Magnetized Nanobubble Water Formed Under Pulsed-Magnetic Field

K. Uehara[1] and Y. Yano[2]

[1]Uehara Research Institute of Advance Science and Technology, Sakai 593-8315, Japan
[2]Nano.Technology Inc., Tokyo, Japan

Magnetized nanobubbles formed in mineral water (Volvic) under an external regular pulsed-electromagnetic field (2BD6, 1.8 mT) were observed by a dynamic light-scattering method and AFM images. 0.03 mT magnetization was detected for more than 1 day. A possible structure of magnetized nanobubble is proposed.

Index Terms—**AFM image, light-scattering, magnetized nanobubble, pulsed-electromagnetic field, water.**

I. Introduction

MAGNETIC treatment of water has been carried out for practical use, for example, from the viewpoint of application such as protection from corrosion of water steel pipe [1] and is applying in growth acceleration of plant and animal and in therapy without any theory. Most scientist has been suspicious for the presence of the magnetic treated water with magnetic memory because pure water has never been magnetized under weak magnetic field. Water molecule forms a dynamic cluster repeating ultra-fast hydrogen-bonding formation and dissociation in 170 fs $(10^{-15}\ \mathrm{s})$ [2]. It is not a static solid iceberg (cluster) [3] but a dynamic liquid structure and water molecule itself is not a candidate for the media of magnetic memory. Recently stable nanobubble water has been found as a new structure of the water and confirmed by a dynamic light-scattering method [4]. The core of water structure is nanobubble covered by negative charges on the surface and surrounded by protons and metal ions. Magnetic field effects on water have been studied from the Monte Carlo simulation of liquid water in a lower magnetic field (0.2 T) has been shown to increase the number of monomer water involving increase of the tetrahedrality [5]. The increase in refractive index with magnetic field (under high magnetic fields) has been attributed to increased hydrogen bond strength [6].

The present paper succeeded to observe a memory of magnetization imprinted by external cyclic pulsed-electromagnetic field into mineral water. To be interesting, the magnetization of water is correlated with a decrease and an increase in pH of the water, suggesting a trap of free hydrogen oxide ions followed by protons in bulk water into the reformed water structure, nanobabble. We also succeeded to observe AFM images of the nanobubble on the mica coated by poly-L-lysine. A possible mechanism of magnetization is proposed from the viewpoint of the formation of nanobubble water.

II. Experimental Setup

A mineral water (Volvic)and ultra-pure water (Wako Pure Chemical, Ltd.) were used as a sample water. Pulsed electromagnetic field was supplied to 250 ml of water by PEI-201 and MFE-901 (Nano • Technology, Inc., Tokyo), which is constructed by three electromagnetic coils, L1, L2, L3 (Maruha Electronics Ltd., Nagoya), arranged by delta-form and a controle circuit attached with an IC-card encoded 00-2BD6-FF (00 is ULF signal, in this experiment no work was done, 2BD6 means pulse time 112 ms, FF means rotation times 255). Electromagnetic coil L1, L2, L3 were excited in turn for 112 ms, respectively, for anti-clock direction. 1.8 mT of magnetic flow was observed. As a control, a commercial ferrite magnet adjusted a distance to 1.8 mT magnetic flow was employed for static magnetic field.

The magnetization of water was monitored by a hole sensor probe TM-601AXL (Advantest O/E, Ltd., Tokyo) connected to a Tesla-meter TM-601(Kanetec Ltd., Tokyo) offset the natural geomagnetic field in an oven thermostatically controlled at constant temperature (25°C). 250 ml water was pored into a sample bottle held with a cap attached by a hole sensor probe which was dipped into the water (Fig. 2) and vertical magnetic flows were measured. After pulsed magnetic field was applied for pulse time 112 ms × 2550 cycle times (00-2BD6-FFx10), water pored into a sample bottle and was kept in a constant temperature oven (25°C) and then, magnetic flux of water was measured. The magnetic flux values were compensated automatically from natural geomagnetic field. Non-treated water before application of pulsed magnetic field did not show any magnetization or magnetized weakly (S-pole) by a natural geomagnetization. Mineral water applied pulsed-magnetic field clearly showed a positive magnetization (N-pole).

PH of the water before and after magnetization was measured by a pH meter (PH sensor: Omega TB18131, USA; Digital multi-meter: Sanwa Electric Instruments PC-510, Tokyo) under nitrogen atmosphere to avoid contact of air.

Particle size of nanobubble in water was measured by a dynamic light-scattering apparatus (Zeta-potential & Particle size Analyzer) Model ELSZ-2 plus (Otsuka Electronics, Hirakata, Japan) and NanoSight LM10 (NanoSight Ltd., UK).

AFM images of the nanobubble on the mica coated by poly-L-lysine were measured by a high speed AFM Nano Live Vision (Research Institute of Biomolecular Metrogy Co., Ltd., Tsukuba, Japan).

III. Results and Discussion

We succeeded to measure the magnetization (memory) of water imprinted by pulsed magnetic field applied for pulse time

Manuscript received February 22, 2011; accepted May 13, 2011. Date of current version September 23, 2011. Corresponding author: K. Uehara (e-mail: uehara_ion-eng@nifty.com).

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TMAG.2011.2157898

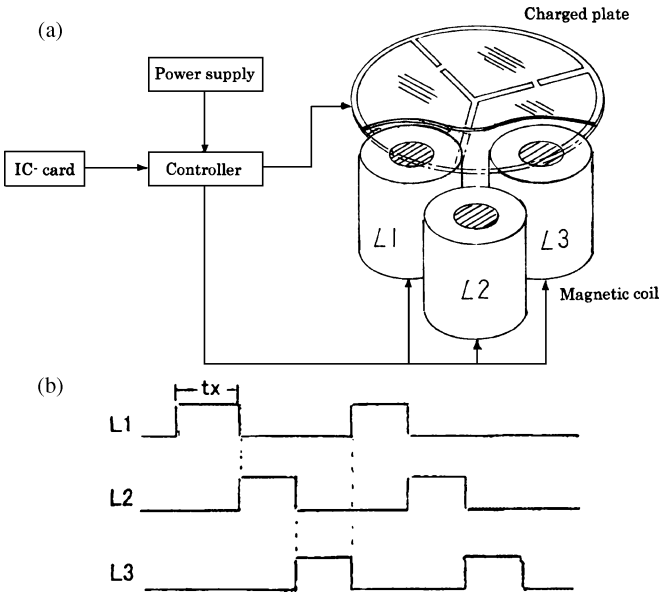

Fig. 1. Block diagram of PEI-201 (a) and pulsed electromagnetic field pattern (b). 2BD6: tx = 112 ms.

Fig. 2. Set up of sample-tube and Tesla-meter (lower) and hole sensor held with a cap (upper).

112 ms × 2550 cycle times (00-2BD6-FFx10). Fig. 3 shows an example of the time-course of the magnetization of water after application of 00-2BD6-FFx10. About 0.03 mT increase in magnetic flux was observed. For reference's sake, natural geomagnetic field (0.03 mT) and static magnetic field with same strong magnetic flux (1.8 mT) by a commercial ferrite magnet gave no change or less effective (data not shown).

PH change under nitrogen atmosphere before and after application of pulsed magnetic field were as follows. For application of 00-2BD6-FF, the pH value of before application (7.189) was changed to 7.143 (0h) → 7.210 (1h) → 7.227 (2h) → 7.456 (6h) with time lapse after stopping application of pulsed mag-

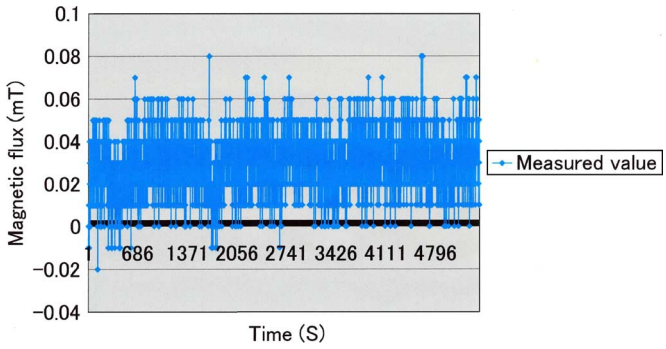

Fig. 3. Time (sec) -course of the magnetic flux of water (mT) after application of pulsed magnetic field 00-2BD6-FFx10.

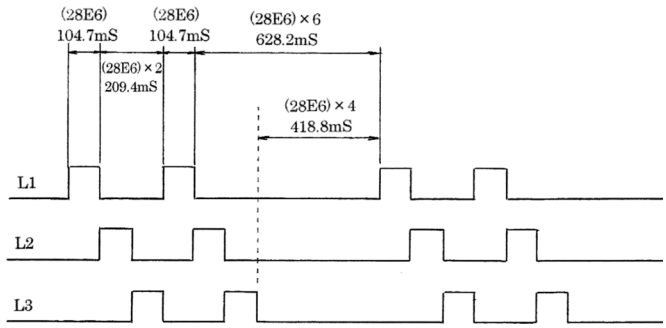

Fig. 4. Pulsed electromagnetic field pattern of ULF. 28E6 = 104.7 mS, P = pause (104.7 mS). L1: 28E6_Px2_28E6_Px4. . .; L2: P_28E6_Px2_28E6_Px4. . .; L3: Px2_28E6_Px2_28E6_Px4. . ..

netic field. For, 2550 cycle times application (00-2BD6-FFx10), pH value changed slightly higher; 7.145 (0h) → 7.210 (1h) → 7.228 (2h) → 7.475 (6h). The pH value is mean of ten runs and error range is below 0.033 pH unit. These pH changes show that proton activity increases immediately after the time stopping application of pulsed magnetic field and decreases gradually with time lapse.

A commercial ferrite magnet (surface magnetic flow 66 mT) adjusted a distance (51 mm) to 1.8 mT magnetic flow showed a similar pH pattern but less effective (data not shown). It might be originated from a proton release and trapping of proton by a re-organization of water structure induced by a magnetic field. These results suggest that pulsed magnetic fields assist effectively weakening the van der Waals bonding between water and gas molecule such as oxygen to form the nanobubble which the nanobubble/water surface is covered by anion such as hydroxyl ion to form a negatively charged core, resulting in a gradual trapping of cation such as proton and ferric ion. Trapping of magnetized metal ion such as Fe, Co, or Mn onto nanobubble surface might induce a fairly strong magnetic dipole moment intersect with the nanobubble. Concomitant decrease and increase in pH of water might be induced by rapid import of OH^- and slow trapping of H^+ into nanobubble surface.

For pure water, these effects were very small and poorly reproducible. No changes in pH have been observed for the doubly distilled water passed through magnetic fields in the range 0 to 24,000 G [7]. The nanobubble is stabilized and increased negative pressure by minus charges [8]. The nanobubble is stable for a few days under room temperature.

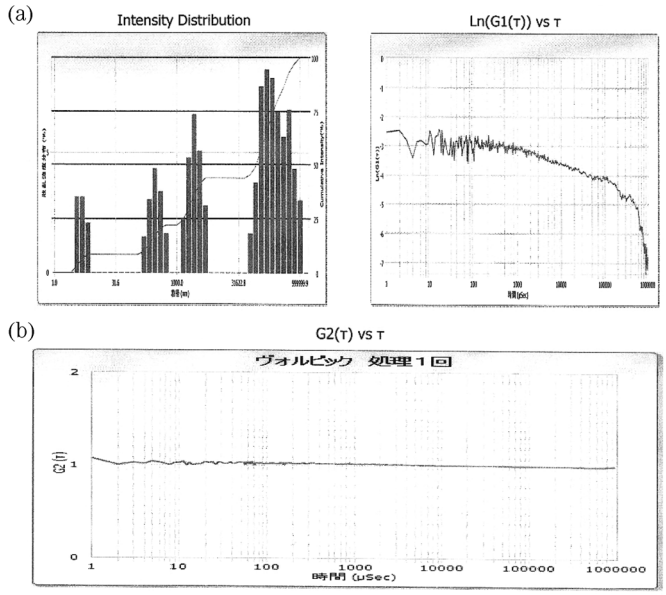

Fig. 5. Particle size of nanobubble in Volvic water before and after pulsed electromagnetization of ULF. (a) Volvic-ULF-2BD6; (b) Volvic-ULF-2BD6-ULF.

TABLE I
SUMMARY OF THE NANOSIGHT DATA

No.	Mean particle diameter	Total concentration
1	366 nm	0.19E8 particles/mL
2	215 nm	0.06E8 particles/mL
3	305 nm	0.40E8 particles/mL

1: Volvic(Base)
2: Volvic-ULF(FF)
3: Volvic-ULF(FF)-2BD6(FF×10)

We found irregular pulsed electromagnetic field (ULF, 1.8 mT) induced a collapse of the nanobubble. Fig. 4 shows the pulsed electromagnetic field pattern of ULF.

Particle size of nanobubble in Volvic water before and after pulsed electromagnetization of ULF are shown in Fig. 5.

The pulsed electromagnetic field pattern of 2BD6 induced the formation of nanobubble and another pattern of ULF might induce collapse of the nanobubble. NanoSight data also support the above results. Scattering intensity distribution and mean diameter of nanobubble are increased after pulsed electromagnetization of 2BD6 but decreased after pulsed electromagnetization of ULF. Table I summerizes the NanoSight data.

AFM images of the nanobubble on the mica coated by poly-L-lysine were measured by a high speed AFM (Nano Live Vision).

Results of 2BD6 nanobubble before (a) and after (b) push-in are shown in Fig. 6.

Push-in experiment of the 2BD6 nanobubble made the height 63.6 nm to 24.6 nm, suggesting that the nanobubble might have elasticity.

Formation of nanobubble might be induced by the degassing effect of low electromagnetic field [9]. Dissolved gas in water

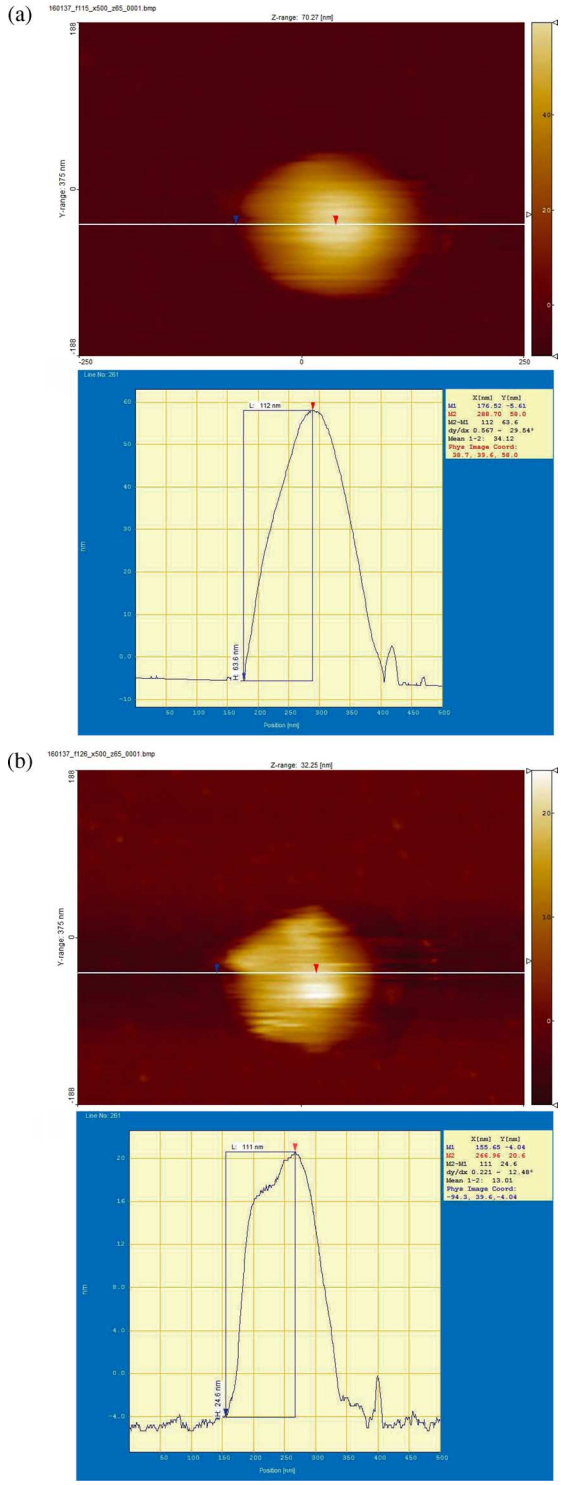

Fig. 6. AFM images of 2BD6 nanobubble before (a) and after (b) push-in ($\mathrm{XY} = 500\ \mathrm{nm} \times 355\ \mathrm{nm}$, $\mathrm{Z} = 65\ \mathrm{nm}$). Hight of particle is 63.6 nm and 24.6 nm, respectively.

stabilized by van der Waals force is degassed in the low electromagnetic fields (2BD6) to make a nanobubble. The mechanism of ULF disruption of nanobubble is in progress.

The structure and mechanism of the magnetized 2BD6 nanobubble may be explained by Fig. 7.

Anions such as hydroxide, chloride, and carbonate at gas-water interface may stabilize the nanobubble and counter

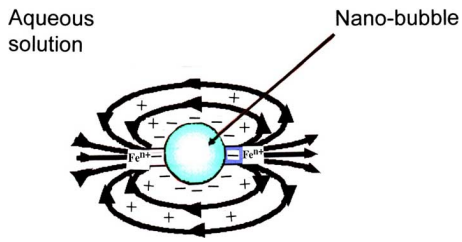

Fig. 7. A possible structure of the magnetized nanobubble.

cations such as proton, sodium, ferrous, and ferric exist in the surface of nanobubble. Trapping of magnetized metal ion such as Fe(II) and Fe(III) onto nanobubble surface might induce a fairly strong magnetic dipole moment intersect with the nanobubble.

ACKNOWLEDGMENT

The authors acknowledge Mr. Nakamura of Otsuka Electronics, Ms. Irie of Quantum Design (NanoSight), and Ms. Kanegami (AFM) for their measurements of the nanobubble.

REFERENCES

[1] V. I. Klassen, *Magnetization of Water Systems*. Moscow: Nauka, 1982.
[2] M. V. Fernández-Serra and E. Artacho, *Phys. Rev. Lett.*, vol. 96, p. 016404, 2006.
[3] G. Nemethy and H. A. Scheraga, *J. Chem. Phys.*, vol. 36, pp. 3382–3400, 1962.
[4] T. Koishi *et al., Phys. Rev. Lett.*, vol. 93, p. 185701, 2004.
[5] K. X. Zhou *et al., J. Appl. Phys.*, vol. 88, pp. 1802–1805, 2000.
[6] H. Hosoda, H. Mori, N. Sogoshi, A. Nagasawa, and S. Nakabayashi, *J. Phys. Chem. A*, vol. 108, pp. 1461–1464, 2004.
[7] T. I. Quickenden, D. M. Betts, B. Cole, and M. Noble, *J. Phys. Chem.*, vol. 75, p. 2830, 1971.
[8] M. Takahashi, *J. Phys. Chem. B*, vol. 109, pp. 21858–21864, 2005.
[9] V. Shatalov, I. Noga, and A. Zinchenko, *Electron. J. Biol.*, vol. 5, no. 5, pp. 67–72, 2010.