them. At the low forward bias, the emission mainly originated from MEMO-PPV. When the applied voltage was increased, more holes got significantly high energy to overcome the barriers in the interfaces of NGC/ITO and NGC/MEMO-PPV and entered HOMO of MEMO-PPV. This resulted in the enhancement of the recombination efficiency in NGC.

Acknowledgements The authors would like to thank the National Laboratory of Molecular and Biomolecular Electronics, Southeast University for their help in spectral measurement. This work was supported by the Natural Science Foundation of Jiangsu Province (Grant No. BK99004).

References

1. Tang, C. W., Slyke, S. A., Organic electroluminescent materials and devices, Appl. Phys. Lett., 1987, 51: 913.
2. Burroughes, J. H., Bradlley D. D. C., Brown A. R. et al., Light-emitting diodes based on conjugated polymers, Nature, 1990, 347: 539.
3. Wang, Y., Herron, N., Semiconductor nanocrystals in carrier-transporting polymers: Charge generation and charge transport, J. Lum., 1995, 66(11): 1316.
4. Colvin, V. L., Schlammp, M. C., Alivisatos, A. P., Light-emitting diodes made from cadmium selenide nanocrystals and a semiconducting polyhmer, Nature, 1994, 370: 354.
5. Uchida, M., Ohmori, Y., Noguchi T. et al., Color-variable light-emitting diode utilizing conducting polymer containing flurescent dye, Jpn J. Appl. Phys., Part II, 1993, 32: L921.
6. Kalinowhki J., Marco P.D., Cocchi, M. et al., Volgate-tunable-color multilayer organic light emitting diode, Appl. Phys. Lett., 1996, 68(17): 2317.
7. Kalinowhki, J., Marco, P. D., Fattori, V. et al., Voltage-induced evolution of emission spectra in organic light-emitting diedes, J. Appl. Phys., 1998, 83(8): 4242.
8. Gao, J., Hua Y., Wei, C. et al., Spectra-variable doped organic TFEL devices, in Proc. of 1994 Intern. Workshop on EL, Beijing (ed. Xu Xurong), Beijing: Science Press, 1995, 479.
9. Wang J., Li, Y., Hu, W., The synthesis and electronic characteristics of poly (*p*-phenylene vinylene) derivatives, Chin. Chem. Lett., 1998, 9(1): 61.
10. Xu C., Cui Y., Sheng Y. et al., Blue-green variable light-emitting diode based on organic-molecule-doped polymer, Appl. Phys. Lett., 1999, 75(13): 1827.

(Received March 3, 2000)

Preliminary analysis of chemical reaction under the radiation of electromagnetic wave

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Abstract Microwave can be used to accelerate chemical reaction and improve the rate of production. Does microwave only act as a heating factor? Do there exist any specific effects? These questions are still holding a violent controversy. Here we will choose the Belousov-Zhabotinsky reaction, which is sensitive to surrounding effects, to study the influence of microwave on chemical reactions. Visible changes of periods have been observed. It appeares that there could have been specific effects of microwave.

Keywords: microwave, electromagnetic wave, Belousov-Zhabotinsky reaction, specific effects.

As a fast and effective heating factor, microwave has been widely used in accelerating chemical reaction and improving the rate of production[1]. Because of the obvious difference between microwave heating and traditional heating, some new features have been observed in chemical reactions, and these features attracted more and more people's attention. Does microwave only act as a heating factor to accelerate reactions and improve the rate of production? Does it have any specific effects which may cause molecular structure and interaction change? These questions are still holding a violent controversy now[2]. Before the microwave is widely used in chemical industry and other fields, these problems must be solved clearly.

Both experiments and theories are needed to study the mechanism of chemical reactions radiated by microwaves. These require us to choose a kind of experiment, which is not only sensitive to surrounding effects, especially to the electromagnetic waves, but also easy to observe. The experiment was carried out under the radiation of microwave that could be accurately controlled. Belousov-Zhabotinsky reaction with high magnetic fields produced by superconductor coil has been studied in the past decades. We use microwave to radiate this reaction and expect that this kind of nonlinear reaction could amplify the effects caused by microwave in order to verify if there exist some specific effects of microwave.

In this note, we will first introduce an experimental apparatus, which is used to study the influence of electromagnetic fields on chemical reaction. And the experiment process will be described as well. Then the results will be discussed and some immature conclusions will be obtained. The results show that there may be some specific influences of microwave on chemical reaction.

1 Experiments

(i) Instruments. A frame of our apparatus is shown in fig. 1[3]. It contains a TEM cell, a test tube with samples, a power source, a circulator, two dual-directors, an amplifier, an A/D converter and a computer. Two dual-directors were used to monitor the incident and reflected waves and the transmitted power in order to know the power absorption in the sample. The light transmittance from the side of the TEM cell was used to monitor the color change of reaction. The voltage from the photocell and the power were recorded *in vivo*. All data were collected by A/D converter and recorded by the computer in every 100 ms. The uniform distribution of electric and magnetic fields could be established between the inner and the outer conductor in the TEM cell. The test tube with samples was placed at the domain between the inner and the outer conductor in order to get uniform irradiation of electromagnetic waves. The TEM cell was used in the frequency range from DC to 1.5 GHz. A stirrer was adopted in order to homogenize the solution. Because the thermometer could be interfered seriously by the microwave, it was very difficult to record temperature *in vivo*. Therefore, only the temperatures before and after radiation of microwave were measured.

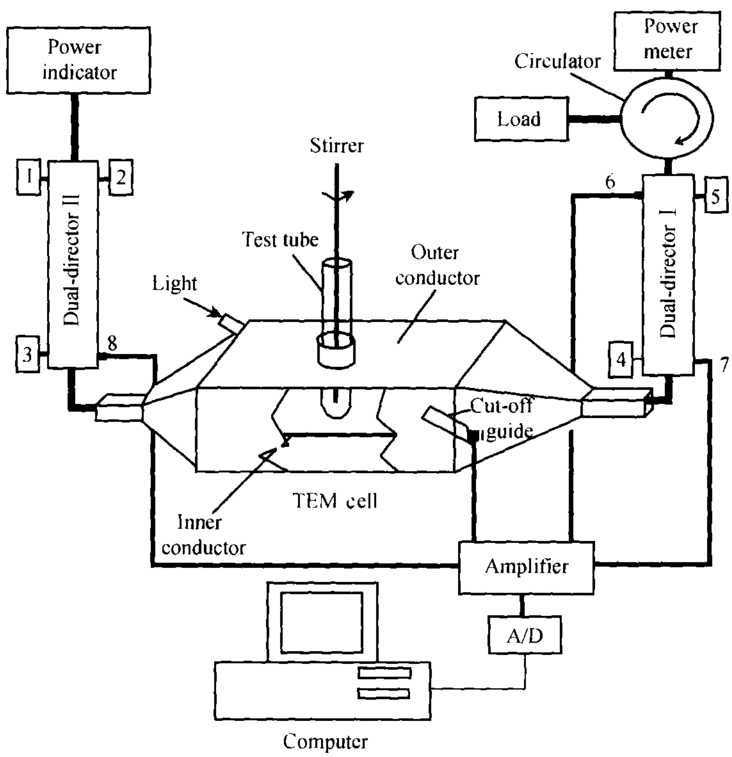

Fig. 1. The experiment system. 1, 2, 3, 4, 5, Load; 6, test port of incident power; 7, test port of reflected power; 8, test port of transmitted power.

(ii) Materials. Three kinds of solution: A, B and C have been prapared. Solution A is potassium iodate (0.14 mol/L). Solution B includes malonic acid (0.15 mol/L), manganese sulfate (0.024 mol/L) and starch (2 g/L). Solution C includes hydrogen peroxide (3.2 mol/L) and perchloric acid (0.17 mol/L).

(iii) Procedure. 2 mL solution was taken from solutions A, B and C respectively and mixed in a test tube. The test tube was placed in the TEM cell immediately and all data were soon recorded. The experiment was carried out under the following three conditions: they were without microwave (control group), with 2 W microwave radiation and with 20 W microwave radiation, respectively. The radiation time was controlled manually.

2 Results and discussion

The changes of voltage from the photocell with respect to time are shown in fig. 2. Meanwhile, the period change with time is drawn in fig. 3. The initial peak was assigned and in this way we could count periods easily.

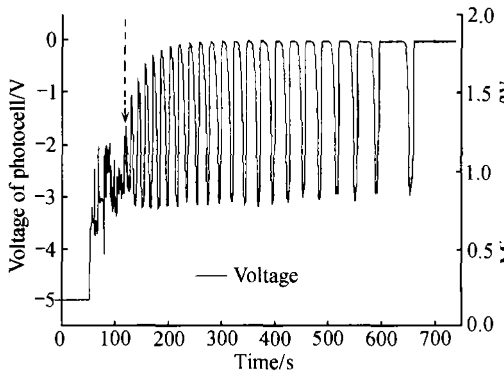

Fig. 2. Typical time-voltage history of the photocell without microwave radiation. Arrow, The first counting peak.

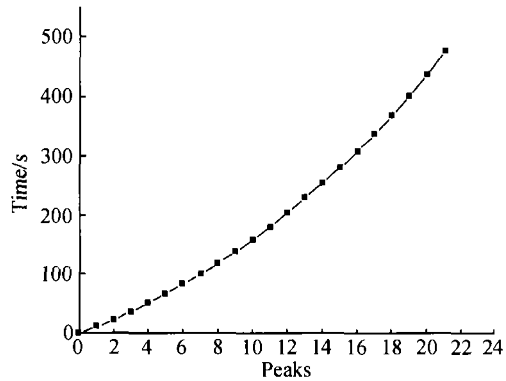

Fig. 3. Period change with respect to time.

(i) Radiation without microwave (control group). The results in figs. 2 and 3 were used as standard results of control groups which were compared with the data of other group. The starting temperature was 25.0℃ and the stopping one 26.8℃. The difference was 1.8℃.

(ii) 2 W microwave radiation. The whole process was radiated by the microwave at 600 MHz and the power was 2 W. The changes of voltages and periods with time are shown in figs. 4 and 5 respectively. From fig. 5 we can see that the microwave radiation made the reaction rate changed. The starting temperature of this reaction was 25.0℃ and the stopping one 29.2℃. The difference was 4.2℃. The reaction rate varied gradually with temperature change. This means that the influence of temperature was cumulative.

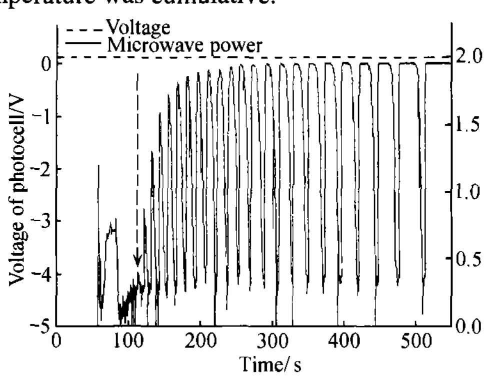

Fig. 4. Time-voltage history of the photocell, the whole process of the reaction was irradiated by microwave (2 W). Arrow, the first counting peak.

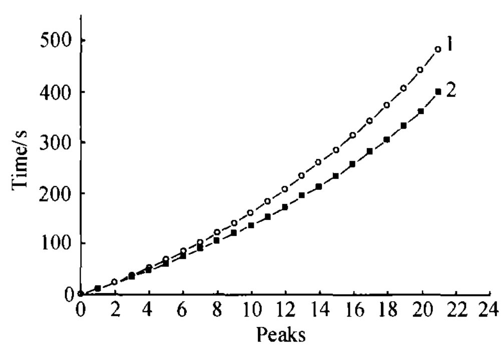

Fig. 5. Period change of with respect to time.

(iii) 20 W microwave radiation. The whole process was radiated by microwave at 2 450 MHz and the power was 20 W. Two different ways of radiation were used: i) The reaction was radiated in two separate periods (shown in fig. 6); ii) the second half of the reaction was radiated (shown in fig. 7). The corresponding changes of the periods are shown in fig. 8.

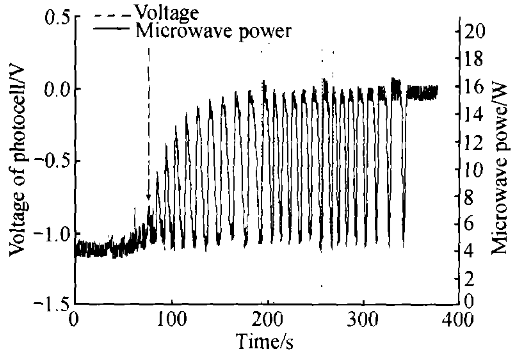

Fig. 6. Time-voltage history of the photocell, two period of the reaction were irradiated by microwave (20 W). Arrow, The first counting peak.

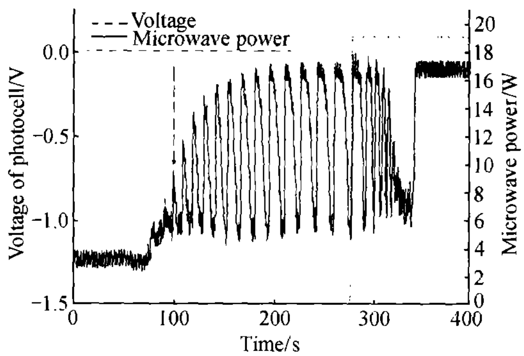

Fig. 7. Time-voltage history of the photocell the last part of the reaction was irradated by microwave (20 W). Arrow, The first counting peak.

From fig. 8 we can see that the periods changed immediately when the radiation started. Especially from curve 1, we find that the periods changed immediately from decrement to increment when the power was switched off. That is to say, under the condition of 20 W microwave radiation, the periods changed instantaneously with the microwave. However, during the process the temperature changed gradually. This means that there might be some specific effects of microwaves on the chemical reaction. The temperature measured in the above two different ways in this experiment is listed in table 1. The range of the temperature varies from 13℃ to 18℃. Whether all these changes were caused by thermal effect of microwave is still not clear. A detailed study will be presented later. Besides, another interesting thing is that we could not observe the oscillation of the reaction if the solution was radiated at the beginning of reaction. That means that the initial condition for oscilation might not be satisfied.

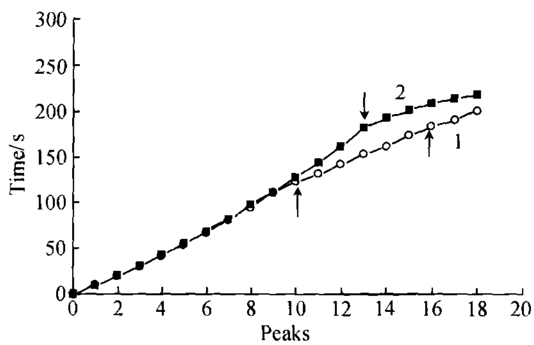

Fig. 8. Change of periods with respect to time. Arrow, The irradiation starts here.

Table 1 Temperature in reaction radiated by 20 W microwave

	Microwave radiation at the beginning of reaction	Microwave radiation in two separate periods	Microwave radiation in the second-half of reaction
Starting temperature/℃	27.5	27.5	27.5
Stopping temperature/℃	—	41.0	45.0
Temperature difference/℃	—	13.5	17.5

Acknowledgements This work was supported by the National Natural Science Foundation of China (Grant Nos. 69631040 and 69771021).

References

1. Jin Qinghan, Dai Shushan, Huang Kama, Microwave Chemistry, Beijing (in Chinese): Science Press, 1999, 30—50.
2. Stuerga, D. A. C., Gaillard, P., Microwave athermal effects in chemistry: A myth's autopsy, J. of Microwave Power and Electromagnetic Energy, 1996, 31(2): 87.
3. Huang Kama, Liu Ning, Experimental apparatus used to study the influence of electromagnetic fields on biochemical reaction, in Proceedings of the 4th Asia-Pacific Conference on Medical & Biological Engineering, Seoul: the Korea Society of Medical & Biological Engineering, 1999, 133.

(Received March 30, 2000)