The comparison of two methods used to observe a nonlinear system: potentiometry and holography

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Abstract: The transition from state I (characterized by low iodide and iodine concentration) to state II (high iodide and iodine concentration) occurs in a nonlinear Briggs-Rauscher (BR) oscillatory reaction. This transition was studied by two methods: potentiometric and holographic. The first derivative technique was applied to the obtained electrochemical and holographic curves of the transition state I→state II to obtain the corresponding slopes. Based on these slopes, the results of the two methods are compared. The obtained holographic slope for the transition from state I to state II is higher than the potentiometric one in all selected reaction sections. In the initial phase of the transition from state I to state II, it is clear that the velocity of the holographic method is twice that of the potentiometric method. While this trend shows a twofold increase at the beginning of the phase transition, it deviates in the other phases, where the holographic measurements show a 1.5-fold higher rate in the middle. The obtained results could have a strong impact on the study of nonlinear systems in the future.

Keywords: oscillatory reaction, nonlinear chemical system, state I to state II transition, potentiometry, holography

1. Introduction

Some established methods are used to measure nonlinear systems, such as chemical oscillatory reactions. One of the commonly used methods is the potentiometric method [1], which measures the electric potential (and throughout the Nernst equation concentration of certain species). This is of particular importance in terms of the Briggs-Rauscher (BR) oscillatory chemical reaction [2] and therein state I to state II transitions, which are followed by phase transition - solid iodine observation [3]. Due to BR oscillatory reaction having plenty of oxide-redox species, there is no general agreement concerning the potential determining redox pair for a working electrode in the BR reaction [4].

The researchers compared the commonly used method with the innovative possibility of holographic monitoring of the state I to state II transitions in BR oscillatory reaction [5,6]. The holographic method uses laser light to monitor nano-level system dynamics. Depending on the laser wavelength, the classical disturbance of the system could be avoided, which is one of the advantages of this method.

This work uses math to measure outcomes from both potentiometric and holographic methods.

2. Methods

For the investigation of the BR reaction, two completely different methods were used: a potentiometric method as a representative for methods to observe state I to state II transition in BR reaction, and holography as a contemporary method for monitoring this kind of nonlinear systems.

2.1 Potentiometric method

The potentiometric method measures and compares the potential between two electrodes, namely the reference electrode with a known potential and the working electrode (usually Pt or iodide ion-selective electrode) immersed in BR solution. See Figure 1.

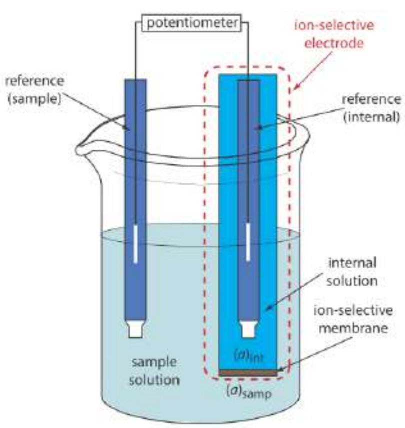

Figure 1. The potentiometric method with iodide ion-selective and reference electrodes immersed. In this investigation iodide ion-selective and Ag/AgCl, as working and reference electrodes are used, respectively.

The concentrations of BR reactants and reaction volume are the same as in reference [3], with one exception, the temperature is maintained at 25 °C.

2.2 Holographic method

The researchers outline the optical scheme and detailed procedure for monitoring the state I to state II transition in BR reaction by the holographic method elsewhere [5,6].

3. Results and discussion

The comparison of different methods (potentiometric and holographic) at the beginning, and in the middle of state I→state II phase transition, is done. Below is a palette of standardized diagrams to provide the possibility of comparing two methods for phase transition - solid iodine observation. To compare the rate of overall process measuring, we simply applied the first derivate technique (and determined the slope) for both (Figure 2). To be precise, we compared the tangent slopes gained with two described methods in different parts of the reaction. Figures 2A-2D for the state I to state II transitions in BR reaction are obtained from the conversion of potentiometric and holographic diagrams explained in detail in reference [6].

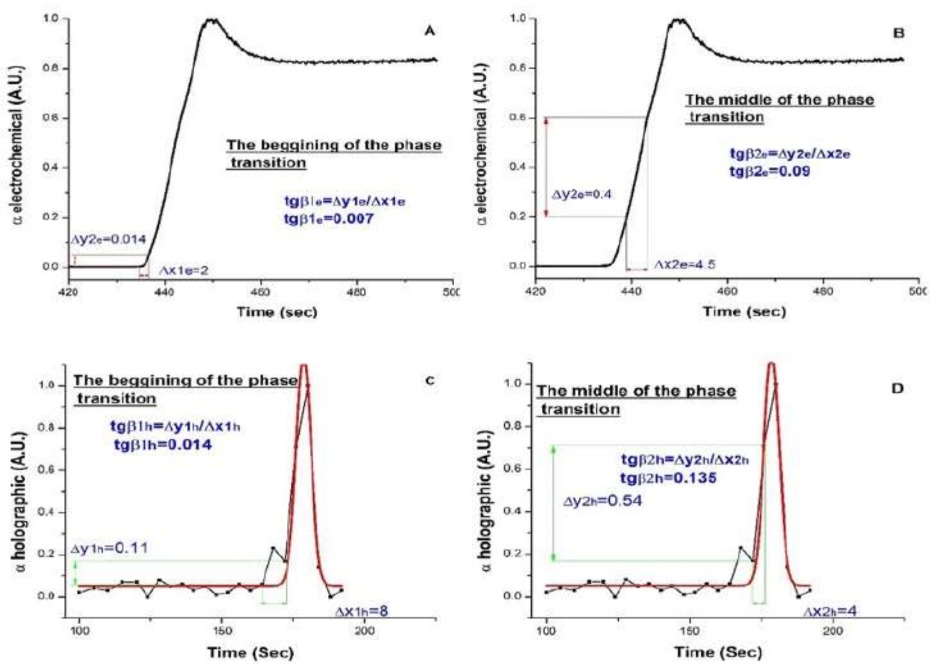

Figure 2. Graphical representation of the comparative use of two measurement methods: Potentiometric measurement of the beginning (A) and the middle (B) of the phase transition; Holographic measurement of the beginning (C) and the middle (D) of the phase transition. As it is known the transition is irreproducible and therefore does not start at the same time for both methods applied.

Here, we see that the speed of the holographic method is twice as high as the potentiometric method in the beginning of the state I to state II transition. This trend is not preserved during all phase transition (at the beginning it is twice as high, while in the middle this rate is 1.5 higher for holographic measurements). However, the holographic method during all stages of reaction (state I→state II transition) has a larger slope. The results obtained surely open new questions. What is monitored by a holographic method? Do these two methods measure the concentration of the identical reaction species?

Moreover, the holographic method is more sensitive and faster, which could have the strong influence in the investigation of oscillatory reactions and, in general, nonlinear systems, in the future.

4. Conclusions

Sometimes, it is very important to implement different scientific techniques to get more information about the investigated system. In this paper, the state I to state II transition in nonlinear Briggs-Rauscher oscillatory reaction was followed by two different methods: potentiometric and holographic. The technique of the first derivative was applied on obtained electrochemical and holographic curves of the state I→state II transition. The holographic curves during all stages of the transition have a larger slope, indicating a more sensitive and faster technique. Results found could have strong influence in the investigation of nonlinear systems in the future and require further investigations.

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