In situ Observation of Local High Temperature at Contact Point of SiC Particles under Microwave Heating using Luminescing Molecular Thermometer

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Abstract: Microwaves can induce non-equilibrium local heating at the surface of solid catalytic particles, which accelerates reactions speeds and reduces the reaction time and the energy consumption. However, it is difficult to identify the local high temperature and measure the temperature under microwave heating. Here, we demonstrate an in situ observation of the high temperature occurred at a contact point of SiC particles under microwave heating. The temperatures were determined under microwaves by a molecular thermometer containing Tb^{3+} and Eu^{3+}, whose emission intensity ratio (I_{Tb}/I_{Eu}) was dependent on temperatures. Occurrence of the non-equilibrium local heating was confirmed at the contact points therein.

Keywords: Microwaves, Non-equilibrium local heating, Molecular Thermometer.

1. Introduction

Non-equilibrium local heating by microwaves is a key factor for accelerating the chemical reactions in gas-solid catalytic systems and reducing the energy consumption[1,2]. Moreover, microwaves can be concentrated on the contact points between solid catalyst particles, which can also bear the local high-temperature field[3]. These special heat dynamics can improve catalytic reactions, however, it is difficult to measure the temperature of the solid surface acting as the reaction field under microwave irradiation[4].

We have selected on a molecular thermometer composed of lanthanides, $[Tb_{0.99}Eu_{0.01}(hfa)_3(dpbp)]_n$ (hfa: hexafluoro acetylacetonato, dpbp: 4,4'-bis(diphenyl-phosphoryl)[5]. This lanthanide complex has two emissions: the one is Tb^{3+} emission at 545 nm whose intensity is strongly dependent on temperature, and the other is Eu^{3+} emission at 615 nm whose intensity is weakly dependent (Figure 1). Using the intensity ratio (I_{Tb}/I_{Eu}), the temperature of the area attaching the molecule can be determined accurately within 1 °C error. In this work, we demonstrate a new temperature-measuring method under microwave irradiation using $[Tb_{0.99}Eu_{0.01}(hfa)_3(dpbp)]_n$ in a model system of SiC particles which absorb microwaves efficiently (Figure 1). We discuss the observed special heat dynamics in the present work.

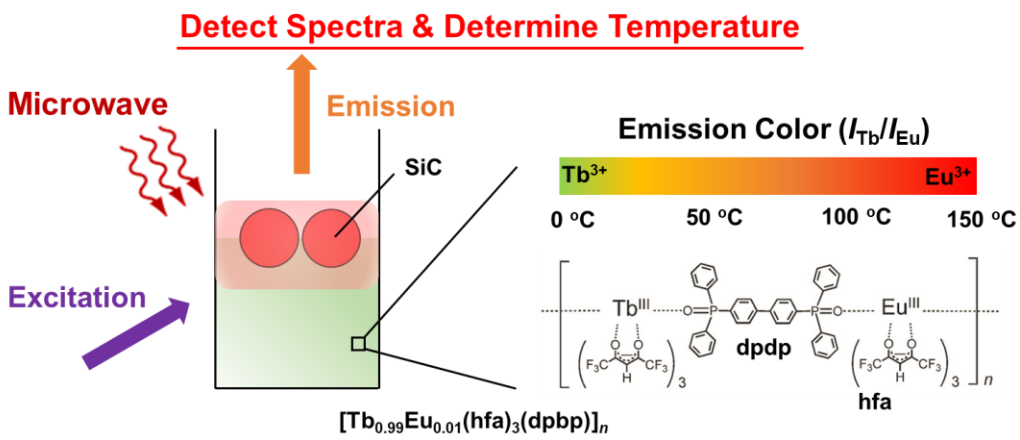

Figure 1. Temperature-measuring scheme with the molecular thermometer, $[Tb_{0.99}Eu_{0.01}(hfa)_3(dpbp)]_n$. Since the emission color (I_{Tb}/I_{Eu}) was dependent on temperature, the SiC temperature was determined from the emission spectra of $[Tb_{0.99}Eu_{0.01}(hfa)_3(dpbp)]_n$.

2. Experimental

The mixture of two SiC particles with millimeter size and $[Tb_{0.99}Eu_{0.01}(hfa)_3(dpbp)]_n$ particles with sub-micrometer size were put in a quartz cell. This sample was embedded in a chamber of a microwave applicator (Figure 2a). A camera was used for observing the SiC particles to determine the line position shown as the blue line in Figure 2b where the detector could measure the emission spectra to determine the intensity ratio (I_{Tb}/I_{Eu}) value. The detector has 128 elements array and can determine the I_{Tb}/I_{Eu} of 128 points of the line respectively. Temperatures of the 128 points were calculated from the I_{Tb}/I_{Eu} using the relationship between the temperature and the I_{Tb}/I_{Eu}[5]. Therefore, the temperatures of the various positions of the line of the SiC particles were measured at one time under microwaves.

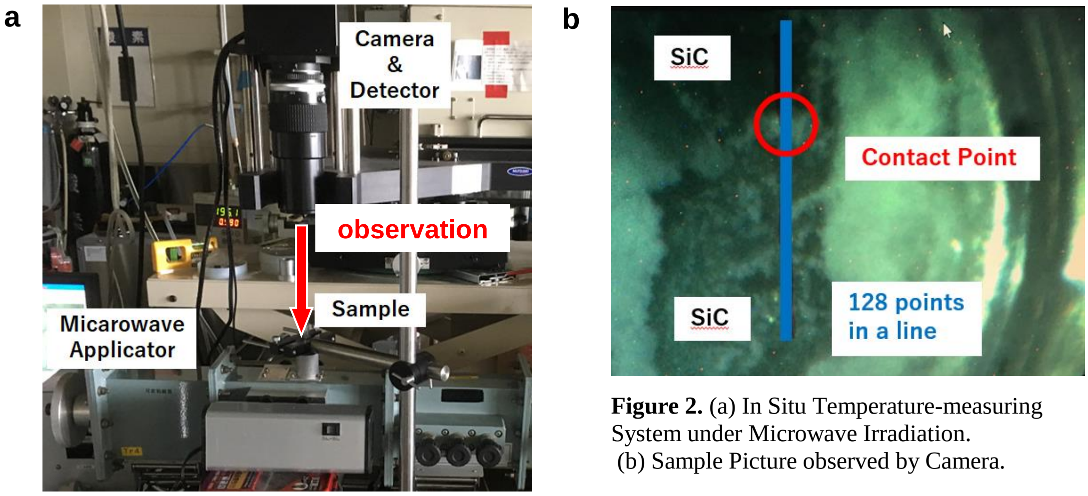

Figure 2. (a) In Situ Temperature-measuring System under Microwave Irradiation.
(b) Sample Picture observed by Camera.

3. Results and discussion

Figure 3 shows temperature dynamics with the irradiation time of 100 watt microwaves. The temperature of the contact point was calculated from the I_{Tb}/I_{Eu} values of the 10 points of the line nearby the contact point. The temperatures of the contact point were increased against microwave irradiation time, and all of them were about 9 ºC higher constantly compared with the average temperatures of the 128 points of the line. This result shows that microwaves are concentrated on the contact point and induce the non-equilibrium local heating at the contact point.

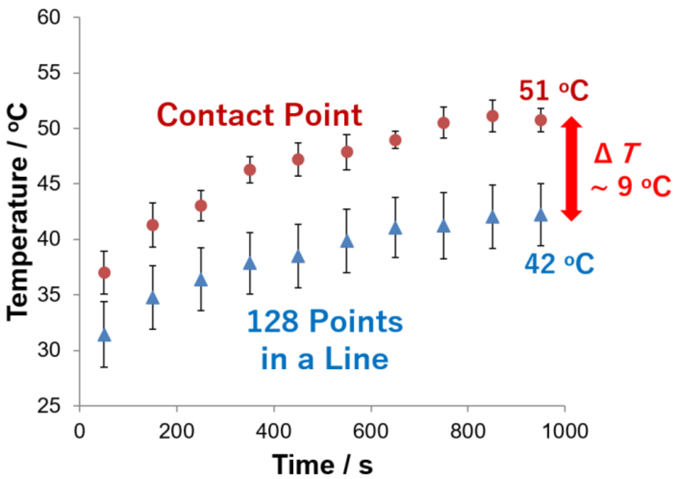

Figure 3. Temperature Dynamics of SiC surface under Microwaves.

4. Conclusions

We applied $[Tb_{0.99}Eu_{0.01}(hfa)_3(dpbp)]_n$ as molecular thermometer for measuring the accurate temperature of the SiC particles. The luminescence spectra of $[Tb_{0.99}Eu_{0.01}(hfa)_3(dpbp)]_n$ are detected under microwave irradiation, and they are analyzed to determine the temperature from the I_{Tb}/I_{Eu} values. The heat dynamics in solid catalytic systems can be examined by this temperature-measuring method, which helps us design the microwave-driven catalytic system and use the microwaves energy more efficiently.

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