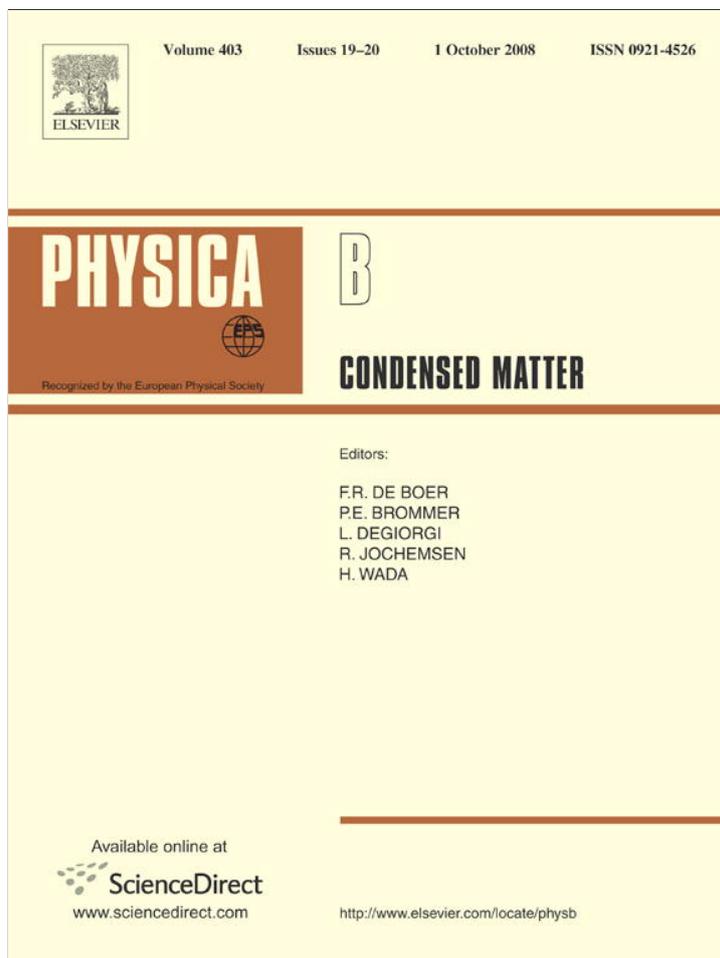


Provided for non-commercial research and education use.  
Not for reproduction, distribution or commercial use.



This article appeared in a journal published by Elsevier. The attached copy is furnished to the author for internal non-commercial research and education use, including for instruction at the authors institution and sharing with colleagues.

Other uses, including reproduction and distribution, or selling or licensing copies, or posting to personal, institutional or third party websites are prohibited.

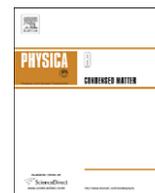
In most cases authors are permitted to post their version of the article (e.g. in Word or Tex form) to their personal website or institutional repository. Authors requiring further information regarding Elsevier's archiving and manuscript policies are encouraged to visit:

<http://www.elsevier.com/copyright>



Contents lists available at ScienceDirect

Physica B

journal homepage: [www.elsevier.com/locate/physb](http://www.elsevier.com/locate/physb)

# The changes of macroscopic features and microscopic structures of water under influence of magnetic field

Pang Xiao-Feng<sup>a,b,\*</sup>, Deng Bo<sup>a</sup>

<sup>a</sup> Institute of Life Science and Technology, University of Electronic Science and Technology of China, Chengdu 610054, Sichuan, PR China

<sup>b</sup> International Centre for Materials Physics, Chinese Academy of Sciences, Shenyang 110015, PR China

## ARTICLE INFO

### Article history:

Received 17 April 2008

Received in revised form

26 May 2008

Accepted 28 May 2008

### PACS:

66.30.Lw

03.65.Ge

61.20.Gy

75.30.Sg

### Keywords:

Magnetic field

Macroscopic property

Microscopic structure

Newtonian fluid

Water

Viscosity

## ABSTRACT

Influences of magnetic field on microscopic structures and macroscopic properties of water are studied by the spectrum techniques of infrared, Raman, visible, ultraviolet lights and X-ray. From these investigations, we know that the magnetic fields change the distribution of molecules and electrons, cause displacements and polarization of molecules and atoms, result in changes of dipole-moment transition and vibrational states of molecules and variation of transition probability of electrons, but does not alter the constitution of molecules and atoms. These are helpful in seeking the mechanism of magnetization of water. Meanwhile, we also measure the changed rules of the surface tension force, soaking effect or angle of contact, viscosity, rheology features, refraction index, dielectric constant and electric conductivity of magnetized water relative to that of pure water. The results show that the magnetic fields increase the soaking degree and hydrophobicity of water to materials, depress its surface-tension force, diminish the viscosity of water, enhance the feature of plastic flowing of water, and increase the refraction index, dielectric constant and electric conductivity of water after magnetization. These changes are caused by the above changes of microscopic structures under the action of magnetic field. Therefore, our studies are significant in science and has practical value of applications.

© 2008 Published by Elsevier B.V.

## 1. Introduction

Water is the most familiar matter in nature, our life and work require and use it from time to time, the growth and development of human beings, animals and plants need plenty of water. Therefore, we can say that there is no life without water in the world. However, we do not yet clarify the molecular structures and changed rules of properties of water under actions of external factors, although these problems have been studied for about 100 years. Changes in features of water to be exposed in a magnetic field are a typical example. Experiments demonstrate that water can be magnetized when exposed to a magnetic field [1–13]. Magnetized water has extensive utilizations in industry, agriculture and medicine, for example, it can aid in the digestion of food, is helpful in eliminating the dirt in industrial boilers, etc. Currently, many properties of water, for

instance, the electromagnetism, mechanics, optics and thermodynamics will be changed after it is magnetized. However, what are the characteristics of these changes? What are the variations of microscopic structures, such as electrons, atoms and molecules? Therefore, it is very necessary to investigate deeply and in detail the changes of macroscopic properties and microscopic structures of water when exposed to a magnetic field. Through these investigations we can not only know the features of macroscopic behaviors of magnetized water but also gain an insight into the characteristics of atomic and molecular structures and the mechanism of influences of magnetic field on them. In this paper, we describe in Section 2 the changes of microscopic structures, including the electronic, atomic and molecular structures of water, by the techniques of spectra of infrared light, visible light, ultraviolet light and X-ray because these spectra represent the features of electronic motion, atomic and molecular structures of water, respectively. In Section 3 we study the changes of the macroscopic property of water including surface tension force, soaking effect, rheology feature, conductivity, refractive index and dielectric constant. Finally, we give the conclusion of the study in Section 4.

\* Corresponding author at: International Centre for Materials Physics, Chinese Academy of Sciences, Shenyang 110015, P.R. China. Tel.: +86 2883202595; fax: +86 2883208238.

E-mail address: [pangxf@mail.sc.cninfo.net](mailto:pangxf@mail.sc.cninfo.net) (X.-F. Pang).

## 2. The influences of magnetic fields on the microscopic structures of water

### 2.1. The infrared spectrum of absorption and Raman spectrum of magnetized water as well as its changes in molecular structures

As are known, the infrared spectrum of absorption and Raman spectrum of water provide an insight into its molecular structure. Thus, we first collect the spectrum of infrared absorption of magnetized water using a Nicolet Nexus 670-FT-IR spectrometer with a resolution of  $4\text{ cm}^{-1}$ . The magnetized water used in this experiment is extracted from a glass of 250 mL of pure water at  $25\text{ }^{\circ}\text{C}$  exposed to a static magnetic field of 4400 G for 15 min. The infrared absorption spectra of magnetized and pure water are shown in Fig. 1, which is obtained by 16 scan. So-called pure water consists only of water molecules without other impurities and has a pH value of about 7–7.1; its nature is assessed and checked using the instruments. This experiment is reproduced many times using pure water collected at different times and in different places and the results are the same as in Fig. 1. From this figure, we see that the strengths of absorption peaks of magnetized water are increased in the region of  $400\text{--}3800\text{ cm}^{-1}$ , but their positions or frequencies do not change, when compared with that of pure water. At the same time, we also collect the absorption spectra of infrared light for magnetized and pure water in the range  $8000\text{--}10,000\text{ cm}^{-1}$  by using the ATR full-reflective technique in a Nicolet Nexus 670-FT-IR spectrometer, where magnetized water is still extracted from a beaker of 250 mL of water at  $25\text{ }^{\circ}\text{C}$  exposed in the magnetic field of 4400 G for 25 min, which is shown in Fig. 2. From this figure, we see that there is a new peak of infrared absorption at  $9340\text{ cm}^{-1}$  in both magnetized and pure water, but the strength of the peak in the former is larger than that in the latter. This phenomenon also occurs in the region of larger wavenumbers of  $4500\text{--}6000\text{ cm}^{-1}$  as shown in Fig. 3, in which we discover a new peak of  $5198\text{ cm}^{-1}$ , its strength of absorption is increased for magnetized water as compared with that of pure water (i.e., curve  $t = 0\text{ min}$ ), which is obtained by using the ATR full-reflective method in a Nicolet Nexus 670-FT-IR spectrometer. These phenomena were not found to date. From Figs. 1–3 we see that the magnetic field changes the property of infrared absorption of water; thus we can say that water is, in truth, magnetized when exposed to a magnetic field. However, there are only increases in the strengths of absorption peaks, no changes in the positions or frequencies of peaks in such a case. This shows that the molecular constitution of water does not change, but its polarized feature and transition dipole moments of molecules are enhanced relative to that of pure water due to the displacements

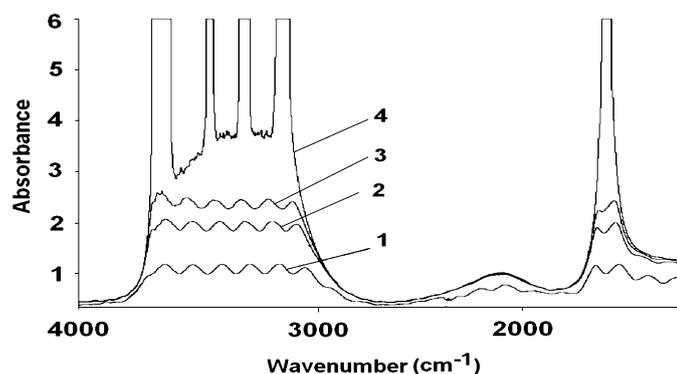


Fig. 1. The infrared spectra of absorption of water and its changes with magnetized time.

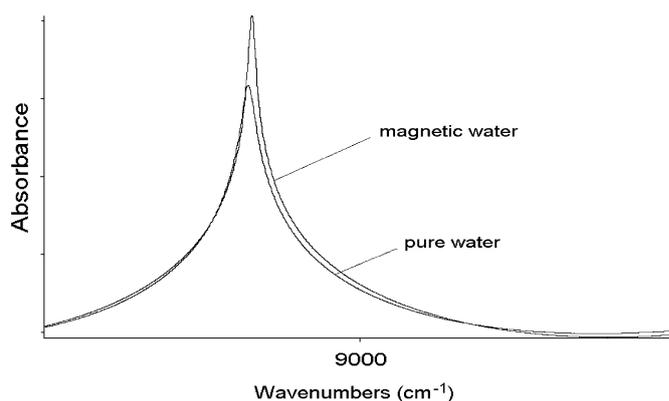


Fig. 2. The absorption spectra of magnetized and pure water in the range of  $8000\text{--}10,000\text{ cm}^{-1}$ .

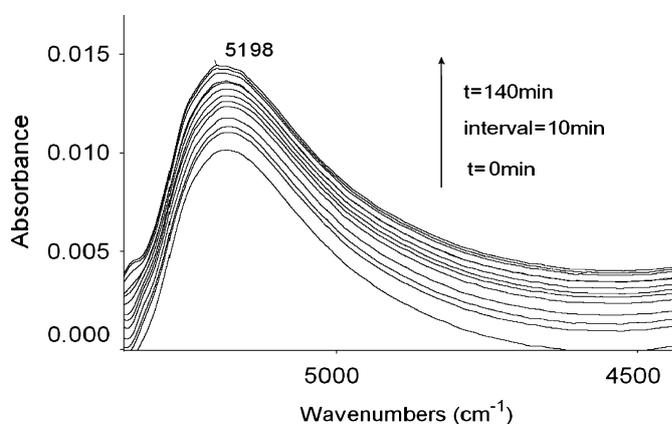


Fig. 3. Changes in the infrared absorption of water with increasing magnetized time in  $4000\text{--}6000\text{ cm}^{-1}$ .

of atoms constituting water molecules and change in the magnetic moment of molecules through magnetic interaction under the action of the magnetic field. This conclusion can be verified by the results shown in Figs. 1 and 3, in which we show the changes in the properties of infrared absorptions of magnetized water with magnetized times. In Fig. 1, the curves 1, 2, 3 and 4 denote the values for pure water, magnetized water of magnetized times of 10, 20 and 60 min, respectively. In Fig. 3, we show the gradual variations in the infrared absorptions of magnetized water with the magnetized times from 10 to 140 min. The two figures show clearly that strong or weak magnetic field can result only in the increases in the strength of infrared absorptions of water, not in the changes in the frequency of infrared vibration of molecules. Thus, we can affirm that the effects of magnetization of water are only the variations of distribution and polarization of water molecules, but does not result in changes in the molecular constitution of water.

We also measure the Raman spectra of scattering of magnetized and pure water using a JY-U1000 Raman spectrum instrument with a power of 400 mW and a source of an  $\text{Ar}^+$  ionic laser made in Japan. The magnetized water is extracted from a beaker of 200 mL of pure water at  $25\text{ }^{\circ}\text{C}$  exposed to a magnetic field of 4000 G for 30 min. The experimental results in the regions of  $20\text{--}2000$  and  $2000\text{--}9000\text{ cm}^{-1}$  are shown in Fig. 4. From this figure, we see that the frequency shift of some peaks and a new peak of  $7900\text{ cm}^{-1}$  occur in the range of  $7000\text{--}9000\text{ cm}^{-1}$ ; in  $20\text{--}2000\text{ cm}^{-1}$ , the strengths of all peaks are greatly increased, but the frequencies of these peaks do not change relative to that of pure water; for example, the relative strengths of absorption of

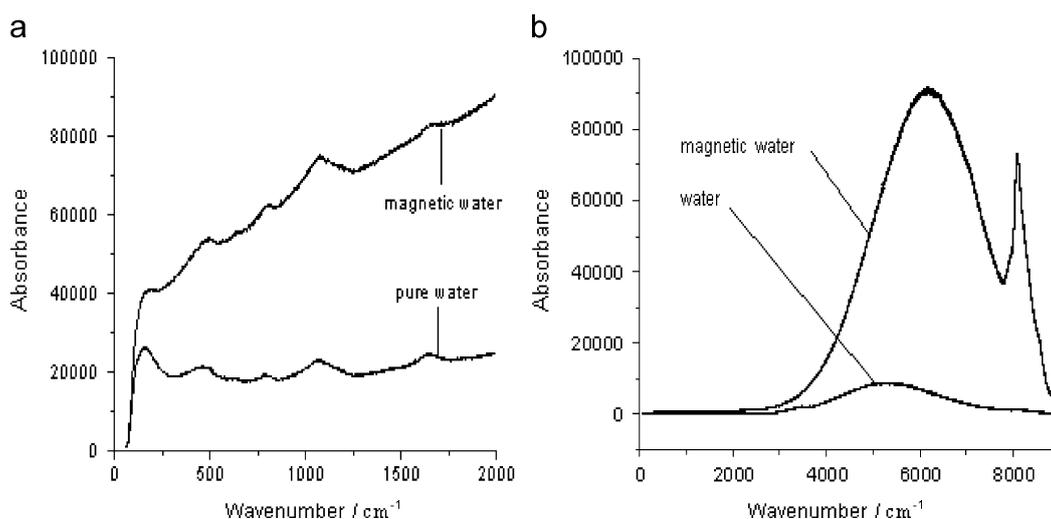


Fig. 4. The Raman spectra of magnetized water and pure water in the ranges of 20–1900  $\text{cm}^{-1}$  (a) and 2000–9000  $\text{cm}^{-1}$  (b), respectively.

the 1000  $\text{cm}^{-1}$  peak for the magnetized and pure water are 7400 and 2300, respectively, their ratio is about 3.5 times. This result agrees with Jiang Y.J. et al. [6] and Walrafen et al. [14–17]. Thus, we can say that the properties of magnetized water differ greatly from pure water, i.e., water is magnetized by a magnetic field. Since the amplitude of Raman scattering of water is only increased in such a case, we can affirm that the externally applied magnetic field results only in the changes of distribution and polarization of water molecules, not in the changes of molecular constitutions. The new peak of 7900  $\text{cm}^{-1}$  occurring in the range of 7000–9000  $\text{cm}^{-1}$  indicates only the existence of a new Raman scattering mode and new polarized states of molecules, not changes in the molecular constitution of water in such a case.

Therefore, we conclude from Figs. 1–4 that the externally applied magnetic field causes variations in the property of water, and results only in the changes in the distribution and polarizations of molecules, not in constitutions of water. This is just the essence of magnetization of water.

## 2.2. Influences of magnetic fields on spectra of visible, ultraviolet light and diffraction of X-ray as well as the changes of electronic motions and atomic structure of water molecules

It is well known that the visible and ultraviolet light radiated by matter and the X-ray diffraction of matter are related to the transitions of energy levels and to changes in the state of valence electrons, bonded electrons and inner-layer electrons in the atoms and molecules, respectively. Therefore, to study the features of these spectra of visible and ultraviolet light, X-ray diffraction of water is helpful to reveal and exhibit the properties and mechanisms of the influence of magnetic fields on electronic motions and atomic structures in the water molecules. Thus, here we first measure the spectra of visible and ultraviolet light for magnetized and pure water using a UV-2201 ultraviolet spectrometer made in Japan. This result is shown in Fig. 5. This figure shows clearly that the intensity in the absorption of ultraviolet light for magnetized water increases exponentially with increasing wavelength of light in the region of 150–260 nm relative to that of pure water. This means that the externally applied magnetic field greatly changes the feature of ultraviolet absorption of water. This rule of exponential variation of ultraviolet absorption for magnetized water with its frequency is never

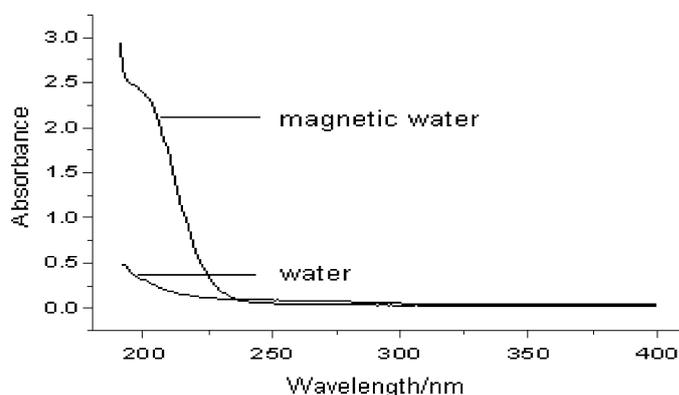


Fig. 5. Absorption spectra of ultraviolet light for magnetized and pure water.

observed, thus its essence is worth to studying deeply. Obviously, this is a result of transition of the valence electrons and bonded electrons in the water molecules, clustered and polarized, which greatly enhance the transition dipole moment of electrons in atoms due to the action of magnetic field, according to the theory of emission of ultraviolet light. In other words, the externally applied magnetic field alters the positions of atoms and enhances the clustering of water molecules, which directly results in great polarizations of the atoms and increases in the transition dipole moment of electrons in water molecules [18–21].

We also collect the diffraction spectrum of X-ray for magnetized and pure water at 25 °C by an XD-2 X-ray diffractometer with a Cu target made by Chinese Beijing General Co. with a tube voltage of 40 kV, a tube electric current of 30 mA and a scan step length of 0.02°. The magnetized water is taken from a beaker of 250 mL of pure water at 25 °C, which is exposed to a magnetic field of 4400 G for 40 min. The results for the magnetized and pure water are simultaneously shown in Fig. 6. From this figure, we see that the intensity of X-ray diffraction of magnetized water is larger than that of pure water, the diffraction intensity of the highest peak in the magnetized water increases to 42,872 from 39,417 cps in pure water. Thus, the features of X-ray diffraction of water are changed under the action of a magnetic field. It is evident that this is a result of the enhancement of transition probability and change in the distributions of electrons in the

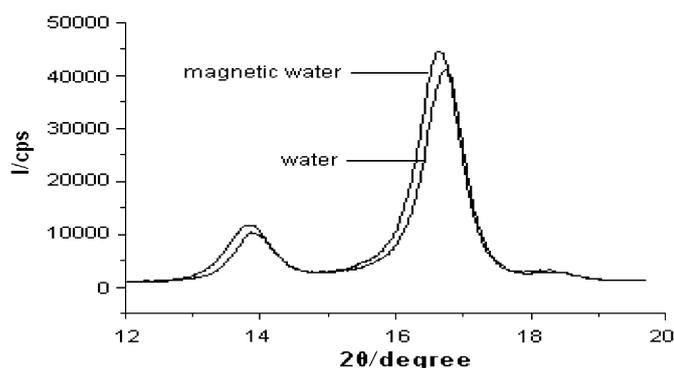


Fig. 6. Diffraction spectra of X-ray for pure and magnetized water.

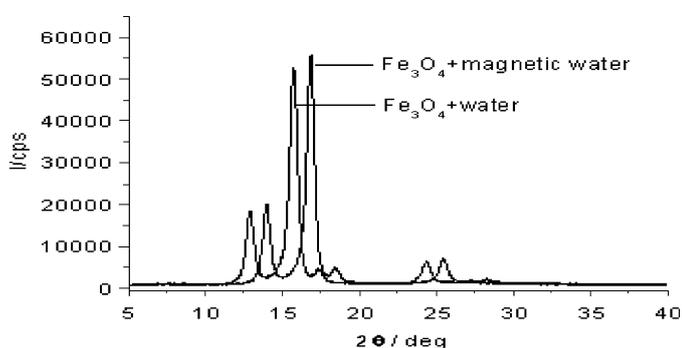


Fig. 7. The spectra of X-ray diffraction for the complexes of magnetized water plus nanometer  $\text{Fe}_3\text{O}_4$  and pure water plus nanometer  $\text{Fe}_3\text{O}_4$ .

internal layers of atoms, which is due to the changes of polarization and structure of atoms in water molecules after magnetization, when compared with that of pure water.

From the above investigations, we know clearly the different variations of microscopic structures, including the molecular and atomic structures of water, from the changes in the properties of infrared absorption, Raman scattering, ultraviolet absorption and X-ray diffraction of water, when exposed to an externally applied magnetic field. Thus, we can confirm that the water can be magnetized using a magnetic field. In the meantime, we can also verify experimentally that magnetized water has, in truth, certain magnetism. In this experiment, we simultaneously add 2 mg magnetized nano $\text{Fe}_3\text{O}_4$  into 20 mL of magnetized and pure water, respectively, and collect the diffraction spectra of X-ray from nano $\text{Fe}_3\text{O}_4$  plus magnetized water and nano $\text{Fe}_3\text{O}_4$  plus pure water in the above-mentioned way. The results are shown in Fig. 7. From this figure we can clearly see that the X-ray diffraction spectrum for nanometer  $\text{Fe}_3\text{O}_4$  plus magnetized water underwent a red-shift relative to that of nanometer  $\text{Fe}_3\text{O}_4$  plus pure water, which is the same as pure water's. Thus, it appears that magnetized water has certain magnetism, although this effect is weak because there is magnetic interaction and combination between the nanometer  $\text{Fe}_3\text{O}_4$  and magnetized water. Thus the red shift can occur, but the nano $\text{Fe}_3\text{O}_4$  cannot interact with pure water; hence their X-ray diffraction spectrum does not vary. This study for the first time, proves experimentally that magnetized water has magnetism. Its weaker magnetism is due to the small number of protons and water molecules responsible for this conductivity in the closed hydrogen-bonded chains, which are only a portion of the protons and water molecules in water [18–21]. This lends further support to the hypothesis that there are the closed hydrogen-bonded chains in water [18–21].

### 3. Changes in the macroscopic properties of water under the action of magnetic fields

#### 3.1. Changes of surface tension force and soaking effect or angle of contact of water

The above investigations show that the microscopic structures of water molecules change when exposed to a magnetic field. This change results necessarily in the variation of the macroscopic properties of water. We measure here, first of all, the variation of surface tension force or the soaking degree of water on a planar surface of material. This effect is signed in the size of angle of contact of magnetized or pure water on a planar surface of materials [22]. In our experiment, we measure the angle of contact of magnetized and pure water on a planar surface of copper, graphite, muscovite and silica gel of PDMS183 in the region of 0–180° and in the condition of humidity of 27° using an OCA40 and OCA20 Micro optical-vision instrument with an accuracy of  $\pm 0.3^\circ$  made by Germany, respectively, where magnetized water is taken from a beaker of 250 mL of pure water at 25 °C, which is exposed to the magnetic field of 4400 G for 30 min. In this measurement, the water injected is about 3  $\mu\text{L}$ , the speed of water injected is about 0.5  $\mu\text{L}/\text{s}$ . It is known that muscovite is hydrophilic, but copper, graphite and silica gel of PDMS183 have different hydrophobicities. We first measure the sizes of angle of contact of magnetized and pure water at five different positions on the planar surface of these materials, and finally find the average of five different values for the angle of contact of magnetized and pure water. The experimental results of the copper, graphite, muscovite and silica gel of PDMS183 are shown in Figs. 8–11. From the four figures, we see that the angles of contact of magnetized and pure water on the muscovite are almost zero, the difference between them being extremely small. Therefore, the soaking degrees of pure and magnetized water to the muscovite are very large. However, for copper, the angles of contact of magnetized and pure water are about 146.8° and 147.2°, respectively; for graphite, they are about 91.2° and 92.6°, respectively; for silica gel of PDMS183, they are about 97.9° and 101.03°, respectively. Therefore, the angles of contact of

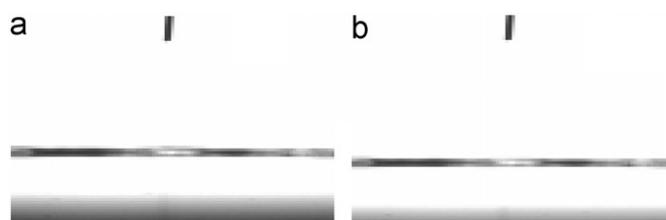


Fig. 8. The angles of contact of magnetized water (a) and pure water (b) on the surface of muscovite.

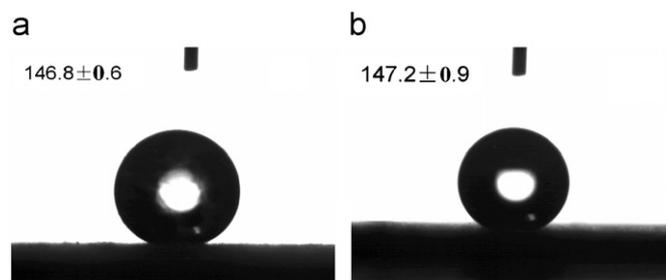
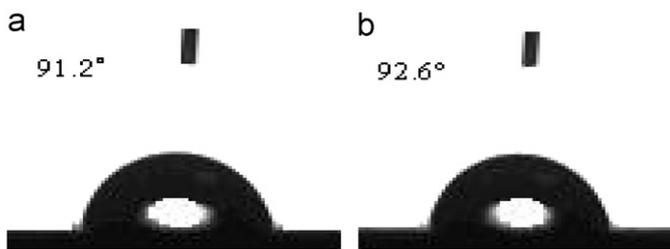
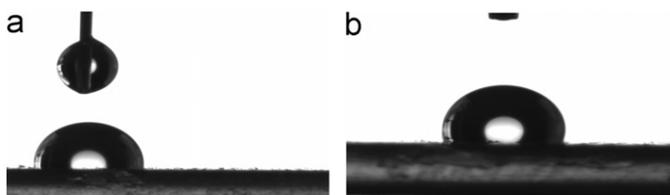


Fig. 9. The angles of contact of magnetized water (a) and pure water (b) on the surface of copper.



**Fig. 10.** The angles of contact of magnetized water (a) and pure water (b) on the surface of graphite.



**Fig. 11.** The angle of contact of magnetized water (a) and pure water (b) on the surface of silica gel of PDMS183.

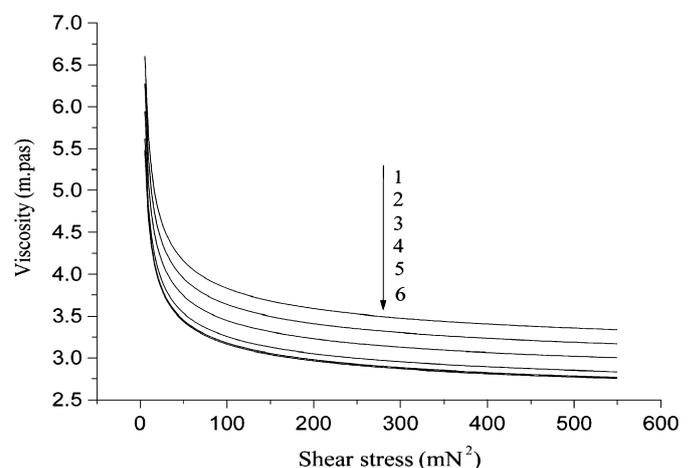
magnetized water on the surfaces of hydrophobic materials are decreased relative to that of pure water, the extenuation quantities of the angles of contact are about  $0.4^\circ$ ,  $1.4^\circ$  and  $3.13^\circ$  for copper, graphite and silica gel of PDM S183, respectively; i.e., for silica gel of PDMS183, the extenuation of the angles of contact of magnetized water are extremely evident. This means that when the soaking degree of magnetized water to the hydrophobic materials increases, its hydrophobicity decreases. This shows that the magnetic-field can change the hydrophobicity of water. This is quite a useful and valuable result, which has well foregrounded in the practical application in industry, agriculture and medicine. Obviously, the extenuation of angles of contact of magnetized water is due to increases of polarized effect and the changes in the distribution of molecules in magnetized water. Thus we conclude that the surface tension force of magnetized water does decrease relative to that of pure water.

### 3.2. Variations of viscosity and rheology features of water under the influence of a magnetic field

The so-called viscosity of fluid,  $\eta$ , is its inner frictional force acting on one unit area,  $\tau$ , when the velocity gradient of fluid,  $dV/dH$ , changes by one unit. It can be represented by the formula [23–26]:  $\eta = \tau / (dV/dH)$ , where  $V$  is the velocity of fluid,  $dV$  is the increment of velocity,  $dH$  is the increment of thickness of fluid or spacing between the neighboring layers. If  $dV/dH = 0$ , then  $\tau = 0$ . This means that the static fluid has no inner fractional force. When the fluid flows under the action of an externally applied force, the volume of the fluid in the neighboring layers distorts due to the shear force. Then the shear stress of fluid denotes just the shear force acted on one unit area and is denoted by  $\tau$ . Therefore, if shear stress represents directly the relative displacements among neighboring layers and shear distortion of fluid, then the speed of shear distortion,  $\dot{\gamma}$ , is determined by [23–26]  $\tau = \eta \dot{\gamma}$ . Hence, larger the viscosity of fluid, then larger the speed of shear distortion. When viscosity is a constant, the speed of shear distortion is directly proportional to shear stress. When the fluid is in static state, there are no relative motions and shear distortions of fluid; thus,  $\tau = 0$ . Hence, the viscosity of fluid represents, in truth, a necessary shear stress to generate a determinant speed of shear distortion [23–26]. When the

viscosity is a constant, the fluid is a Newtonian fluid, for which the speed of shear distortion is directly proportional to the shear stress, their relationship is a straight line passing the origin of the coordinate. Or else, the fluid is referred to as a non-Newtonian fluid, or a plastic fluid in which the speed of shear distortion versus shear stress is a straight line without passing the origin of the coordinate, its viscosity increases (or decreases) with increase in the speed of shear distortion. These phenomena arise from the structures of chains or polymers and the clustering or groups of molecules or atoms existing in the fluids, and can be observed by a rheology instrument [23–26].

We measure and collect the viscosity of pure and magnetized water using a FASCO-2050A rheology instrument. The magnetized water of 5 mL is taken from a beaker of 50 mL of pure water and exposed to a magnetic field of 4400 G at  $37.5^\circ\text{C}$ . The dependence of the viscosity of pure and magnetized water on the shear stress at different magnetized times is shown in Fig. 12, where “1” denotes the result of pure water, “2”, “3”, “4”, “5” and “6” denote the results of magnetized water at the magnetized times of 15, 30, 45, 60 and 75 min, respectively. (the following denotations in Fig. 13 are same). From this figure, we see clearly that the viscosities of pure and magnetized water are not a constant and decrease with increasing shear stresses; namely, the larger the magnetized time, then the more the decreases of viscosity of the magnetized water. Meanwhile, we found that viscosity does not change when the magnetized time is further increased after 60 min. This means that the viscosity of magnetized water reached a minimum in this condition. Obviously, it is related to the saturation effect of magnetized water [18–21], i.e., the saturation effect of magnetized water results in its constancy of viscosity in certain conditions. In Fig. 13, we exhibit the changes of the viscosity of pure and magnetized water with the speed of shear distortion at different magnetized times. The figure shows that the viscosities of pure and magnetized water are not a constant and decrease with increasing speed of shear distortion: the larger the magnetized time, the more the decreases of viscosity of the magnetized water. Therefore, we can affirm from Figs. 12 and 13 that pure and magnetized water have features of non-Newtonian fluid. Hence, we see that the externally applied magnetic field can change the viscosity of water, and enhance its plastic feature of flowing. Meanwhile, these results show that there a great number of chains or clustering of molecules, except for the free molecules in water, especially in magnetized water. Hence, Pure and magnetized water becomes a plastic fluid. This is a new discovery and has been not sought to date.



**Fig. 12.** The changes of the viscosity of magnetized water with the shear stress at different magnetized times.

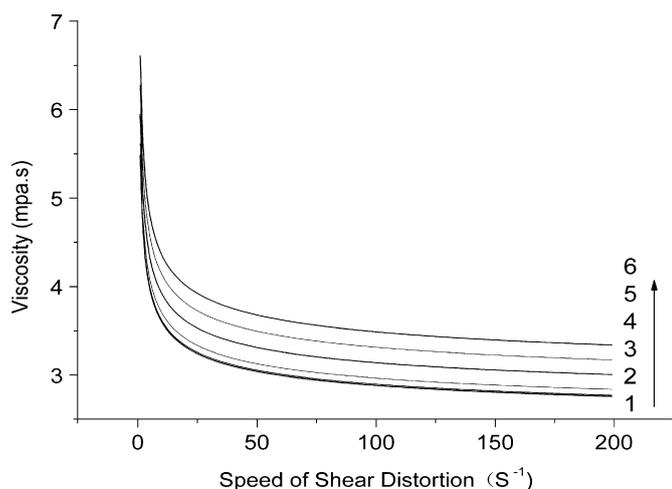


Fig. 13. The changes in the viscosity of pure and magnetized water with the speed of shear pure and distortion at different magnetized times.

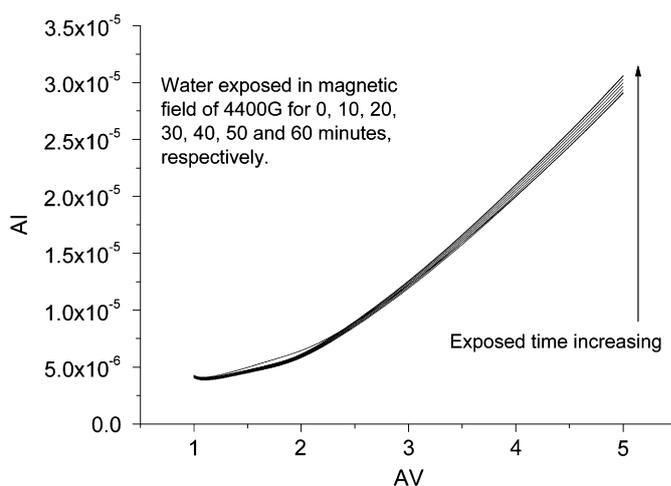


Fig. 15. The relationship of the electric-current strength (AI) versus voltage (AV) for magnetized water at different magnetized times of 0, 10, 20, 30, 40, 50 and 60 min.

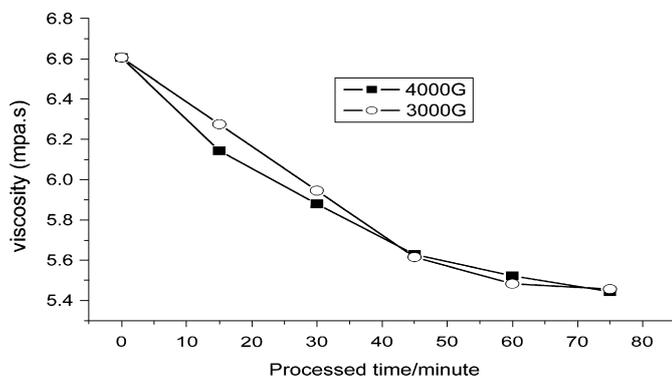


Fig. 14. The changes in the viscosity of magnetized water with increasing magnetized times at 3000 and 4000 G, respectively.

We further measure the rules of change of viscosity of magnetized water under the influence of different magnetic fields, which is shown in Fig. 14, where we show the changes of viscosity of magnetized water with increasing magnetized times at magnetic fields of 3000 and 4000 G, respectively. Thus, we see that stronger the magnetic field, the more the decreases of viscosity of magnetized water, when the magnetized time is less than 45 min. However, it is contrary in the range of 45–67 min, and the viscosity reaches a constant value after 68 min [18–21]. These results show that the externally applied magnetic field can depress the viscosity of water and increase its velocity of plastic flowing. This is a very interesting and valuable result. This feature has application values in industry, agriculture and medicine.

### 3.3. Changes in the electromagnetic property of magnetized water

We measured the change in the refractive index of magnetized water at 25 °C by an Alber refraction instrument; the result shows that it becomes 1.3346 from 1.3336 of pure water. In this experiment, the sample used is extracted from a glass of 250 mL of pure water at 25 °C exposed to the magnetic field of 4400 G for about 30 min. Thus, we can infer that the dielectric constant of magnetized water increases correspondingly, when compared with that of pure water. Evidently, this is a result of enhancements of chain structure or clustering of water molecules with the

electric dipole moment of 1.8 D after magnetization. Furthermore, we also measure the electric conductivity of magnetized and pure water by a Keithley4000 semiconductor instrument made by America with an accuracy of  $10^{-6}$  Scm. The relationship of the electric-current strength versus voltage for magnetized water at the magnetized times of 0, 10, 20, 30, 40, 50 and 60 min is shown in Fig. 15, respectively, where the curve of magnetizing times of 0 min denotes the values of pure water. This figure shows that the electric-current strength, or electric conductivity of magnetized water, increases as compared with that of pure water, when the voltage applied on it is higher. Very clearly, this is due to the increase of charged particles, for example, hydrogen ions ( $H^+$  or protons), or  $H_3O^+$  and  $OH^-$  in magnetized water, and the action of higher voltage or strong electric field, which compels the polarized water molecules in the molecular chains or group of molecules to separate as  $H^+$  or  $H_3O^+$  and  $OH^-$ . Thus the electric conductivity of magnetized water increases as compared with that of pure water.

## 4. Conclusion

When water is exposed to a magnetic field, we find that its properties are changed. This is called magnetization of water. In order to recognize and clarify the influences of magnetic field on microscopic structures and macroscopic properties of water, we first collect and determine the changes of properties by infrared, Raman, visible, ultraviolet and X-ray spectra of magnetized water relative to that of pure water. From these properties, we can obtain an insight into the microscopic structures of water, including molecular and atomic structures and electronic motions, and their rules of changes. From these investigations and analyses of infrared, Raman, visible, ultraviolet and X-ray spectra of magnetized water, we find that the externally applied magnetic fields cause displacements and polarization of molecules and atoms, and result in changes of dipole moment in the transition and vibrational states of molecules. Thus the distribution of molecules and the transition probability of valence, bonded and inner-layer electrons are varied, but the constitution of molecules and atoms do not alter in such a case. From these changes of microscopic structure, we can seek the mechanism of magnetization of water.

In the investigation of influences of magnetic field on the macroscopic properties of water, we mainly measure the changed

rules in the surface tension force, soaking effect or angle of contact, viscosity, rheology features, refraction index, dielectric constant and electric conductivity of magnetized water relative to that of pure water. Our experiments show that the externally applied magnetic fields depress the angles of contact of water, and increase the soaking degree to solid matter. Thus the surface tension force of water and hydrophobicity of materials decrease after magnetization. We also measured and collected the rheology features of pure and magnetized water, and discover that the viscosities of both magnetized and pure water are not constant, and decreases with increasing shear stress and speed of shear distortion. Meanwhile, the viscosity of magnetized water increases with decreasing intensity of magnetic field and magnetized time. Thus, we infer from the rheology theory that water has some features of non-Newtonian fluid. From these experimental results, we affirm that there are great number of molecular groups and hydrogen-bonded chains in water, which result in changes of flowing features and in the magnetization of water under the action of a magnetic field [18–21]. From the measurements of the electromagnetic property of magnetized water, we know that the magnetic field increases the refraction index, dielectric constant and electric conductivity of water. Obviously, the macroscopic properties of magnetized water are due to the variations of the microscopic structures of water; for example, the distribution of molecules and electrons, displacements and polarization of molecules and atoms, dipole moment of transition and vibrational states of molecules, under the action of a magnetic field as mentioned above. Therefore, our investigation here is helpful in understanding the properties of structure of water molecules and to reveal and exhibit the mechanism of magnetization of water. On the other hand, we can infer that the magnetized water, which possesses the above-mentioned novel properties, has extensive applications in industry, agriculture and medicine. Therefore, our studies also have important significations in science and in the value of applications [26].

## Acknowledgment

The authors would like to acknowledge the National “973” project of China: for financial support (Grant no: 2007CB936103)

## References

- [1] Xie WenHui, *Magnetized Water and its Application*, Science Press, Beijing, 1983, p. 34.
- [2] K.M. Joshi, P.V. Kamat, *J. Indian Chem. Soc.* 43 (1965) 620.
- [3] K. Higashitani, *J. Colloid. Interface Sci.* 152 (1992) 125.
- [4] K. Higashitani, *J. Colloid. Interface Sci.* 156 (1993) 90.
- [5] B.N. Ke LaXin, *Magnetization of Water*, Measurement Press, Beijing, 1982, p. 56.
- [6] Jiang Yijian, Jia Qingjiou, Zhang Peng Cheng, Xu Lu, *J. Light Scatt.* 4 (1992) 102.
- [7] K. Muller, *Z. Chem.* 10 (1970) 216.
- [8] J. Liemeza, *Z. Phys. Chem.* 99 (1976) 33.
- [9] P. Bour, *Chem. Phys. Lett.* 365 (2002) 82.
- [10] M.C. Amiri, A. Dadkhah, *Colloid. Surf. A: Physicchem. Eng. Aspects* 278 (2006) 252.
- [11] A.D. Kneya, S.A. Parsons, *Water Res.* 40 (2006) 518.
- [12] D. Eisenberg, W. Kauzmann, *The Structure and Properties of Water*, Clarendon Press, Oxford, 1969, p. 67.
- [13] A.S. Davydov, *Biology and Quantum Mechanics*, Pergamon, New York, 1982.
- [14] G.E. Walrafen, *J. Chem. Phys.* 36 (1962) 1035.
- [15] G.E. Walrafen, *J. Chem. Phys.* 52 (1970) 4276.
- [16] G.E. Walrafen, M.S. Hokmabadi, W.H. Yang, *J. Chem. Phys.* 85 (1986) 6964.
- [17] G.E. Walrafen, M.R. Fisher, M.S. Hokmabadi, W.H. Yang, *J. Chem. Phys.* 85 (1986) 6970.
- [18] Pang Xiao-feng, *Chinese J. Atom. Mol. Phys.* 23 (Suppl-1) (2006) 1.
- [19] Pang Xiao-feng, *Biological Electromagnetics*, National Defence Industry Press, Beijing, 2008, p. 35.
- [20] Pang Xiao-feng, *Eur. Phys. J. B* 49 (2006) 5.
- [21] Pang Xiao-feng, Feng Yuan-ping, *Quantum Mechanics in Nonlinear Systems*, World Scientific Publishing Co., New Jersey, 2005, p. 557.
- [22] K.M. Joshi, P.V. Kamat, *J. Indian Chem. Soc.* 43 (1965) 620.
- [23] L.D. Landau, E.M. Lifshitz, *Fluid Mechanics*, Pergamon Press, London, 1959, p. 104.
- [24] H. Lamb, *Hydrodynamics*, Dover, New York, 1963, p. 45.
- [25] J.J. Chen, L.K. Chu, *Biophysics*, People Education Publishing House, Beijing, 1982.
- [26] Pang Xiao-feng, *Biophysics*, The Press of University of Electronic Scie. Techno. of China, Chengdu, 2007, p. 127.