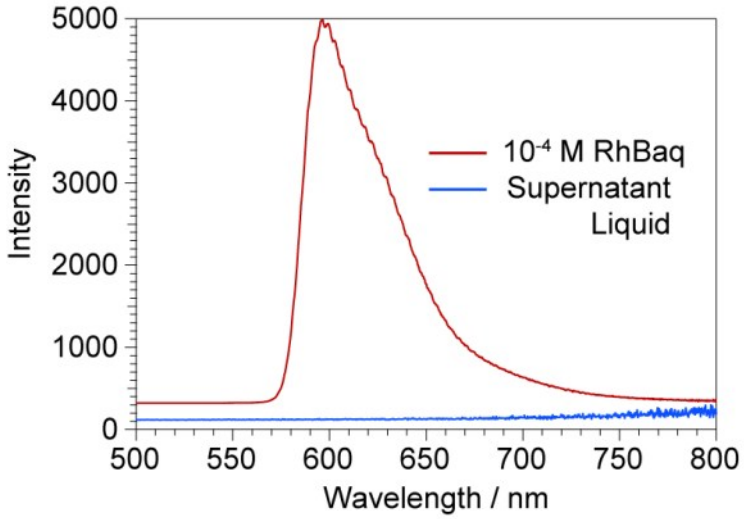
Supplementary Figure 7 | Nitrogen adsorption isotherm of $BaTiO_3$ and $BaTiO_3$-SiO_2. Both of the isotherms showed type III behavior. There was a hysteresis only in the isotherm of $BaTiO_3$-SiO_2.



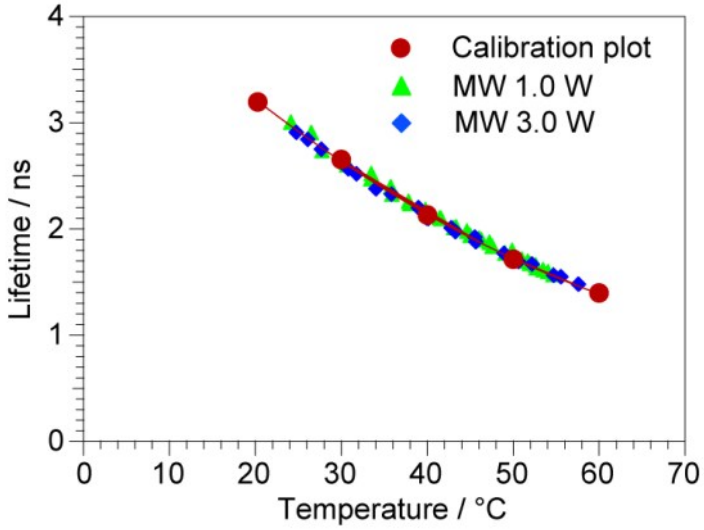
Supplementary Figure 8 | Relationship between PL lifetime and temperature of 10^{-4} M RhB ethanol solution.



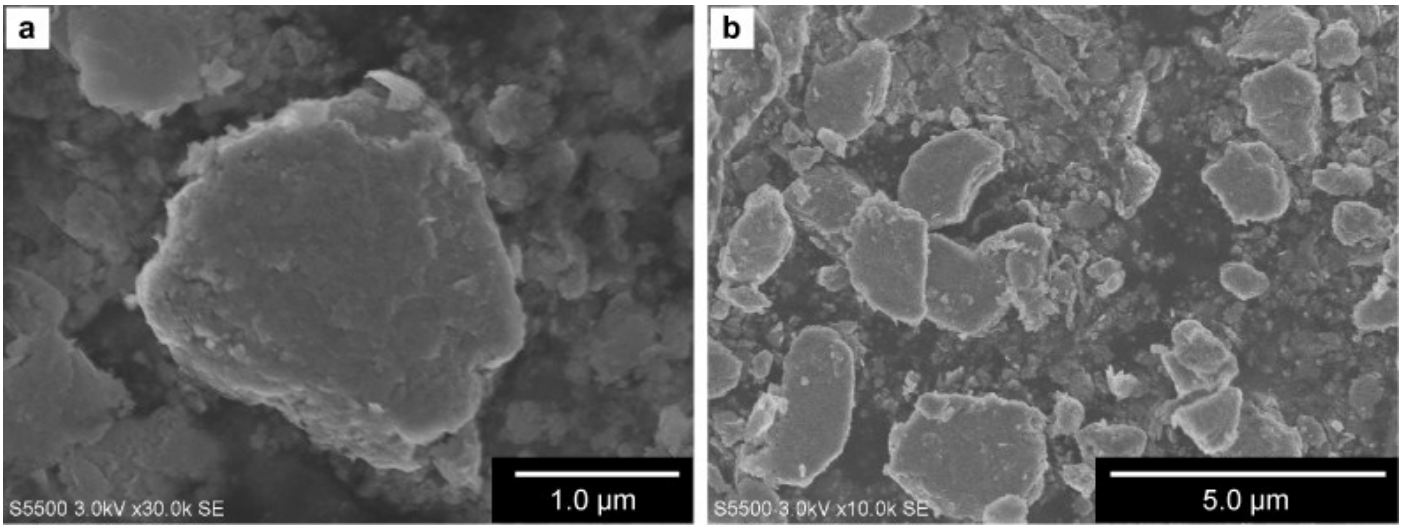
Supplementary Figure 9 | In situ PL decay measurement with $BaTiO_3$-RhB@SiO_2 under microwaves at 12, 16, 24 W. (a) The PL decays of the first plots shown in the Fig. 2c and that of before microwave irradiation. **(b)** PL decay of the measurement before microwave irradiation.



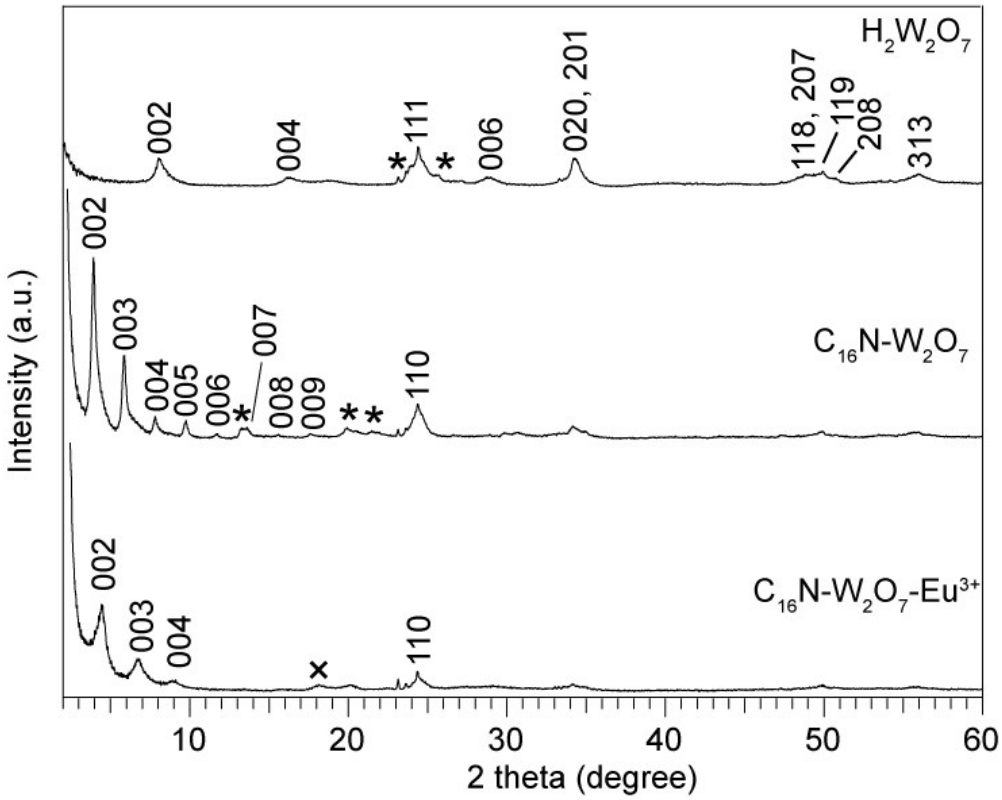
Supplementary Figure 10 | Comparing emission spectrum of supernatant liquid of the solution in which $BaTiO_3$-RhB@SiO_2 dispersed in heptane after the temperature measurement under microwaves with that of 10^{-4} M RhB water. The LED light at 405 nm was used as excitation light. The supernatant liquid did not exhibit any absorption peaks at 600 nm.



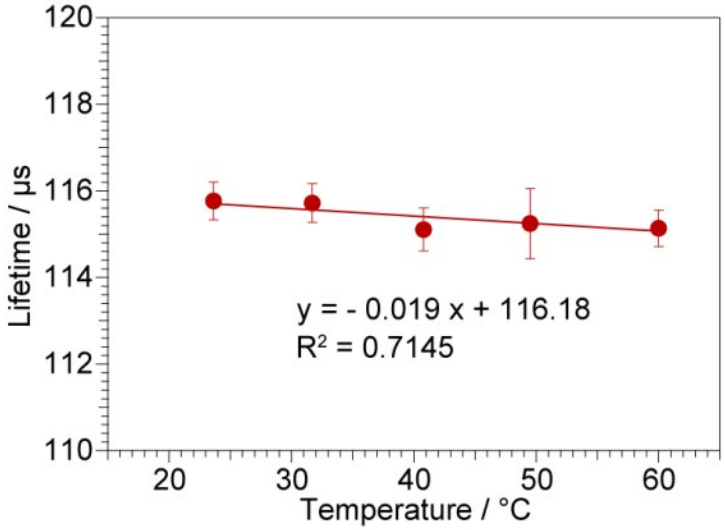
Supplementary Figure 11 | In situ PL lifetime measurement of 10^{-4} M RhB ethanol under microwaves. The PL lifetimes under microwaves at 1.0 and 3.0 W exhibited as same behavior as the calibration curve (Fig. S8).



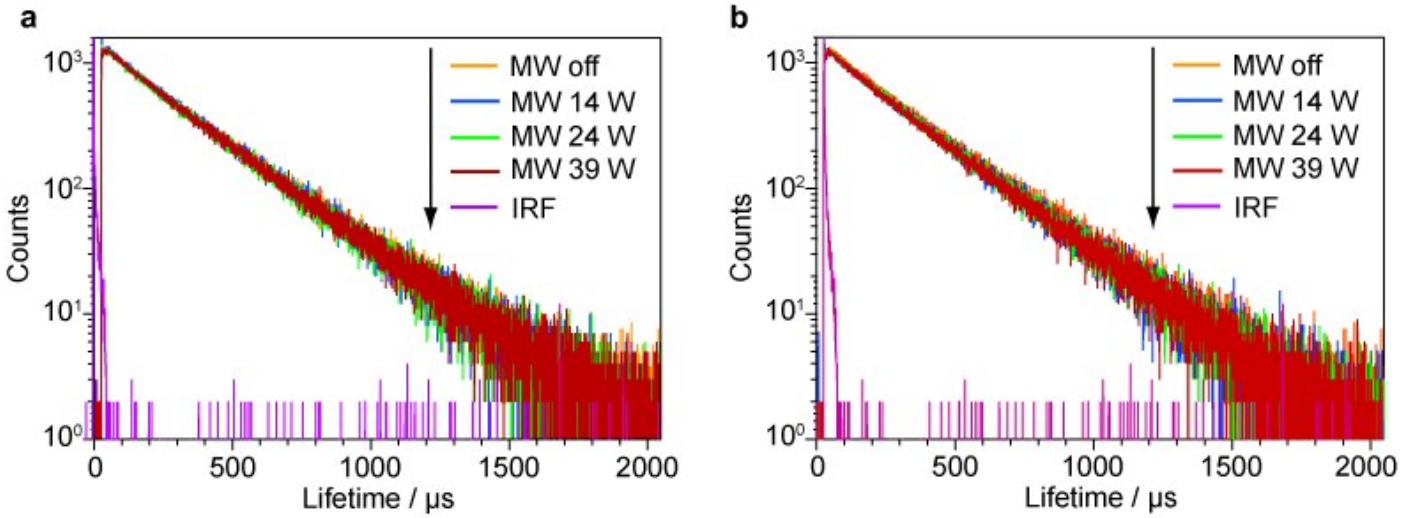
Supplementary Figure 12 | SEM images of $C_{16}N^{+}$-W_2O_7- Eu^{3+}.



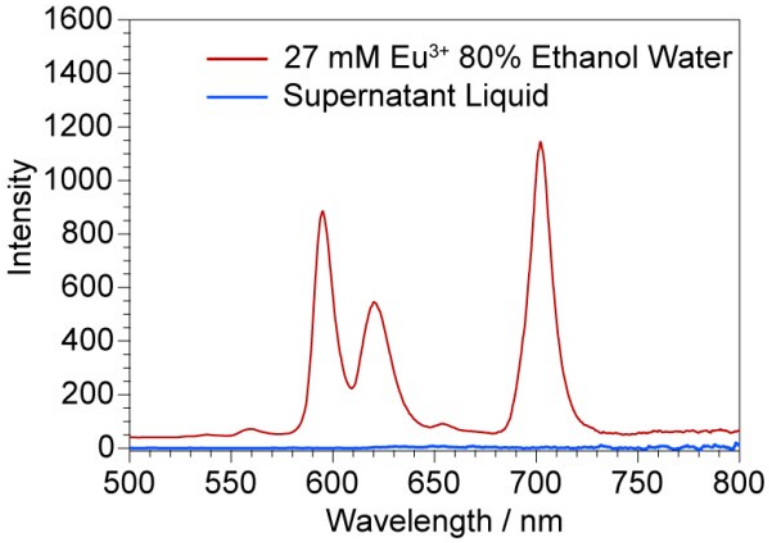
Supplementary Figure 13 | XRD peaks of $C_{16}N$-W_2O_7-Eu^{3+} and precursors. The peaks below 20 ° were attributed to layered structure. The peaks above 20 ° angle were attributed to the structure of each $W_2O_7^{2-}$ layer.



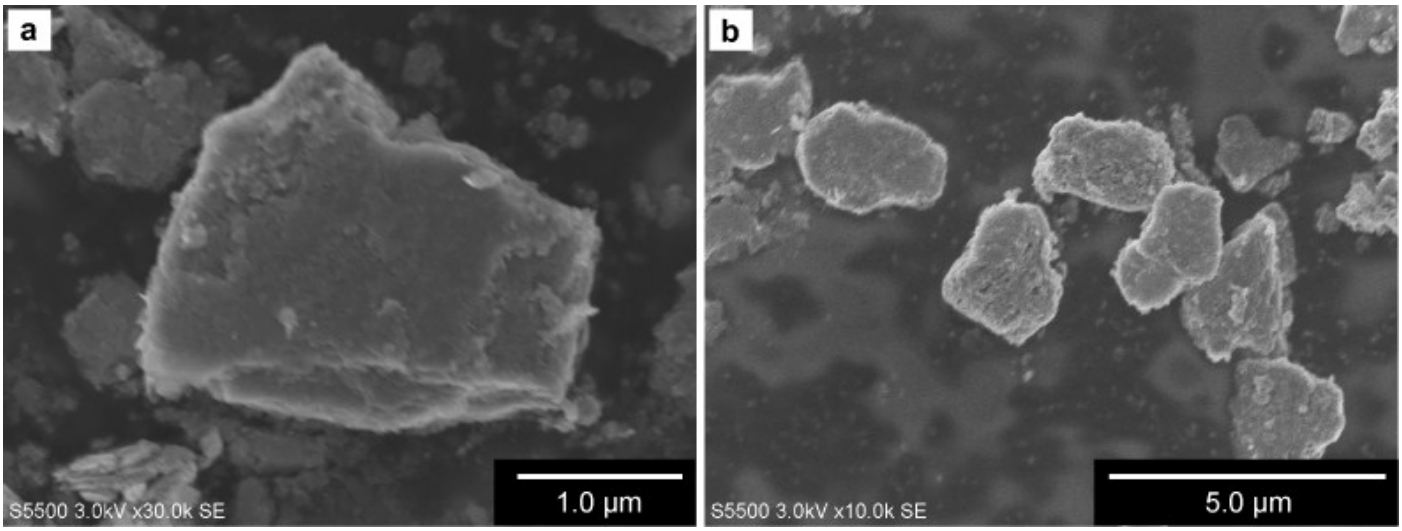
Supplementary Figure 14 | Relationship between PL lifetime and temperature of 27 mM Eu^{3+} 80% ethanol water.



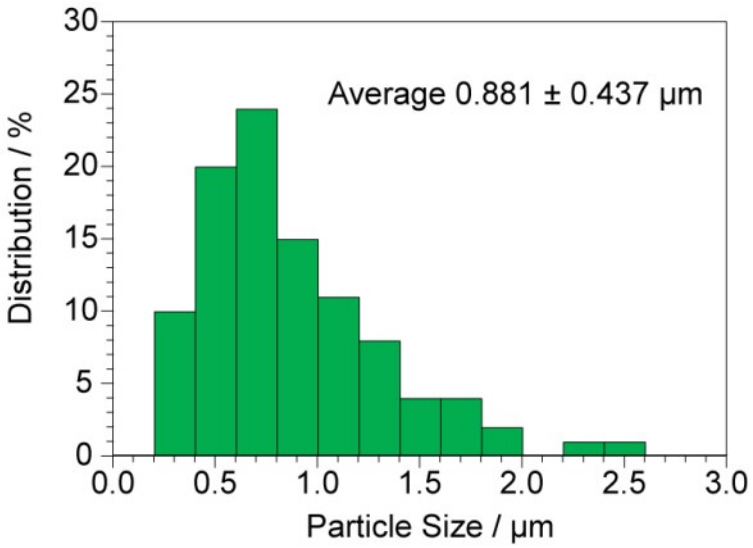
Supplementary Figure 15 | In situ PL decay measurement with $C_{16}N^{+}$-W_2O_7-Eu^{3+} under microwaves at 14, 24, 39 W. (a) The PL decays of the first plots shown in the Fig. 4c and that of the measurement before microwave irradiation. **(b)** The PL decays of the last plots shown in Fig. 4c and that of the measurement before microwave irradiation.



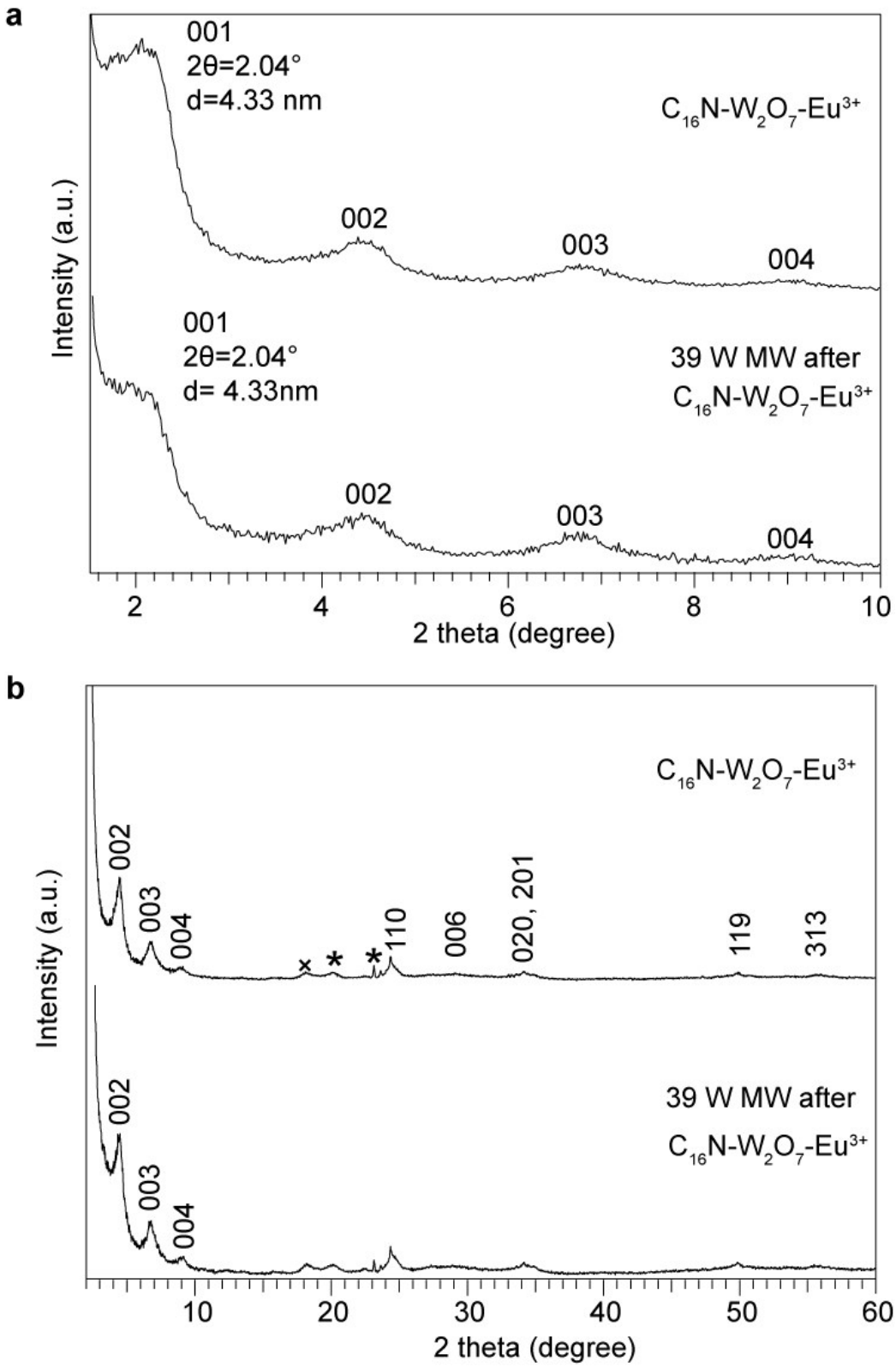
Supplementary Figure 16 | Comparing emission spectrum of supernatant liquid of the solution in which $C_{16}N$-W_2O_7-Eu^{3+} were dispersed in heptane after the temperature measurement under microwaves (27 mM Eu^{3+} 80% ethanol water). The 390 nm light which passed 390 nm bandpass filter from Xenon lamp was used as excitation light. The supernatant liquid did not have any absorption peaks at 595, 620 and 705 nm.



Supplementary Figure 17 | SEM images of $C_{16}N$-W_2O_7-Eu^{3+} after the temperature measurement under microwaves. The images were similar to the images of $C_{16}N^+$-$W_2O_7^{2-}$-Eu^{3+} before microwave irradiation (Fig. S12)



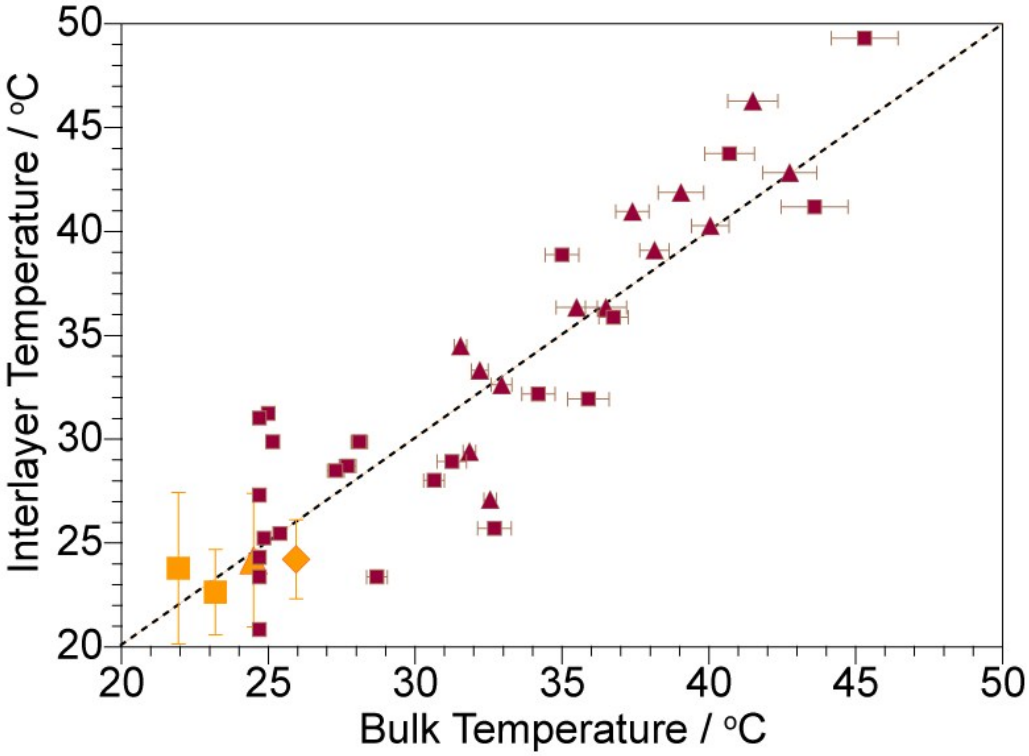
Supplementary Figure 18 | Particle size distribution of $C_{16}N$-W_2O_7-Eu^{3+} after the temperature measurement under microwaves. The distribution was similar to the distribution of $C_{16}N^+$-$W_2O_7^{2-}$-Eu^{3+} before microwave irradiation (Fig. 4b).



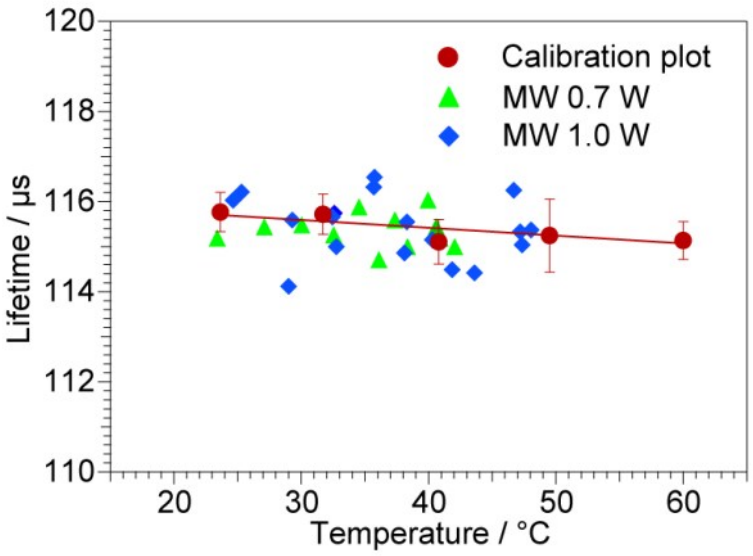
Supplementary Figure 19 | XRD peaks of $C_{16}N\text{-}W_2O_7^{2-}\text{-}Eu^{3+}$ and $C_{16}N\text{-}W_2O_7\text{-}Eu^{3+}$ after the temperature measurement under microwaves. Major changes of the peaks were not observed, showing the each $W_2O_7^{2-}$ structure was remained after the microwave irradiation at 39 W. (a) XRD peaks measured by X'Pert MPD-OEC diffractometer. (b) XRD peaks measured by Mini Flex 600.

Supplementary Table 1 | Chemical composition of $C_{16}N^{+}$-$W_2O_7^{2-}$-Eu^{3+} after the temperature measurement under microwaves at 39 W from CHN analysis and ICP-OES.

	C /wt %	H /wt %	N /wt %	O /wt %	W /wt %	Eu /wt %	$C_{16}N^{+}$ Density / nm^2	Eu^{3+} Density / nm^2
$C_{16}N$ - $W_2O_7^{2-}$ - Eu^{3+} (after Microwaves)	10.6	2.22	0.82	18.4	59.9	8.24	2.29	2.26



Supplementary Figure 20 | Temperature verification of $C_{16}N^{+}$-$W_2O_7^{2-}$-Eu^{3+} interlayer. The interlayer temperature was plotted against the bulk temperature. The orange plots were measured five times before microwave irradiation (diamond: 14 W, triangle: 24 W, square: 39 W). The brown plots were measured after microwave irradiation (triangle: 24 W, square: 39 W). All plots showed the interlayer temperature was the same as the bulk temperatures.



Supplementary Figure 21 | In situ PL lifetime measurement of 27 mM Eu^{3+} 80% ethanol water under microwaves. The PL lifetimes under microwaves (0.7, 1.0 W) were measured exhibiting same behavior as the calibration line (Fig. S14).