

PHYSICAL PROPERTIES OF WATER WITH I_E STRUCTURES

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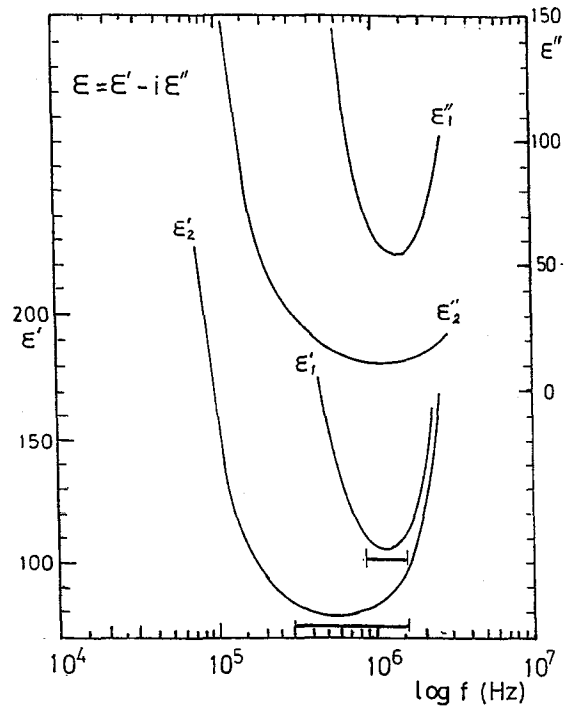
Various physical properties of water with I_E structures are measured. Compared with ordinary water, there is an approximate 20% decrease in dielectric constant for I_E water at MHz as an increase of emf generated by I_E water between two identical stainless steel electrodes, and an increase in resistivity to AC current. Fluorescence at 298 nm peak is seen in I_E water but not in ordinary water. From the thermal variation of UV absorption spectrum, one can estimate the amount of I_E structure to be up to 3%. The elevation of boiling point due to I_E structure can then be used to calculate the molecular weight of I_E structure to be the same as water molecule.

1. Introduction

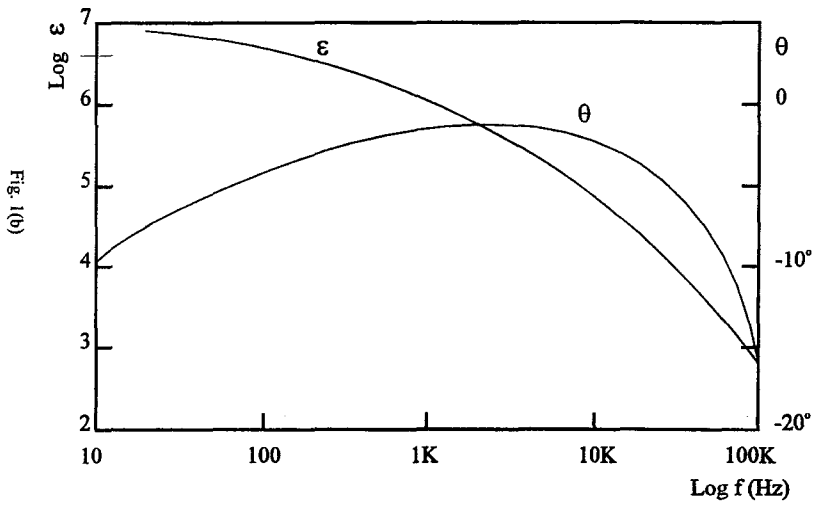
Recently it has been suggested that stable rigid structures (called I_E structures which stands for ice formed under electric field) can be formed from water molecules at room temperature and normal pressure.¹ Rod-like structures are identified in photographs taken by transmission electron microscope. The physical hypothesis behind these I_E structures is that the electric dipole moment of water molecules play a dominant role to attract themselves together to form I_E structures, which itself may have some electric dipole moment. To justify such an hypothesis, it is necessary to look for electrical and other properties of these I_E structures. We have measured five different properties: dielectric constants; the electromotive force (emf) using two identical electrodes; resistivity; fluorescence; stability as a function of temperature. We find these properties are different from pure water. Pure water shall be defined to be used in this paper as having 18 megaohms of resistance and having less than several parts per billion Total Dissolved Solids, which for our experiment is supplied by Millipore RO Plus system.

2. Dielectric Constant

Water molecule has a very large electric dipole moment and is forced to rotate to respond to an alternate external electric field. Hence water as a liquid has a



(a)



(b)

Fig. 1. (a) Real ϵ' and Imaginary ϵ'' part of the dielectric constant ϵ for distilled water ϵ_1 , and water with I_E structure ϵ_2 . The I_E structured water is prepared as discussed in Ref. 1. Within the bracket, impedance matching of external circuit with internal circuit is most optimal. (b) The absolute value ϵ of dielectric constant and its phase θ of I_E structured water.

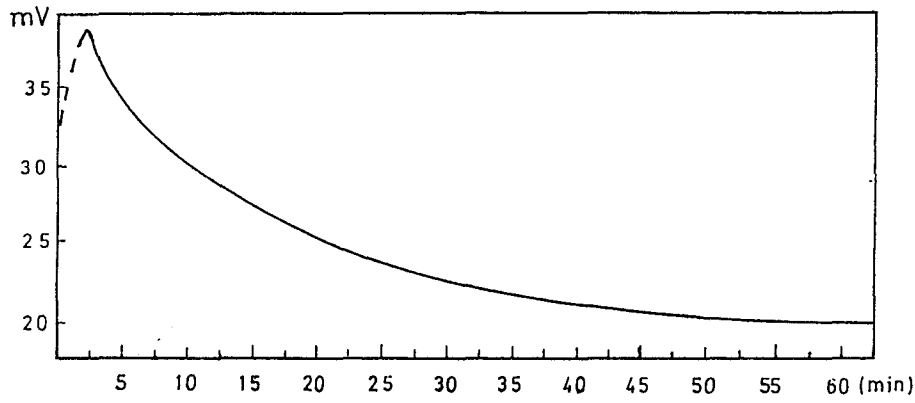
very large dielectric constant 80. If water molecules group together to form larger structures such as the I_E structure that is proposed, then the resulting structured water should have a larger dielectric constant. When an external AC field is applied, these I_E structures will respond and cause a change of the dielectric constant. We use the Hewlett Packard Corp. 4192A LF Impedance Analyzer (5 Hz \sim 13 MHz) to measure the pure and the imaginary parts of the dielectric constant $\varepsilon = \varepsilon' + i\varepsilon''$ of structured water and pure water. This is shown in Fig. 1. The absolute value of dielectric constant and its phase θ of I_E structured water is also presented separately in Fig. 1(b). There is a minimum value of the phase at around 1 kHz. The distilled water has a dielectric value $\varepsilon_1 = (\varepsilon_1'^2 + i\varepsilon_1'')^{1/2} \cong 80$ at frequency $\sim 10^6$ Hz, and the I_E structured water has a twenty percent smaller dielectric constant $\varepsilon_2 = (\varepsilon_2'^2 + i\varepsilon_2'')^{1/2}$.

3. Electromotive Force

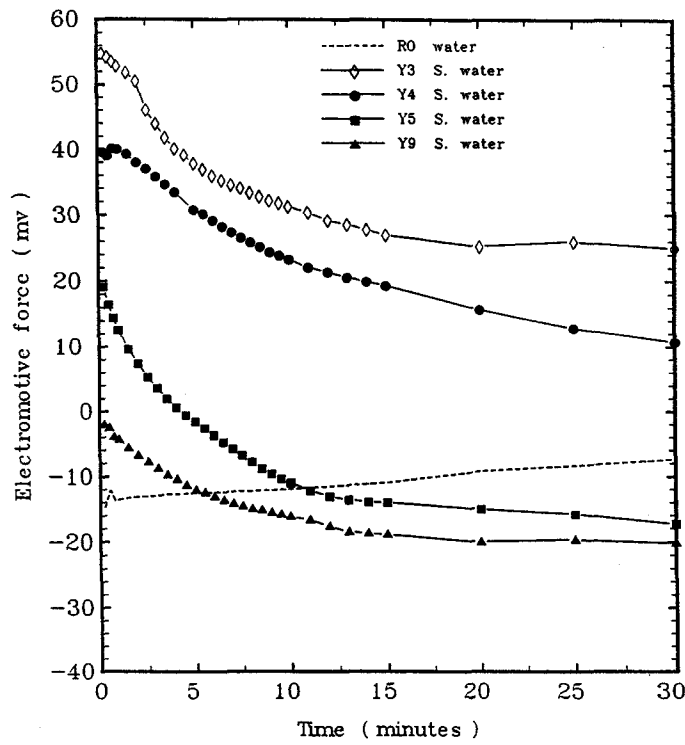
It is well known in electrochemistry that an emf is generated between two different electrodes in a solution and no emf is generated between same electrodes in a solution. We immerse a pair of stainless electrodes in I_E structured water, and we have found that a finite emf of 10 mV or more is generated. In Fig. 2(a), we have shown one typical curve for a concentrated I_E structured water that lasts for an hour. The first 2 to 3 minutes irregular reading, then approaches a maximum of 38 mV, and then drops slowly over the next hour. Figure 2(b) shows emf for a variety of I_E structure water. The physical explanation of these figures is that the electric dipoles of the I_E structures are pointing at different direction randomly in water in the beginning. As the first electric dipole attaches to the electrodes an emf is set up between the electrodes. This emf will force a more regular alignment of I_E structures in water between the two electrodes. The more aligned the electric dipoles are, the higher the emf. However as time goes on the thermal vibration of water molecules will tend to cause disorder in the alignment of I_E structures. The emf will decrease as a result.

If we stir the I_E structure water with a glass rod during measurement procedure, the emf will alter immediately, and then slowly returns to its original value. The amount of I_E structures in the I_E structured water is small, and their orientations are random. So the measurements are different each time as shown in Fig. 2(b), but clearly there is a common quality to the measurement which differs from that of pure water. The amount of emf measured also depends on the surface of the electrode. The sharper microstructure on the metal surface is expected to generate a bigger electric field, and hence a larger realignment of I_E structures. These microstructures on the metal can be broken or screened by the I_E structures or created in cleaning by acid. When we wash the electrodes with nitric acid for cleaning purpose, we get a larger emf with the same I_E structured water.

We insert the same electrodes in pure water (reverse osmosis water from Ultra-pure Millipore plus system). An emf of 3 \sim 7 mV is also seen. The emf is much smaller and changes much less in time. The control sample for emf measurement is



(a)



(b)

Fig. 2. (a) A typical emf generated by a concentrated I_E structured water on two stainless steel electrodes. (b) Emf generated by a variety of I_E structured water on two stainless electrodes. The I_E structured water are prepared in a way described in Ref. 1 for NaCl solution with various molar concentrations: Y9 (10^{-11} M), Y5 (10^{-7} M), Y4 (10^{-6} M), Y3 (10^{-5} M).

no longer pure water because it is expected that water molecules cluster together due to the hydrogen bonding as discussed in flickering cluster model of water inside.² These flickering water clusters the electric dipole moment of their constitute water

molecules probably do not completely cancel one another, therefore, these water clusters have some residue electric dipole moment. These small amount of electric dipole moment probably constitute the emf that is observed here.

Some general comments on experimental procedure in measuring various physical properties of water with I_E structure are in order. Firstly, the I_E structures are created not in a completely controlled fashion. The amount and size of I_E structures are not controlled precisely. These I_E structures also keep on changing in size and amount in water if it is disturbed. A qualitative definite results are reproducible, but a quantitative reproducible results for some measurements are almost impossible. Secondly, I_E structures are electrical in nature. They attach to container very strongly and cannot be easily washed away. They also break up easily and reproduce. Sometimes the more you wash with the cleanest water available to you, the more I_E structures you may end up with. For each measurement, it is important to establish a base line without the influence of I_E structures. Otherwise measurements become meaningless and not reproducible.

4. Resistivity

If the I_E structures in water are electric dipoles, any ion moving close to them in water will be attracted to them. When ions are attached to a much larger size I_E structures which could be as big as micron size, their movement in water will become slower. The mobility of ion μ_i becomes the mobility μ of ion plus the I_E structure, which is larger. Hence the conductivity of structured water which is proportional to the mobility will also decrease. Or the resistivity will increase. We use standard resistivity meter constructed by Ω omega. CDB-94, which consists of a pair of platinum electrodes, operating at 100 Hz with a voltage of 1 volt. The results are shown in Fig. 3. There is an abrupt large change in the first minute after the voltage is being applied probably due to the rapid orientation of the I_E structures in water. Then as alternative voltage drives the ions attached to I_E structures back and forth. It is equivalent to shaking them mechanically. I_E structures break down into smaller pieces and grow bigger. Then more ions will be attached to more I_E structures that decreases again the conductivity.

It is, in general, easy to conceive a background mechanism that increases conductivity of pure water because most dirt contains some soluble materials that produce more ions in water and hence bigger conductivity. It is difficult to construct some simple background signal that decreases conductivity measurement. We have performed our experiment in a clean room environment, which is confirmed by the constant value of conductivity of pure water.

5. Fluorescence Spectra

We use Hitachi 850 Fluorescence Spectrophotometer to compare I_E structured water with pure water. For pure water and ice I, there is no fluorescence spectra, whereas there is a distinct peak at $\lambda = 298$ nm using various excitation UV light at $\lambda = 200$,

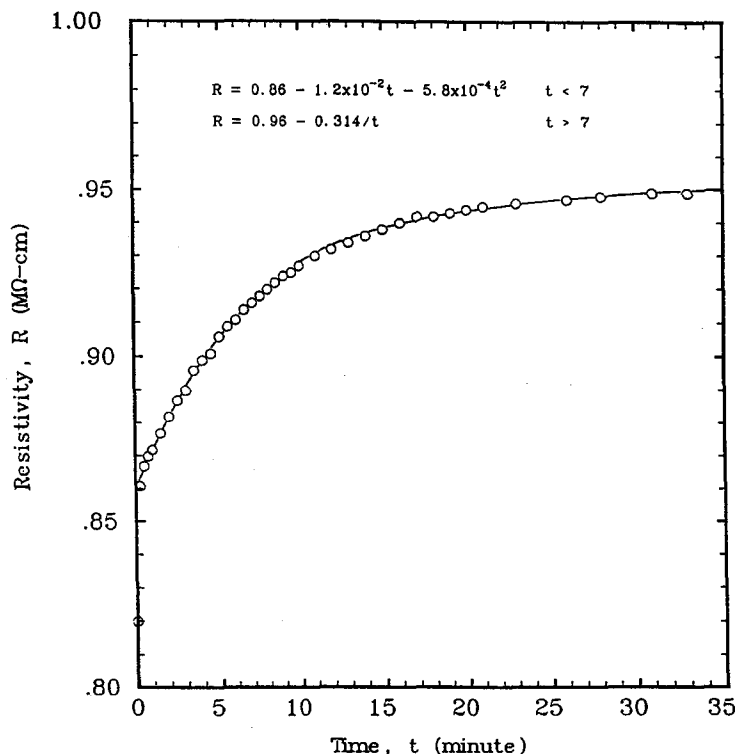


Fig. 3. Resistivity of concentrated I_E structured water prepared as discussed in Ref. 1 under AC voltage as a function of time.

230, 276, 285 nm. This is shown in Figs. 4 and 5. The interpretation is that with a big cluster of molecules in I_E structures, electrons may be shared among different molecules in the same I_E structures, which can be excited by UV light to a new state. Fluorescence light is emitted when the new excited state jumps back to ground state.

6. Thermal Stability

An interesting question on I_E structures is how stable is it with respect to heat? We have put I_E structured water in quartz cells and observe its UV transmission characteristics. We prepare different strength of I_E structured water by method described in previous paper. The strength of the I_E structured water is given by the UV transmission in percentage in reference to pure water. We use a dual beam Perkin Elmer Lambda 2S spectrophotometer. One reference cell is filled with pure water and the other cell is filled with structured water. The UV transmission T is a ratio of readings through the two cells. The sample cell is first filled with pure cell to get a baseline of almost $T = 100\%$ reading. Then the simple cell is filled with I_E structured water with various strength for UV transmission measurement.

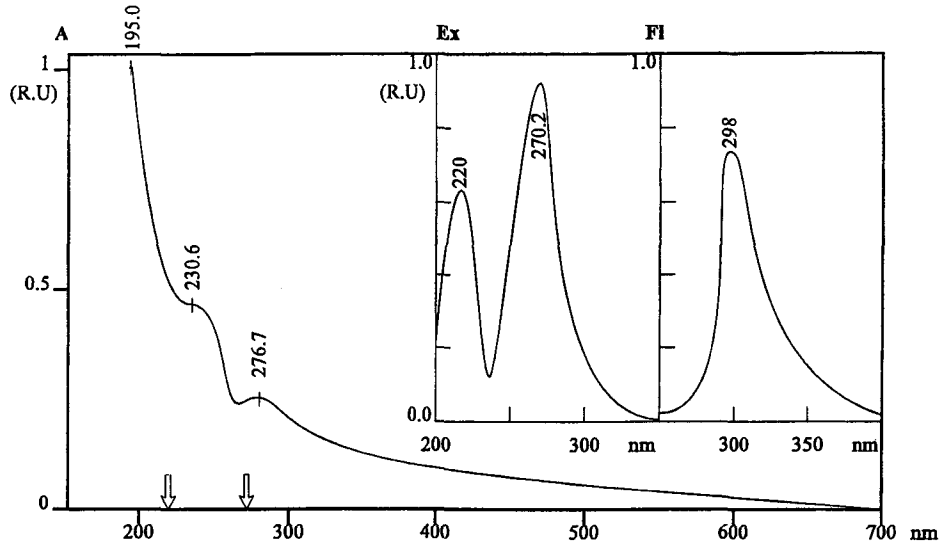


Fig. 4. Absorption spectrum, Excitation (Ex) spectrum and Fluorescence (Fl) spectra of I_E water. Two arrows mark the excitation wavelength (220 & 270.2 nm) where we measured. They are located under the absorption band 230.6 nm and 276.7 nm. They both have the same fluorescent peak at 298 nm.

The difference of transmission of these two UV transmission measurement at wavelength $\lambda = 190$ nm is used as a measure of the strength of various I_E structured water. So a $T = 2.3\%$ solution is a weak solution, and 80% is a strong solution. Then we measure the UV transmission characteristic for 2.4%, 20%, 40%, 60%, 80% and 96% solution as a function of temperature. The cell holding the sample is heated up through warm water bath gradually from room temperature to 80°C and then cool down. We have shown the results in Fig. 6. We also find that as the cell cools down from 80°C to room temperature, UV transmission characteristic returns indicating that the I_E structures are stable under heating to at least 80°C.

The measured absorbance A is a linear combination of those from water A_w and I_E structures A_I :

$$A = r_w A_w + r_I A_I - A_r \quad (6.1)$$

where r_w , r_I are ratios of water and I_E structures respectively in the solutions with $r_w + r_I = 1$ and A_r is the absorbance of the reference cell. We can fit all the data with:

$$A_w = -0.00864 - 0.002843T + 0.00012688 T^2 \quad (6.2)$$

where $A_I = 77.11$ and $A_r = 0.176$. The amount of I_E structures in various solutions are

$T(\%)$	2.4	20	40	60	80	96
$r_I(\%)$	0.06	0.32	0.60	1.22	2.18	3.79

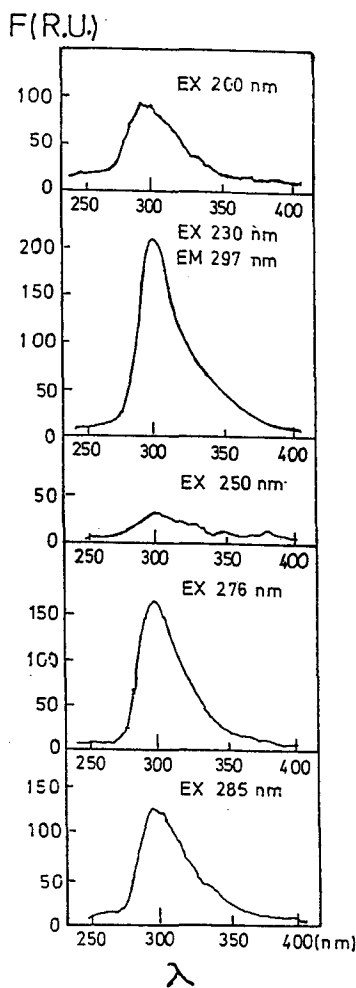
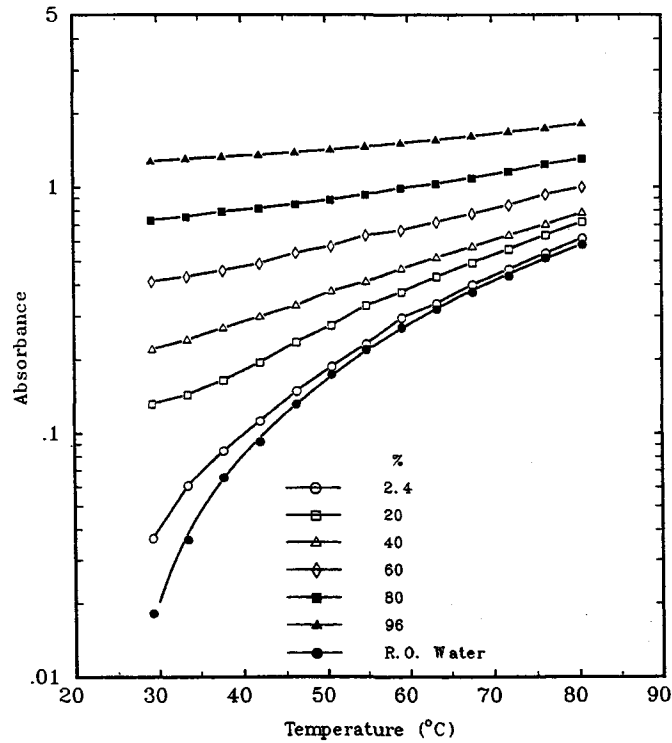


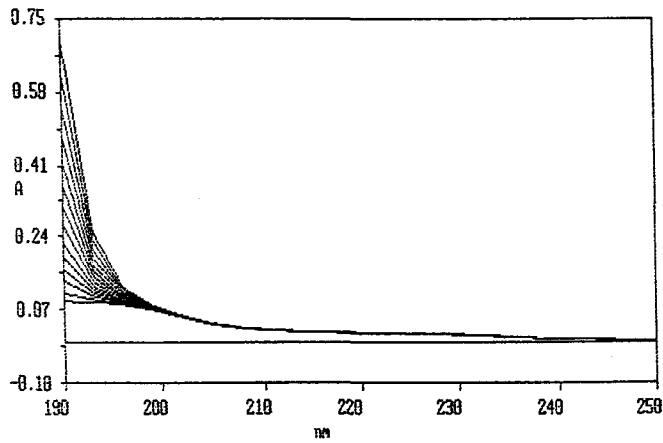
Fig. 5. Fluorescence spectra of I_E water from various excitations at 200 nm, 230 nm, 276 nm, and 285 nm.

The highest concentration of I_E structures in our samples is about 3.79%.³ The solution with $t = 96\%$ is found to have an increase of boiling temperature $\Delta T_b = 1.0^\circ\text{C}$.⁴ Using the usual formula $\Delta T_b = K_b m$ where $K_b = 0.514$ for water and m is the molar concentration, one can deduce that the I_E structures have a molecular weight of 17.5, which is consistent with that of water (=18).

We have also heated the I_E structured water to 121°C at 1.1 atmospheric pressure. We see no change in its UV absorption spectrum before and after heating to such a high temperature and pressure. We also possess some samples of I_E structured water that does not change its UV absorption characteristic after a period



(a)



(b)

Fig. 6. (a) Absorbance measurement of solutions with various concentration of I_E structures as a function of temperature. (b) The variation of absorbance at different temperature for UV spectrum from $\lambda = 190$ nm to 250 nm for a concentrate I_E structured water with $T = 20\%$. All measurements are made in exactly same mechanical arrangement of all equipments and sample with only hot water circulating.

of two years. In our previous paper we mention that in a rotary evaporation unit, very little change in UV spectrum is found between the original I_E structured water, the evaporated water, and the residue water. This indicates the unit cells that constitute these I_E structures are stable even during evaporation process.

We have analyzed the solution for inorganic impurity with Inductance Coupling Plasma Atomic emission spectrometry (ICPAS) with metallic ions less than 0.1 ppm. We also use High Pressure Liquid Chromatography (HPLC) to determine organic impurity. We find only less than 0.2 ppm of our nucleated dielectric material that we added in the beginning. No peak from other organic compound is found.

7. Summary

We have found about 20% decrease in dielectric constant for I_E water at 10^6 Hz, as compared with ordinary water. The emf generated by I_E water for identical stainless steel electrodes is much more than ordinary water. Passing small amount of AC current through I_E water increases its resistivity significantly. Normal dirt in water has an opposite effect.

Fluorescence at 298 nm peak is seen in I_E water but not in ordinary water. I_E is very stable in hot temperature up to 121°C . Different thermal response of UV absorption spectrum of I_E water enables us to estimate the amount of I_E structures in water to be as high as three percent in some cases.

References

1. S.-Y. Lo, *Novel Stable Structures of Water*, preprint, submitted for publication.
2. See e.g., A. W. Adamson, *Physical Chemistry*, 3rd edition (1986), p. 299; S. W. Benson, *J. Am. Chem. Soc.* **100**, 5640 (1978).
3. We have viewed the solution in a fluid cell by Atomic Force Microscope. The amount of structures is consistent with this value. Details will be published.
4. We wish to thank Professor Selim Senkan of UCLA for his help in this measurement.