Proceedings of the International Conference on Biomedical Engineering and Systems
Prague, Czech Republic, August 14-15, 2014
Paper No. 59

Increase of Dissolved Oxygen in Water by Applying High Electric Field and Its Application to Bio-system

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Abstract **-** In this paper, firstly it is shown that water evaporation is promoted or restrained by applying high AC electric field to the water in beaker between electrodes. Next, the Raman spectroscopy is introduced to analyse the cluster-structure of the water, and finally the increase of dissolved oxygen is found in the water. As an application, the water rich in dissolved oxygen is added to a bio-system, and a growth promotion effect is observed from radish sprouts.

Keywords**:** Water, Electric field, Water evaporation, the Raman spectroscopy, Dissolved oxygen, Bio-system.

1. Introduction

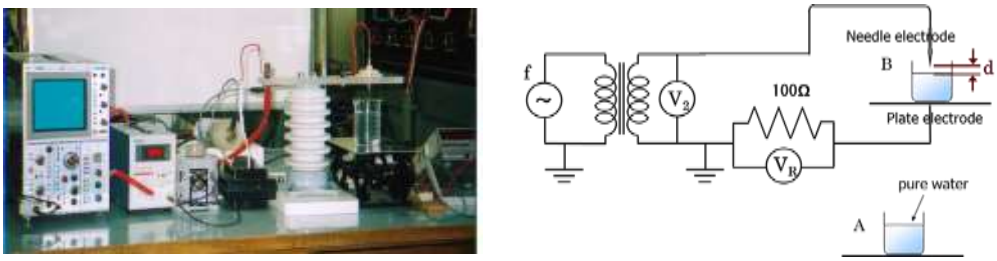
The phenomenon known as electric wind was one of the earliest manifestations of gaseous discharge and a subject of active investigation among electrical experimenters. After the investigation, the electric wind mechanism was applied to fluid pumps, high voltage generators, loudspeakers, thermoelectric converters and other devices (Robinson, 1962). Then, the electric wind was considered later as ionic wind by introducing needle-plate or wire-plate electrodes, and was expanded to the removable function of SO_2 gas by a wet-type electrostatic precipitator (Adachi, 1973). Furthermore, it has been shown that the combustion speed of gas and liquid increases considerably, and the heat transfer is promoted or retarded by electric field (Asakawa, 1976). In addition, the water flow in beaker caused by the ionic wind was considered analytically as electromagnetic hydrodynamics (EHD) (Yabe et al., 1978), which has been discussed in detail (Chang, Watson, 1994). Especially, the EHD fluid motion induced by surface corona discharge was treated for the visualization (Ohyama, Kaneko, 1998).

On the other hand, it has been told as an oral tradition in Japan that the growth of plants is promoted by thunderstorm, that is, the electric field and the rain.

In this paper, for studying the oral tradition, we firstly reproduce the ionic wind between needle-plate electrodes, and show that the water evaporation in beaker is promoted or restrained by applying high AC voltage to electrodes. Next, the Raman spectroscopic analysis is introduced to analyse how the cluster-structure of water is changed by the electric field, and the change is shown to correspond to an equivalent temperature-difference of water. Then, we find an increase of dissolved oxygen in the water by applying high AC or DC voltage to plate-plate electrodes. Finally, the water rich in dissolved oxygen is applied to a bio-system in order to show a growth promotion effect of radish sprouts.

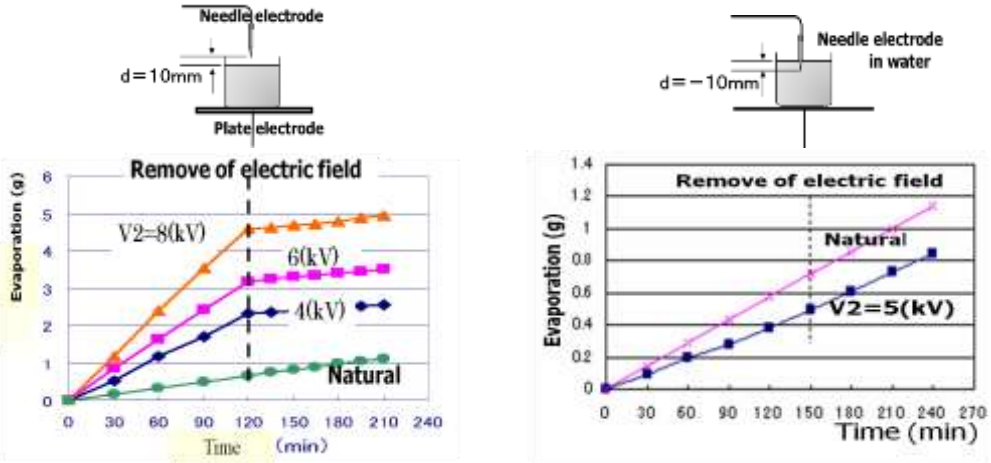
2. Promotion and Restraint of Water Evaporation

An equipment for the experiment to generate ionic wind is shown in Fig. 1(a), and the equivalent circuit is given in Fig. 1(b), respectively. An AC 60Hz source is supplied in the primary circuit, and the AC high voltage is applied to the electrodes. The secondary voltage is V_2, and the secondary current I is obtained



(a) Equipment (b) Equivalent circuit

Fig. 1. Experiment.



(a) Promotion (d=10mm) (b) Restraint (d=10mm)

Fig. 2. Water evaporation.

by measuring the voltage V_R at both ends of the resistor. The natural evaporation and the evaporation under electric field of pure water in beakers A and B are observed, respectively. After setting up needle-plate electrodes, the quantity of evaporation is measured by an electronic balance.

For the case of needle-plate electrodes, the distance d between the tip of needle and the water surface is d=10mm in Fig. 2(a), and the voltage V_2=4, 6 or 8kV is applied. It is observed that the quantity of evaporated water increases in accordance with the V_2 (Krasikov, 2000). Moreover, since the ionic wind reaches from the tip of needle to the surface of the water, the water temperature decreases approximately by 1℃. However, the evaporation speed of water does not return to the speed of natural evaporation after removing the electric field. In general, the natural evaporation speed of water is known to depend on the room temperature, the humidity and the atmospheric pressure.

For the case of d=-10mm in Fig. 2(b), that is, when the tip of needle is in water, a partial discharge is not generated, and the EHD fluid motion is not created. However, it is interesting to note that the evaporation of water is restrained, and the evaporation speed is lower than that of natural evaporation (Kawamoto, Yamachi, 2003). Here, it should be emphasized that no ionic wind is generated, and the water temperature has no change before and after applying the electric field. In this case, the restraint of water evaporation is thought to be caused by the electric force among water molecules under electric field.

3. Raman Spectroscopic Analysis

In this Section, the Raman spectroscopy is introduced to analyse how the cluster-structure of water is affected by applying high electric field.

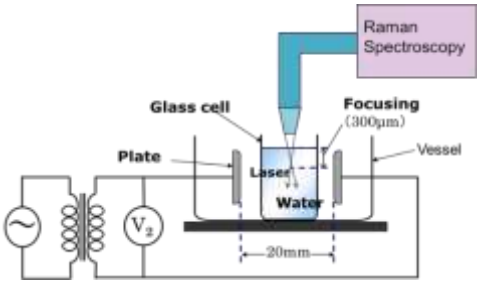
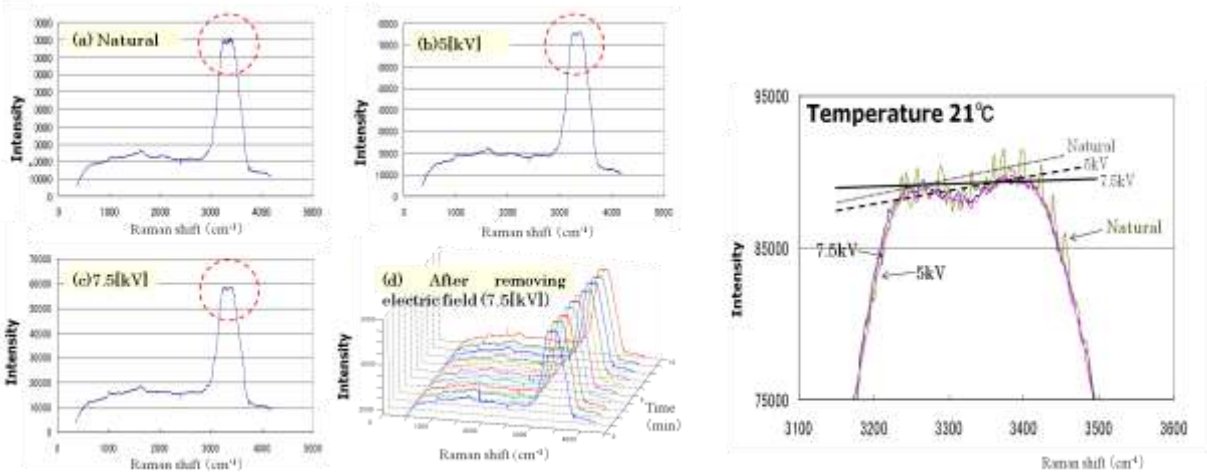


Fig. 3. The Raman spectroscopy circuit.



(a) Intensity (b) Angular difference

Fig. 4. The Raman spectroscopic analysis.

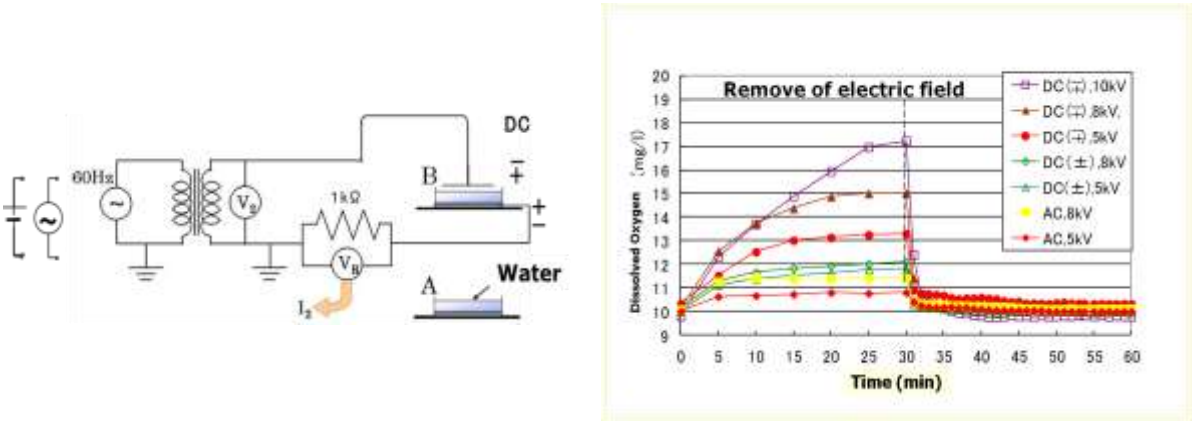
The Raman spectroscopy circuit is illustrated in Fig. 3. A high AC electric voltage 5.0 or 7.5kV is applied to plate-plate electrodes with a distance 20mm placed on the outside of a small glass cell for water, and the Raman spectroscopic laser beam is focused on the depth 300 μ m in the water. Then, the intensity of scattering light is measured, and the Raman spectra with two peaks between the Raman shift 3,200 and 3,500cm^{-1} are given for the water under electric field in Fig. 4(a). The peak data of the three cases (a) – (c) in Fig. 4(a) are piled in Fig. 4(b).

In general, the scattered intensity under constant excitation power is constant and independent of the intensive quantity that gives rise to the spectral changes, for pure water. For example, absolute and isotropic Raman spectra with two peaks are measured, and exact isosbestic points are obtained from the spectra for water between 3 and 85℃ (Walrafen et al., 1986).

For the experiment, we find each slope of three tangent lines of the spectra with two peaks in Fig. 4(b), and have an equivalent temperature-difference 10℃ of water corresponding to the angular difference of slope between the natural case (no electric field) and the case of 7.5kV. Therefore, it is thought that a change of the Raman spectra by applying AC voltage 7.5kV corresponds to that of the cluster-structure of water at different temperatures. That is, the water evaporation would be restrained by applying high electric field, which agrees qualitatively with the result Fig. 2(b) in Section 2.

4. Increase of Dissolved Oxygen in Water

In Section 3, we have considered how the cluster-structure of water is changed by applying high electric field. Therefore, it is discussed in this Section what changes quantitatively in the water under electric field, by using the multi water quality meter MM-60R, DKK-TOA CORPORATION (Web-1).



(a) Measurement circuit (b) Dissolved oxygen level

Fig. 5. Dissolved oxygen in water.

The measurement circuit for dissolved oxygen in the water and the measured data are given in Fig. 5. In the circuit, plate-plate electrodes are used in order to prevent the generation of ionic wind, and the high AC 60Hz or DC voltage is applied to the electrodes for the beaker B, where the beaker A is not under the electric field. The result shows in Fig. 5(b) that the dissolved oxygen level in the water increases uniformly after applying the AC or DC voltage, and decreases rapidly after removing the electric field. Especially, the quantity of dissolved oxygen depends on the voltage value of AC or DC. Therefore, for example, the difference of saturated dissolved oxygen level between two cases (AC 0 and 8kV) at the water temperature of 19.7℃ corresponds to an equivalent temperature-difference between 10 and 20℃ (Web-2) under no electric field. From the result, it is thought that the dissolved oxygen increased in the water would be ionized-oxygen coming from the atmosphere after the change of cluster-structure in water under electric field.

5. Its Application to Bio-system

As an application of the water rich in dissolved oxygen, we introduce a bio-system shown in Fig. 6, and observe a growth of radish sprouts by adding the water. Since the growth effect of root-zone environment with rich oxygen level is known (Kozai et al., 1992), we especially make a comparison of the beaker A (no electric field) with the beaker B (electric field by applying AC 8kV) in order to find a growth promotion effect of radish sprouts. Then, as shown in Fig. 7, the beaker B has a clear difference from A in the growth after 4 days (Ogawa et al., 2008).

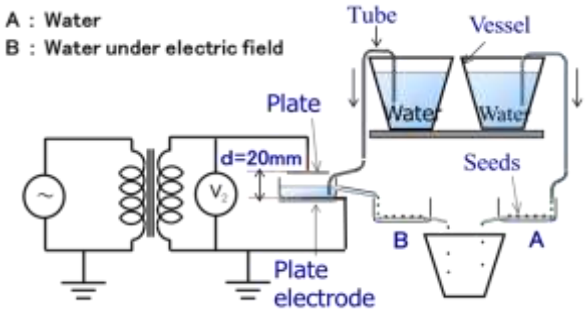


Fig. 6. Bio-system.

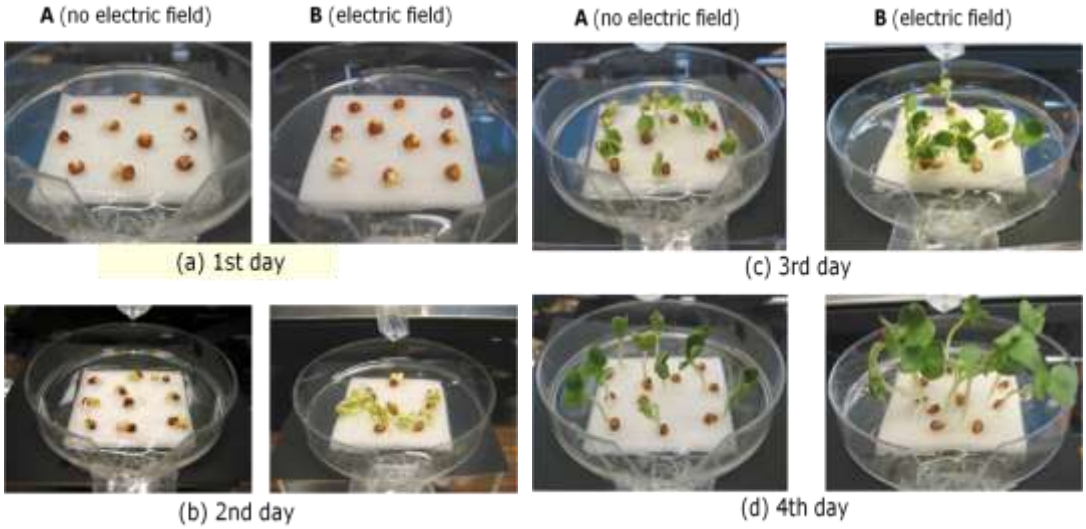


Fig. 7. Growth promotion of radish sprouts.

5. Conclusion

We have discussed firstly the ionic wind generated by applying AC electric field to the water in beaker between needle-plate electrodes, and have shown that the water evaporation is promoted or restrained. Next, the Raman spectroscopic analysis is introduced in order to analyse how the cluster-structure of water is changed by applying electric field. Then, we have found quantitatively the increase of dissolved oxygen in the water, and have obtained an effect of growth promotion from radish sprouts in the bio-system.

According to the effect of growth promotion, the increase of dissolved oxygen in water by applying electric field could be an important fact for the oral tradition which has been told in Japan.

Acknowledgements

The author would like to thank Professor Y. Nakayama, Osaka University, for his encouragement on the Raman spectroscopy, and the graduate students at Osaka Prefecture University for their helpful discussion and experiments.

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