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Electrical Dehydration of Organic Gels

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We have reported that agar gel can be dehydrated electrically at a considerable faster rate than the natural evaporation. Rather amount of water begin to exude from a specimen gel at the electrode when the electric current is started to pass through the gel. As the electric power applied to the specimen gel is very small, the Joule heating of the gel was negligible to affect this dehydration. Several other organic hydrogels were observed and found to exhibit the same dehydration phenomenon. It seems that the electrical dehydration is a common characteristic of hydrogels. This suggests interesting electrical interactions between polymer network and solvent molecule of hydrogels. The rate of this dehydration seems to depend on the density of the electric current.
Key words: organic gel, hydrogel, agar, dehydration

1. INTRODUCTION

Polymer network and solvent molecule of gels interact to show interesting behavior during the drying process, and some hydrogels have been reported to turn into glass like materials [1–3].

During investigating electrical characteristics of hydrogels, we have found and reported that agar gel can be dehydrated electrically at a considerable faster rate than the natural evaporation [5]. Rather amount of solvent water begins to exude from a specimen gel at the surface which is in contact with the electrode when the electric current is applied to pass through the gel.

The present study reports that several organic hydrogels exhibit the same dehydration phenomenon. It seems that the electrical dehydration is a common characteristic of hydrogels, however, the strength of dehydration quite differs among the gels,

2. EXPERIMENTALS

For the purpose of investigating electrical dehydration of gel, it is necessary to measure electric current, voltage and to estimate the degree of dehydration, in addition, to consider the influence of natural evaporation. In the previous study [5], we introduced a method to fulfill this requirement as follows: (1) a pair of gel blocks is prepared, (2) electric current is applied to one gel block sample while another gel block for estimating natural evaporation is kept under the same condition with the exception of not applying electric current, (3) after appropriate period, both gel blocks are removed from the experimental system for measuring their weights, (4) these gel blocks are placed original position again, then this process is repeated from the step (2).

As shown in Fig. 1, we employed the same experimental system introduced in the previous study [5] with a modification that each electrodes has a sheet of graphite on its surface. As a result, the specimen gel is no longer in contact with metal surfaces of the electrodes. This is intended

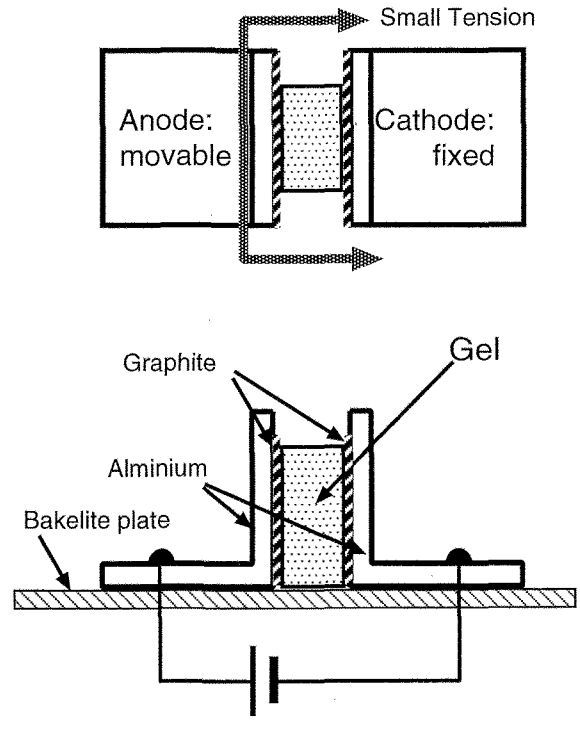

Fig. 1 A schematic diagram of experimental system for observing change in the weight of the hydrogel specimen due to electrical dehydration. The cathode is fixed to the Bakelite base plate and anode is not fixed and pulled to the cathode with a plastic tape tied to a hanging weight of 50 g.

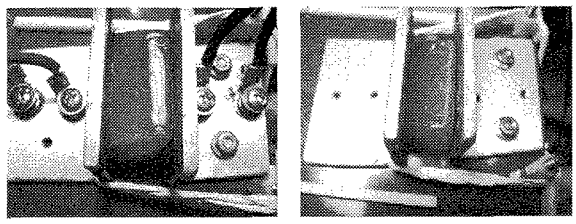

Fig. 2 Pictures of an agar specimen between wired electrodes (left) and a reference agar specimen for natural evaporation between dummy electrodes without wires (right).

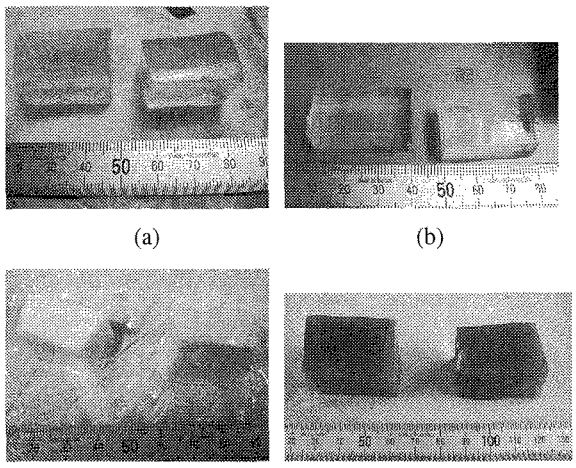

Fig. 3 Pictures of four pairs of specimen of organic gels. (a)Agar, (b)Gelatin, (c)Egg White, and (d)Konjac.

to prevent the problem that the metal ion, from the electrode, permeates into specimen gel, which was found in the previous study [5]. Carbon particles of graphite tend to stick to the surface of the gel, however, they does not seem to penetrate into the gel. Figure 2 shows an example of actual usage of the system.

In the present study, we investigated agar, gelatin, egg white gel and konjac gel. While gelatin were 1st grade reagent (Kishida Chemical Co.,Ltd.), other gels used in this study were foodstuffs on the market.

Agar powder was dissolved in distilled water at a concentration of approximately 1.0 wt%, heated to boiling and cooled down to form a gel. Then a pair of blocks was cut from the lump of gel. Those blocks were approximately 25 mm × 20 mm × 10 mm in dimension (Fig. 3(a)). Gelatin granules were also dissolved in water at a concentration of approximately 2.0 wt%, heated and cooled down to form a gel. A pair of blocks was cut to have a dimension of approximately 30 mm × 20 mm × 15 mm (Fig. 3(b)). Egg white naturally contains water, however, which does not seem sufficient for this study, distilled water was mixed until nearly twice its weight and then it was boiled for gelation. The dimensions of egg white gel blocks were roughly 20 mm × 10 mm × 15 mm (Fig. 3(c)). Konjac gel for food were cut to blocks of about 30 mm × 25 mm × 25 mm (Fig. 3(d)).

Figure 4 shows a picture of the present experimental system used for agar, at one hour and several minutes after applying electric current to the specimen gel block. Comparing with Fig. 2, it is easily seen that the gel specimen between electrodes had shrunk considerably.

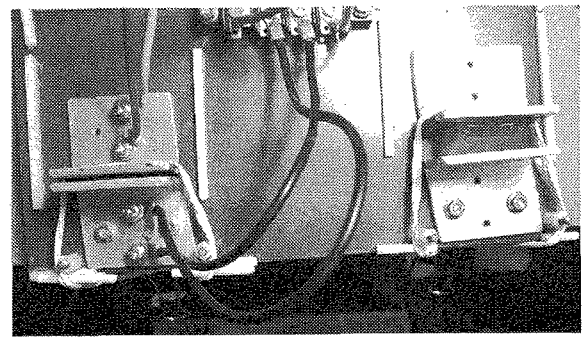

Fig. 4 A picture of the experimental system at one hour and several minutes after applying electric current to a agar gel specimen (left side) with another gel block (right side) simultaneously placed for natural evaporation.

Fig. 5 Pictures of the water discharged from organic gel blocks during the present study: ejected water flowed down the agar gel to form a large drip (left), and water come out with bubbling from egg white gel at the surface in contact with cathode (right).

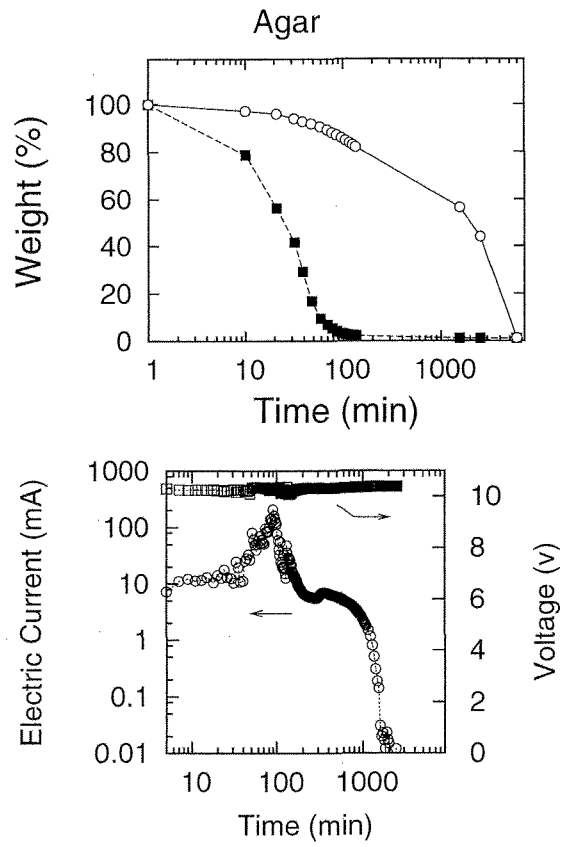

Fig. 6 Observed changes in the weight of the agar gel. Closed box denotes the weight of the agar gel specimen for electrical dehydration and open circle denotes that of another specimen for natural evaporation (top). Recorded electric current and voltage during the experiment (bottom).

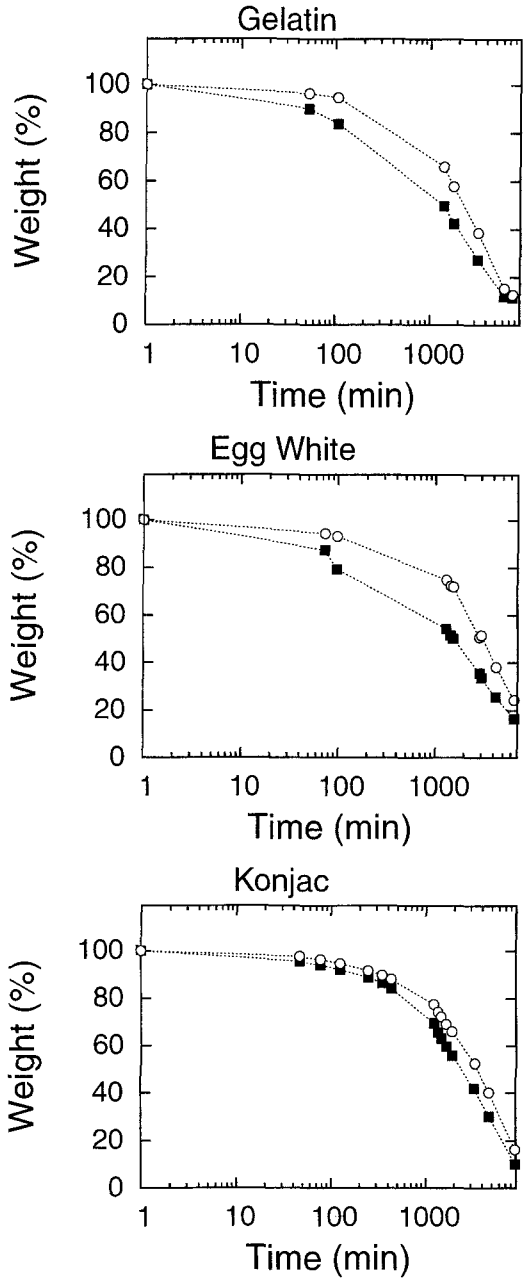

Fig. 7 Observed changes in the weights of organic gels during the dehydration experiment. An unnatural dip in the weight data of the egg white gel near 100 min. might be caused by the fact that some portion of the gel is attached to the electrodes and teared off from the gel block in weight measuring procedure.

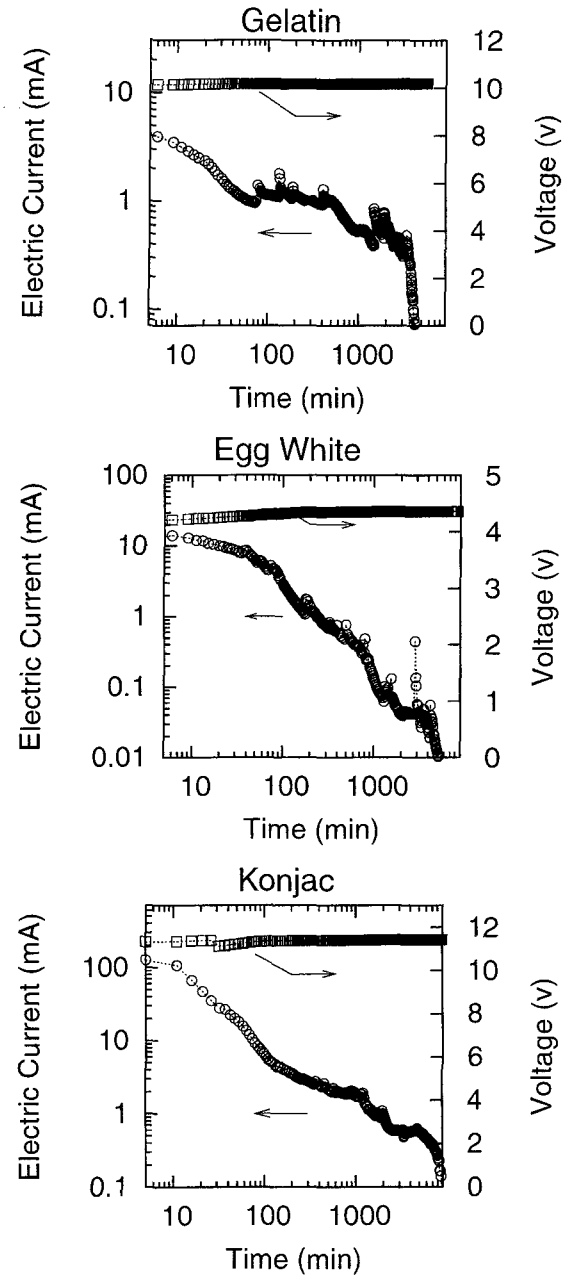

Fig. 8 Recorded electric current and voltage during the electrical dehydration experiment of organic gels.

3. RESULTS AND DISCUSSIONS

Examples of the water leaked out from gel blocks due to the electrical dehydration are shown in Figure 5. In the present study, it is observed in all investigated organic gels that the solvent water of the gel begins to exude from the gel, as the electric current begins to flow through the gel specimen. However, the amount of discharged water strongly depends on gel substance, in particular, agar shows extremely stronger response than other gels in this study.

3.1 Agar

Figure 6 shows observed changes in the weight of the agar gel specimens, and the recorded electric current and voltage during the experiment. It is easily seen that, in this case, the electrical dehydration of agar gel has more than 50 times faster dehydration rate than natural evaporation. In the present study, we have achieved to observe from the beginning to the end of the phenomenon of the electric dehydration, which is not completed in the previous study. It is natural that the voltage data shows almost constant because a voltage stabilized power supply was used. However, electric current data shows large and incomprehensible change in this case; it gradually increased until 100 minutes, then decreased. Gradual

decrease of electric current is consistent with the fact that the conductance of the agar gel decreases with the progress of dehydration [5].

This increase of electric current in early stage of the experiment may be explained as follows: The water exuded from the surface of the gel stays for a while between electrode and gel, and thus it separates the direct contact between them. Because the amount of exuded water gradually decreases with the progress of dehydration, this contact gap also decreases and the electric current increases. Therefor, if an electrode which can maintain contact against the surface of agar gel is used, agar may be dehydrated still more rapidly.

3.2 Gelatin, Egg white and Konjac gels

Observed weight changes of other three substance gels are shown in Fig. 7 They show similar behavior on the whole; electrical dehydration is not strong and after several hundred minutes, there are few difference between each pair of weight change data. Egg white gel used was not physically tight enough and tended to stick to the electrodes, this gel could lost its fraction at weight measuring procedure, and therefore the unnatural dip in its weight data near 100 min. might appeared. Nevertheless, gelatin and egg white gels showed a particularly similar behavior, it may suggests that structural resemblance between these gels has some relation to this similarity.

Electrical data in Fig. 8, show some difference among these gels. In spite of the fact that konjac gel allowed much higher electric current of over 100 mA than other gels at the beginning of the experiment, the amount of water discharged from konjac gel was much less than other gels. Although it is clear that electric current intensity does not directly relate to the electric dehydration, the strength of this dehydration on the same gel depends on the electric current. This may suggest that electric conduction of organic hydrogel does not consist of a single mechanism.

In electric current data, a jump occurred after almost every measuring procedure for the weight of the gel, which was removed from the electrodes and installed between them again. This is explained that the water remaining on the surfaces of the electrodes and the gel is removed more or less in that procedure, and as a result, the contact between electrodes and the gel becomes better.

4. SUMMARY

We have experimentally investigated electrical dehydration in four organic gels, namely agar, gelatin, egg white and konjac. It seems that the electrical dehydration is a common characteristic of hydrogels. However, this dehydration strongly depends on gel substance, in particular, agar shows extremely stronger response than other gels in this study. Agar gel of 1 wt% concentration loses over 80 wt% of solvent water within 50 minutes. The fact that Konjac gel has higher conductivity and less strength of electrical dehydration suggest that electric conduction mechanism of organic hydrogel has important role in this dehydration phenomenon.

In addition, in order to reveal the origin of the strong electrical dehydration in agar, it is important to find a material which shows dehydration similar to that of agar.

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