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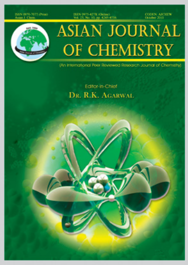

Intensity Dependence of Conductivity in Aqueous NaCl Solution at Microwave Frequency

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The influence of high power electromagnetic fields on conductivity of aqueous NaCl solution at microwave frequency was studied. It was found that microwave field-induced change of conductivity on the system is more significant at higher power. When the intensity of microwaves was above 10^4 V m^{-1}, our calculation indicated conductivity in the solution were interrelated on intensity of microwave we took advantage of rotational langevin equation to simulate dynamics of average hydrogen bond in aqueous NaCl solution in external microwave fields. The results agreed well with experiments. The strongly nonlinear change could be categorized as one of microwave nonthermal effects.

Key Words: Microwaves, Aqueous NaCl solution, Langvin equation, Hydrogen bond.

INTRODUCTION

Aqueous NaCl solutions play a fundamental role in many chemical processes in a variety of chemical and biological systems[1,2]. Detection between aqueous sodium chloride solutions and microwave may become useful for studying the local electrical and chemical properties of samples[3]. Microwave energy is transferred to the kinetic and intermolecular energies, the former enhance mobility of molecule but the latter is stored mostly internally to rearrange water molecules and believed to depend fundamentally on the microscopic characteristics of hydrogen bond[4,5]. Specific sodium chloride concentration different hydrogen-bond structures will be "favoured." Thus, it can be assumed that the dynamical properties of the electrolytes can be described *via* fluctuations in the hydrogen bonds[6]. Bertolini equations for description of hydrogen bonding formation and recombination can establish relation between electric conductivity and lifetime of hydrogen bond.So microwave influence lifetimes of hydrogen bond was used to establish the intensity of microwave dependence of conductivity in aqueous sodium chloride solution. Due to water in the liquid phase is heated *via* the rotational excitation of water electric dipoles[5], the rotational Langvin equation was performed by using an asymmetrical double-well and periodic potential. All runs were started from describing the statistical average hydrogen-bond dynamics of aqueous sodium chloride solution under the constant temperature conditions.

EXPERIMENTAL

Sodium choride had more than 99.8 % purity. Banpo-1 solid state source is used to generate microwave power. The maximum output power of the generator is 100 W and frequency is 2450 MHz. A Tektronix DPO7254 oscillograph was used to measure the reflection coefficients from a special designed coaxial line probe[11], which is merged in the 0.5 mol L^{-1} NaCl aqueous solution. The measurement is carried out at 2450 MHz. The temperature of the solution in beaker was carefully controlled by using of KXS-A trough and a dielectric stirrer to keep the temperature constant. UMI-8 optical fiber thermometer with diameter of 1 mm was employed to measure the temperature near of coaxial line probe. PC was used to record the temperature change. The figure of experiment systems is shown in Fig. 1.

High power microwave employed here permitted the observation of the tangible nonthermal effect. Due to the sensitivity of the permittivity and the conductivity of the NaCl solution to temperature, the reflection coefficient S_{11} is strongly dependent on the temperature of the NaCl solution. We can use the characteristic of S_{11} to eliminate infulence of conductivity with temperature. A detailed description of the temperature control method for measuring conductivity is given elsewhere[1].

Fig. 2 shows NaCl conductivity was responsed to microwave power ranging from 5-40 w, clear changes in the microwave resonance curve were observed as the power exceed 25 w.

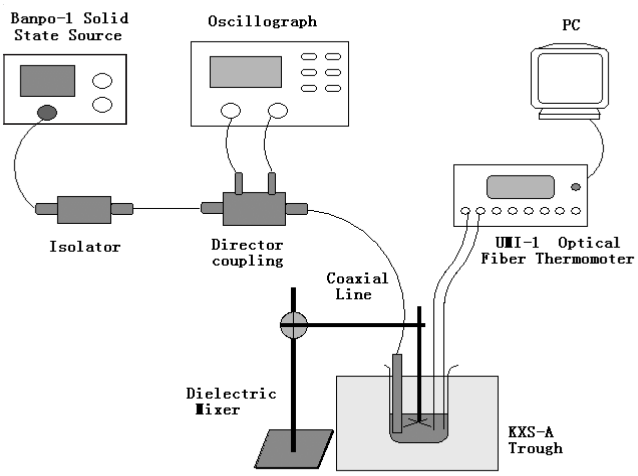

Fig. 1. Experiment system

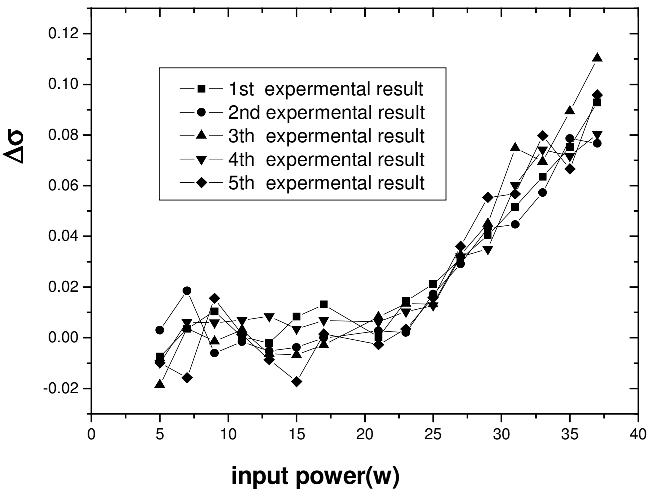

Fig. 2. Microwave input power influence the change of NaCl conductivity

It was found that field-induced effects on the system dynamics were more significant at higher power. The strongly nonlinear changed categorized as one of microwave nonthermal effects.

Our measurements indicate that intensity of microwave was up to 10^4 V m^{-1} in the vicinity of coaxial line probe when power of microwaves was above 25 w. Thus it is hypothesized that microwave can influence the hydrogen bond rearrangement dynamics in the presence of high intensity external microwave fields which made conductivity interrelated on intensity of microwave.

RESULTS AND DISCUSSION

Theory simulation

Model hydrogen bonding in aqueous NaCl solutions in external microwave fields: It was verified that water in the liquid phase is heated *via* the rotational excitation of water electric dipoles, which is delayed from the microwave electric field. Our starting point is the possibility that microwave radiation can excite rotational transitions which be described by Langevin equation for a dipole rotating about an axis normal to the plane of rotation[7],

$$I\phi(t)+\zeta\phi(t)+\frac{dV(\phi)}{d(\phi)}+\Gamma(t) \quad (1)$$

where I is the moment of inertia of a rotator about the axis of rotation, $\phi(t)$ is the angle specifying the orientation of a rotator and $\zeta\phi(t)$ and $\Gamma(t)$ are the frictional and random torques acting on a rotator due to the Brownian motion arising from the heat bath. It is assumed in accordance with the notation of Refs. 1 and 2 potential function (2) is used.

$$\frac{V(\phi)}{KT}=-2\sigma\cos\phi^2-\xi\cos\phi-\frac{\xi^2}{8(\sigma)}=-2\sigma\cos(\phi+h)^2 \quad (2)$$

where $\sigma=\frac{V_0}{KT}$ is the HB barrier height parameter, $\sigma=\frac{\mu E\cos\omega t}{(KT)}$ is the external microwave field parameter, E is the external microwave field intensity, $h=\frac{\xi}{(4\sigma)}$ and KT is the thermal energy. $V_0 = 0.24$ eV[7] is statistical average hydrogen-bond potential energy. The Box mueller algorithm and Bertolini fuction[8-10] is used for numerical solution.

Simulation results: In Figs. 3 and 4 can be seen life time of hydrogen bond less than 10^4 V m^{-1}, intensity of microwave field corresponds to the minimum value and seems to be not associated with the structural properties of the water molecules. But above 10^4 V m^{-1} the aqueous solution system has got its intensity dependence in life time of hydrogen bond indicating further that a structural property prevails in solution, which are in approximate qualitative agreement with experiment result. Hot solution is significantly less changed than the solution at room temperature, because the electric dipoles follow the microwave field with less phase lags due to less friction, which is consistent with our daily experiences.It also appears that microwave energy is transferred to the kinetic and intermolecular energies of water,the former is not concerned because of simulation under heat bath. where the latter is stored internally to rearrange water molecules induce the change of aqueous solution conductivity.

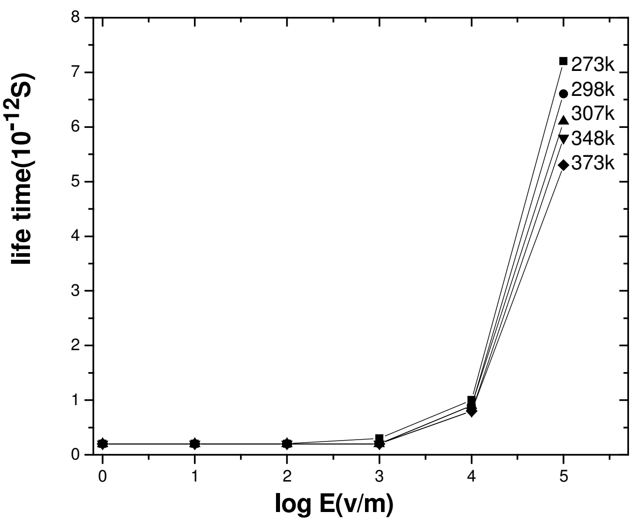

Fig. 3. Microwave intensity influence life time of hydrogen bond

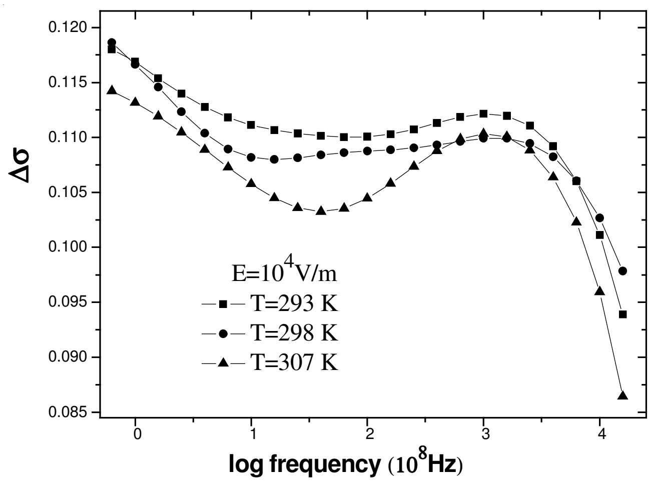

Fig. 4. Microwave frequency influence the change of conductivity

Summary: In this paper, we have studied the dynamics process of aqueous NaCl solution by microwave irradiation. Microwave energy is partly transferred to intermolecular energies of water, which induce intensity dependence of life time of hydrogen bond and conductivity in aqueous NaCl solution at microwave frequency. The strongly nonlinear change can be categorized as one of microwave nonthermal effects.

REFERENCES

1. K.-F. Han, *IEEE Trans*., **29**, 48 (1991).
2. D.A.C. Stuerga and P. Gaillard, *J. Microwave Power Electromagn. Energy*, **31**, 101 (1996).
3. S. Chowdhuri and A. Chandra, *J. Chem. Phys*., **115**, 3732 (2001).
4. A. Babajanyan, J. Kim, S. Kim, K. Lee and F. Barry, *Appl. Phys. Lett*., **689**, 183504 (2006).
5. M. Tanaka and M. Sato, *J. Chem. Phys.*, **126**, 034509 (2007).
6. C.J. Burnham, M.K. Petersen and T.J.F. Day, *J. Chem. Phys*., **124**, 024327 (2006).
7. Y.P. Kalmykova, *J. Chem. Phys*., **123**, 094503 (2005).
8. R.L. Honeycutt, *Phys Rev*., **A45**, 600 (1992).
9. R.F. Fox, *Phys Rev*., **385A**, 938 (1988).
10. J.A. Roberts, X. Zhang amd Y. Zheng, *J. Chem. Phys*., **100**, 1503 (1994).