

Polarized microwave and RF radiation effects on the structure and stability of liquid water

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It is now established that liquid water has many structures with distinctive properties. We have established that ultradilute (≈ 1 ppm) aquasols are different both in structure and properties. We present here, the effects of electromagnetic radiation on water, including our own work from Penn State established in the past decade on the effects of polarized microwave (2.45 GHz) on solids and liquids and radiofrequency (RF) (13.56 MHz) radiation on water. Detailed Raman spectroscopy provides the data on major changes in the water structure including striking reduction in the main stretching modes. The time required for relaxation of the structure at room temperature is in hours.

Keywords: Aquasols, electromagnetic radiation, polarized microwave, radiofrequency.

THE most important condensed matter phase on the planet by almost any measure is certainly liquid water. Yet materials scientists have largely ignored it. The term, 'structure of water' has almost exclusively dealt with the molecular structure, and has been studied extensively by chemists since Lavoisier, Priestley and Faraday sorted out its composition. Martin Chaplin's review masterfully summarizes the status of the huge amount of literature on this topic (<http://www.lsbu.ac.uk/water/chaplin.html>). Most of this monumental work deals with molecules with composition H_2O which do exist under various circumstances. Thousands of beautiful cartoons of innumerable monomer, oligomer and polymeric molecules are shown and discussed. However, of greater significance is not just the constituent units alone (the molecules) like the bricks of a building, but the size and shape of the rooms, and the arrangement in space of the units within such. Chaplin has recently^{1,2} provided two useful reviews encompassing some of the latter also. Figure 1 gives first an enlightening summary of the density of water in both the solid crystalline, and the liquid states. As the first law of materials science says that properties are determined largely by structure, it is clear that the various polymorphs of crystalline ice increase in density with pressure. What is striking is that liquid water follows the

same pattern, without the discontinuities of a first order transition. Indeed, it can be seen that the much researched glassy water shows roughly the same pattern. Figure 2 taken from E. Stanley's review² on (glassy) water provides further data. The highly anomalous shapes of the property versus P - T show that we have changes in structure of water and hence require higher order transitions – as would be expected – in the structure of liquid water. We note that the breaks in the many different properties are at several different temperatures, indicating that there are several structures of water in the 0–100°C range at 1 atm. In Figure 2, the behaviour of typical liquids is indicated by a dashed line, which, roughly is an extrapolation of the high-temperature behaviour of liquid water. The anomalies displayed by liquid water are apparent about the melting point T_m , but are more striking below it.

In a lengthy review, Roy *et al.*³ have marshalled the arguments from the condensed matter physical chemistry evidence in liquids in general, especially in covalently bonded liquids. Vezzoli *et al.*⁴ showed in the 1970s that different thermodynamically stable phases of common liquids exist in modest P - T ranges. And recently, Kawamoto⁵ obtained data exactly analogous to these, in the same pressure range, showing at least one other stable liquid phase of water.

In analogy with the transmission electron microscopy (TEM) structure of glasses, Roy *et al.* also supported their argument for the virtually certain existence of nano-heterogeneous liquid water. The different clusters of oligomers discussed for decades as being present in water, fit in well with such extensive data on glasses. Roy *et al.* adduced a further thermodynamics argument towards phase separation (often metastable) in all non-ideal systems, as conducive to such heterogeneity. Thus, studies by Chaplin at the molecular level, and Roy *et al.*'s data from the property data, and thermodynamic and phase diagram approach provide a solid base for building a model of multistructures for water.

A hundred year long controversy has persisted in the science community against the possibility of different waters surviving for any specific time periods – hours to

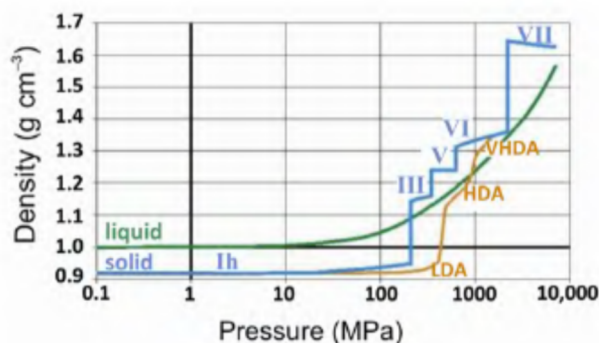


Figure 1. The density of liquid and solid water in relation to glassy amorphous ices.

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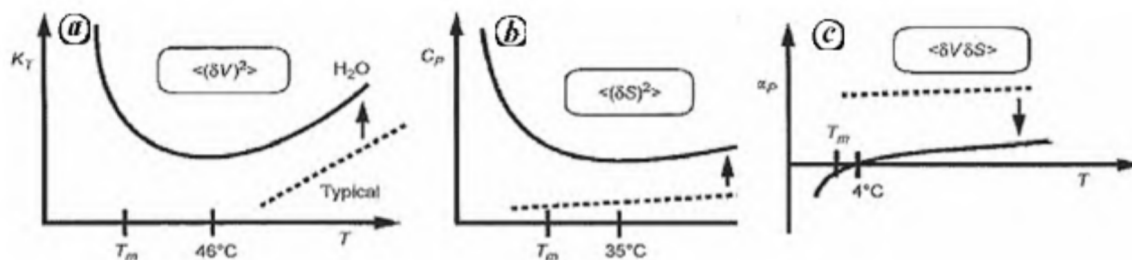


Figure 2. Schematic dependence on temperature of (a) isothermal compressibility K_T , (b) constant-pressure specific heat, C_p , (c) coefficient of thermal expansion α_p .

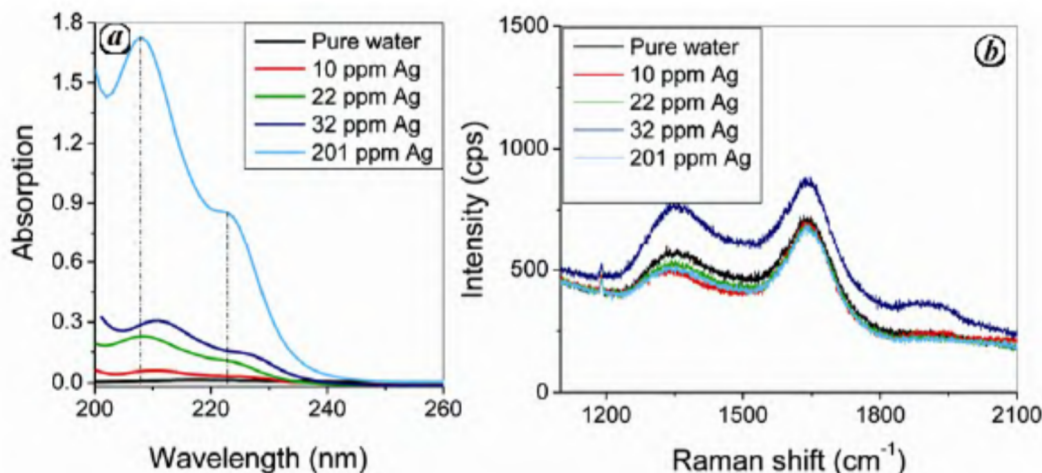


Figure 3. a, UV-spectra of colloidal silver samples with varying silver concentration. Note their implication on the structure of water at lower wavelengths (200–220 nm). b, Raman spectra of colloidal silver water showing structural variations.

years. Much of this is derived from the confusion between 'structure' and 'composition' and an understanding that 'water is just water' and hence is chemically identical; it cannot have changed at all. The classic example of diamond and graphite definitively diffuses this confusion. Graphite and diamond are identical in composition, interconvertible nowadays in milliseconds, and have different properties.

We demonstrate here that among the various vectors that alter the 'structure of water', radiation plays a significant role as also the presence of second solid phase typically noted in the case of ultradilute metallic sols. The colloidal state also provides an excellent bridge to demonstrate the biological effects on ultradiluted water samples. Metallic silver has been known for millennia and used for its exceptional antibacterial properties. Silver aquasols at ≤ 30 atom ppm concentrations are powerful broad spectrum antibiotics. The synergistic and additive effects of colloidal silver with various well-established antibiotics have been well documented. For our study, we obtained our samples from several different companies that produce colloidal metal particles suspended in minuscule quantities (\sim few ppm) in water. Recent work⁶ on ultradilute (nano in both concentration and size) Ag-aquasols has demonstrated the role of

Ag–O–H₂O in detailed TEM and high resolution TEM (HRTEM), the extraordinary bactericidal effects. The nature of the liquid phase in such ultradilute colloids is of significant interest. Our detailed experimental approach to use the state of art spectroscopic techniques (FTIR, UV-Vis and Raman) proves that the presence of colloidal particles (1–30 ppm) does indeed alter the structure and biological properties of water^{7,8}.

Figure 3a shows the UV-Vis absorption spectra of a series of silver aquasols varying in Ag concentration, ranging from 10 to 200 ppm. The UV absorption spectra was carried out in a double beam monochromatic UV-Vis spectrophotometer using silica glass cuvettes. Although Ag plasmon radiation in the UV absorption spectra conventionally appears in the 400–420 nm regime, our analysis indicates major structural absorption effects in 200–240 nm range due to the changes in the structure of water. Notable changes are also seen in the Raman spectra as indicated in Figure 3b. The presence of charged nanoparticles in water alters the bulk structure of water, by the influence of charge (positive or negative) on the first nearest neighbours to the charge species, which in turn affects the second nearest neighbour and so on.

It has been previously believed that the femtosecond vibrations of O–H bonds and the somewhat loose H–O–H

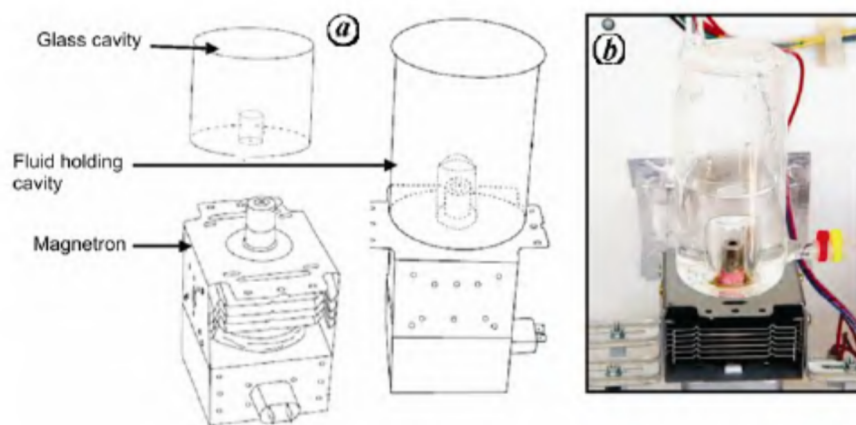


Figure 4. *a*, Schematic of the set-up that was used to generate the microwave-treated water. *b*, The actual set-up used in the process.

atomic associations to form H_2O would render it impossible to sustain any longer term structures in the fluid state. However, as cited in the general introduction and further substantiated by the work of Chaplin¹ (<http://www.lsbu.ac.uk/water/chaplin.html>), different structures in liquid water do exist and persist with certainty. There has been a substantial body of work on the 'structuring' of water by radiation, certainly with 'memories' sufficiently long for confirmation in the laboratory. We now have multiple tools to evidence the sustained changes in the 'structure of water' caused by extrinsic factors. The most dramatic effects of the ability of electromagnetic fields on condensed matter are, possibly, those demonstrated by Roy and co-workers⁸⁻¹¹ on the radically different phase formation and direct decrystallization of many solids, including the most important phases used in the electronic industry, viz. ferrites, barium titanates and even elemental silicon. In these papers, it has been shown that using separate E and H fields from 2.45 GHz radiation in a single mode cavity, dramatic differences are found in the structure of solids as confirmed by X-ray diffraction (XRD), scanning electron microscope (SEM), TEM and Raman characterization of the results of exposure, between the electric and magnetic fields. What is most surprising is the ability of these vectored fields to convert in the solid state, crystalline phases to noncrystalline phases. Our study involves similar disruptions of the main bonding structure of condensed matter, in this case, liquid water.

Brooks¹²⁻¹⁴ in a series of patents has presented extensive theoretical models and a general theory of transverse and longitudinal wave effects on matter and the phenomenon of 'spectral catalysis'. This general theory of resonant coupling of a specific frequency to specific bonds in condensed matter is a reasonable base merely for the plausibility of phenomena such as those reported in our earlier work¹⁵. Even earlier, among many others Colic and Morse¹⁶ had shown the influence of resonant radio-frequency (RF) radiation on the gas-liquid interface and on aqueous suspensions and solutions¹⁷. Earlier work on

pH, conductivity and zeta potential of various treated colloidal suspensions in water show residual oscillations even after the field's removal¹⁸⁻²². Higashitani *et al.*²³ have quantified the effects of magnetic fields in several papers dealing with the 'magnetic memory effect'. Pach *et al.* have shown the effect of magnetic fields on CaCO_3 crystal growth²⁴. Tiller *et al.*²⁵ showed the effect of about 100 Gauss DC fields on the pH of specially preprocessed waters. Our work presented here displays that, the polarized radiation alone causes the dissociation of water into its constituent elements H_2 and O_2 .

We report here two experimental results that strikingly alter the structure of liquid water: (i) Influence of single mode 2.45 GHz microwave frequency and (ii) effect of polarized 13.56 MHz radio frequency.

For all the experiments, reverse osmosis, deionized water, henceforth referred to as R/O DI water, was used. Sedlmayr, inventor and co-author of the paper, designed the vectored microwave device for water distillation to generate 'clean' water. A schematic of the set-up is shown as an inset in Figure 4*a*, wherein a vectored microwave field is generated by the special design of the glass vessel stationed on the antenna of the magnetron. The theoretical basis and experimental details of the design of the set-up were published elsewhere²⁶. The image of the actual reaction set-up and the vessel is shown in Figure 4*b*. R/O water collected in a 2.5 l tank was allowed to continuously circulate in the reaction vessel with a control such that the water level in the vessel at a given time remains constant. When the microwave is switched 'ON' water is heated up, vapourizes and is condensed and collected at the outlet. Microwave-distilled water thus collected is allowed to cool to room temperature prior to analysis. We describe here detailed analysis of the microwave-distilled water employing chemical analysis and various spectroscopic techniques such as ultraviolet spectroscopy, foreign transform (FT)-infrared and extensive Raman spectroscopic studies. Intense calibration was carried out on each of the

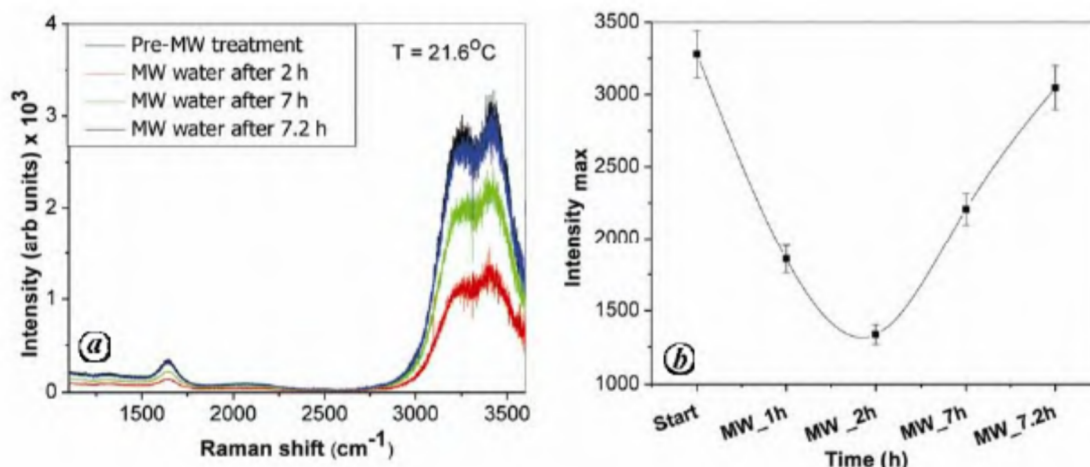


Figure 5. *a*, Raman spectra of microwave water measured at 21.6°C as a function of time. Note that the time of relaxation for the microwave structured water is ~7.2 h. *b*, Plot of intensity_(max) (marked by arrow) of the O-H stretch band as a function of time.

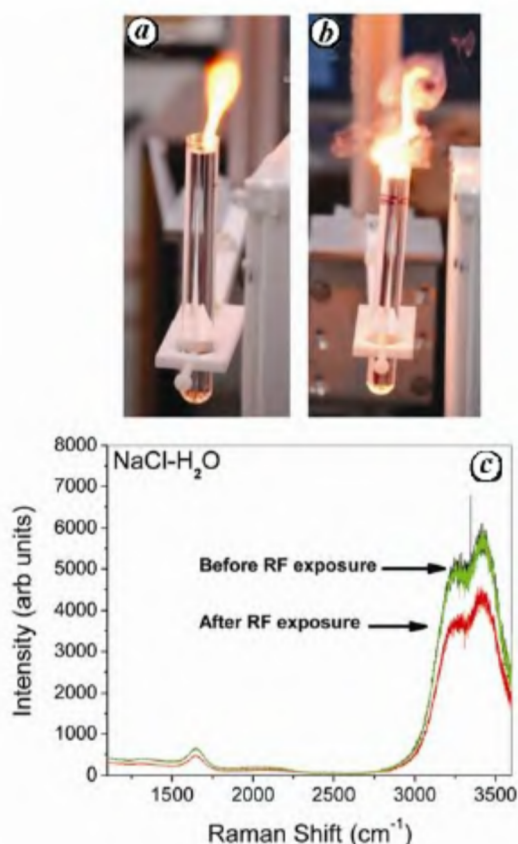


Figure 6. Salt water combustion in polarized radiofrequency field. *a*, 0.3% and *b*, 30% NaCl solution. *c*, Raman spectra of the solution before and after radiofrequency exposure.

instruments at every step in the experimental configuration and procedures. In the immersion Raman spectrometer, we used a laser probe from Inphotonics ($\lambda = 785$ nm) with carefully positioning it into the sample container, and turning 'off' the room lights eliminates all

stray light during the entire experimentation. Multiple Raman scans were carried out on each sample to ensure the reproducibility of the results.

Figure 4*a* shows the schematic of the microwave equipment that was used to generate microwave water. R/O water distilled in a polarized 2.45 GHz microwave field was collected and allowed to cool to room temperature and spectroscopically analysed. Raman spectra of the microwave-water display striking changes in the main O-H stretch bond. Spectral analyses of the microwave water as a function of time were carried out isothermally at 21.6°C. Figure 5*a* shows the Raman spectra of microwave-water showing that the changes in the structure are stable for at least 7 h. Repeated analyses confirm the reproducibility of the results. Plot of intensity_{max} (marked by an arrow) of the O-H stretch band as a function of time, shown in Figure 5*b*, indicates that the maximum change is observed in the sample after 2 h of microwave treatment. The relaxation times for the metastable structures are ~7.2 h. The large magnitude of drop in the intensity of the O-H stretch band of the microwave-treated water as compared to the untreated water is greatly significant from the point that it is indicative of major structural changes in the Van der Waal's bonds holding different units together. The calculated ratio of the O-H stretch to the H-O-H bending mode clearly defines the existence of various water 'structures' in the microwave-treated water. Thus, there exists a statistical-thermodynamic equilibrium of different such 'structures' (cluster units held by Van der Waal's forces) at a given time. On standing for long hours, these units relax to their most stable structural state. This is clearly noted in the Raman data (blue and black curve in Figure 5).

Given here are the various effects of polarized RF field on NaCl-H₂O system. The equipment is described in the published patent applications of Kanzius²⁷⁻³⁰. Sample concentrations were varied from 0.1% to 30% of NaCl.

The solution in a Pyrex test tube containing the salt-solution was held by means of a Teflon stand and was introduced into the RF cavity. In presence of the RF field, the saline solution ignites and combusts with an intense flame. Approximate power for most of our experiments was ~ 300 W as recorded by the output dial of the RF generator. The frequency of the RF was in the 13.56 MHz range³¹. Rudimentary attempts were made to measure the temperature of the flame; they agree with more detailed measurements (about 1800°C) made by Curley at the M.D. Anderson Cancer Center, in connection with their detailed cancer study³².

Figure 6 shows a simple view of the variation of the flame size with the concentration of the solution. At lower NaCl concentrations, the intensity of the flame is lower. Immediately after the RF power is turned 'on', the flammable gas can be ignited. The flame shuts 'off' as soon as the RF power is shut off. We also used concentrations close to the saturation with NaCl that produce somewhat larger flames as shown in Figure 6b. Analysis of the NaCl solutions was done at room temperature, allowing the solutions to equilibrate for ~ 2 h after combustion in the RF field. Samples were analysed for structure changes with UV-Vis and Raman spectrometry before and after exposure to the RF field (Figure 6c). Furthermore, it is important to note that the Raman spectral analysis of the saline solutions before and after the combustion confirms that there are substantial structural changes. These are not discussed further in this context, but show that such changes in the structure of the liquid phase are also correlated with such radiation effects.

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