Surface enhancement of the magnetic field effect of water

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Water is ubiquitous liquid on the earth, and indispensable for life and the environment. And water has many peculiar properties, including large heat of vaporization, high boiling and melting temperatures, and high solubility for charged and polar molecules.[1] The distinctive features of liquid water are mainly due to the three-dimensional hydrogen-bonding (HB) network. Our recent work has revealed that the strong magnetic field varies the refractive index of water. The increase of the refractive indices is about 0.1% under 10T.[2] Here we report this magnetic field effect is much enhanced in the compact layer of water molecules adsorbed on a poly-crystalline Au surface.

Experimental

The refractive index of water was measured by using the surface plasmon resonance (SPR) on the poly-crystalline Au film as well as by the detection of the refraction angle. The angle was estimated by measuring the deflection of the laser beam passing through a water filled quartz cell by the position sensitive detector (PSD). Those independent experiments revealed the change in the refractive index as a function of the magnetic flux density (B). All the measurements were carried out at ambient pressure and temperature of 25.0 °C stabilized within ±1 °C. Ultrapure water was prepared by a commercial water purification system (Direct-Q 5, Millipore Corp., 18.2 MΩ cm).

The SPR sensor and the sample cell were placed in the bore of a super-conducting magnet (JMT-10T150, Japan Super Conductor Technology Inc.) at the point where B is the maximum (B=10T) and the magnetic field gradient is zero (grad$B$=0). The sensor was placed so as the Au film was perpendicular to the magnetic field.

The surface of the SPR sensor was covered with alkanethiol self assembled monoleyers (SAMs) to inhibit the adsorption of water on Au film. The SAMs used was synthesized with 2-pyridinethiol (2-PySH), dodecanethiol (C12SH) and octadecanethiol (C18SH) (Wako Pure Chemical Industries, Ltd.). The Au film of the SPR sensor was cleaned by dipping into H_2O_2 5% and H_2SO_4 5% mixed solution for 10 minutes, [3] and rinsed with ultrapure water. The self-assembling was conducted in ethanol solution containing the thiols.

Results and Discussions

The dependence of the refractive index of pure water on the magnetic flux density is shown in Fig. 1. The refractive indices measured by the SPR setup (filled circles, n_{SPR}) and the PSD setup (filled squares, n_{PSD}) show the increases of 1.8×10^{-3} (0.14 %) and 1.3×10^{-3} (0.09 %) at 10 T, respectively. The increase of n_{SPR} is slightly larger than that of n_{PSD}. The origin of this discrepancy is attributed to the magnetic effect on water at the vicinity of the interface because the SPR is sensing the region in the evanescent field near the Au surface, while the region detected by PSD is the bulk.

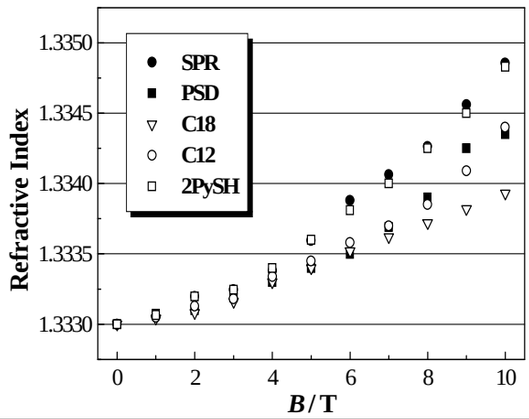

Fig. 1 The dependence of the refractive index on the magnetic flux density and the thickness of the adlayers..

The dependence of the refractive index of water on the adlayers on the Au surface is also shown in Fig. 1. The change in the refractive index obtained by the SPR with the Au film covered by C12SH and C18SH was identical with that obtained by PSD. These SAMs exclude the chemisorbed H_2O molecules on the Au surface. 2-PySH adlayer showed the almost same behavior of that obtained on bare the Au film, which suggests 2-PySH adlayer cannot cover the Au surface perfectly.

These findings demonstrate that the chemisorbed H_2O molecules on the Au surface were affected much by the magnetic field.

Conclusion

In the bulk water, our previous work showed that the magnetic field increases the average number of hydrogen bonds per water molecule.[2, 7] At the surface of the Au the present work revealed that the magnetic field effect is much enhanced. The surface enhancement was probably due the topological effect in the water molecules confined in the inner Helmholtz layer.

References

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