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Introduction to Rheometry
固さと粘さの測り方　－粘弾性測定は商売になるか？－

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1. Introduction

Propagation of ultrasonic wave is determined by the elasticity and viscosity of the medium. On the other hand, the accurate determination of the mechanical properties of material can be carried out by measuring the waves propagating in/on the material. In this presentation, I introduce some kinds of measurement methods for rheological properties uniquely developed in our laboratory. The common feature of them are the noncontact and remote sensing of the mechanical properties using the optical or electro-magnetic interactions. In my talk, some social and economic issues concerning the development of commercially available systems would also be revealed.

2. Ripplon Light scattering

Ripplon is a thermally excited capillary wave propagating on the liquid surface. The phase velocity and the temporal damping of the ripplon is determined by the surface tension and the viscosity, respectively. Its propagation also feels the two dimensional viscoelasticity of the molecular layer adsorbed on the surface, and we can observe the condensation state of the monomolecular layer. The amplitude of ripplon is much less than nm order and we observe their propagation by dynamic light scattering equipped with the optical heterodyne spectroscopy. Figure 1 shows the typical experimental set up of the ripplon light scattering method. This systeme has been successfully applied for the measurement of soluble and insoluble surface molecular layers. For the soluble layers, the dynamic adsorption process can be observed through the surface relaxation. As for the insoluble layers that is so called Langmuir films, phase transition and critical phenomena were investigated.

3. Electric field tweezers

We can apply mechanical force on to the surface of material using light or electric interaction. Here, I introduce the measurement method of surface tension and the viscosity of fluids near the surface. We call the system 'electric tweezers' since it can pick up the local area of sample surface like mechanical tweezers but by a non-contact manner.

The principle is as follows; a sharp needle electrode is set just above the sample surface and the applied voltage generates a localized electric field around the sample surface. The difference of the electricity in between the interface generates the discontinuous stress, which is called Maxwell stress. The material is then picked up towards the direction, where the energy density due to the electric field is lower.

The height of the displacement of the surface is approximately proportional to the inverse of the surface tension, and the speed of the response is determined by the viscosity of the sample. The area of the applied force can be changed by changing the distance between the needle tip and the surface. The system is applied for the noncontact measurement of drying process of paints and coating materials.

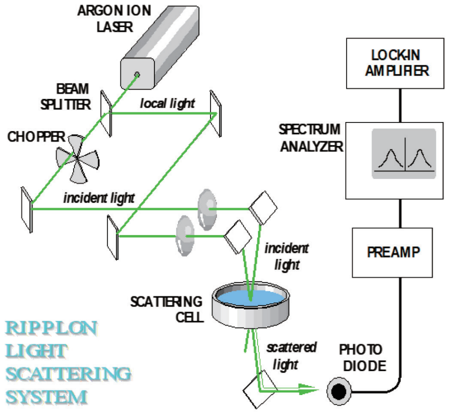

Fig. 1　Schematic view of ripplon light scattering system.

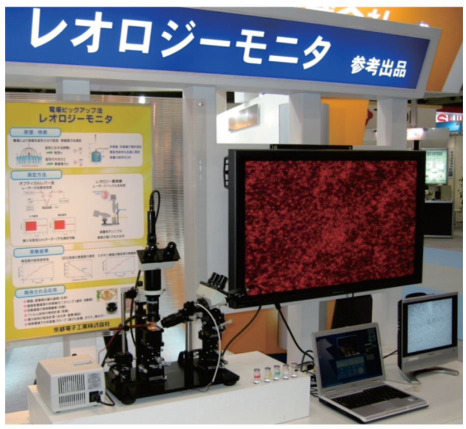

Fig. 2　Exhibition of electric tweezers system at Makuhari Messe.

4. EMS viscometer

In conventional viscometers, probes should be necessarily in touch with the samples. When it is applied to the rheology measurement of bio-hazardous materials such as human blood, for example, risk and cost of the measurement would be serious problems. We developed a new viscosity measurement system, in which a disposable probe rotor is separated from the measurement apparatus and remotely driven by the electromagnetic interaction.

Figure 3 shows the electro-magnetically spinning (EMS) viscometer system, in which a couple of permanent magnets generates a rotating magnetic field. A probe rotor is made of conductive material in which an eddy current is induced due to the temporal modulation of the magnetic field and the Lorentz interaction between the magnetic field and the current drives the probe to rotate following the revolution of the magnetic field.

In the presentation, I would like to show various results of the rheology measurement including the viscosity of human blood. New inventions are recently made. One is the application to the inline measurement. We can carry out continuous monitoring of the viscosity during over weeks, months and years. Another is the extension of remote range of the driving torque up to over 100 mm. This technique can be applied to the in-situ measurement in the reactor or container.

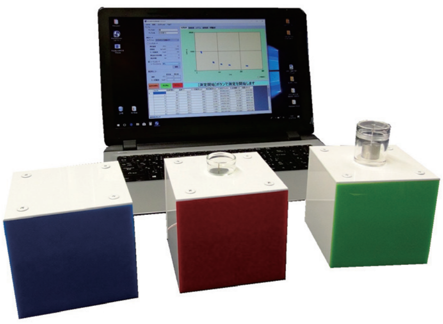

Fig. 3 Photo of EMS rheometer system.

5. Dynamic surface tension measurement

The ripplon light scattering introduced above is a very sophisticate method to measure the adsorption of surfactants on to the surface, but is not an easy and simple method for the industrial use. On the other hand, the importance of the measurement method of dynamic surface tension is increasing these days, since micro-liquid process such as the inkjet and micro-fluidics are rapidly advanced.

To observe the rapid adsorption phenomenon occurring in the time range less than 1 ms, we developed a new surface tensiometer using the technology of high speed generation and non-contact manipulation of airborne micro liquid droplets.

A liquid jet is emitted from the nozzle tip with a diameter of microns. In addition to the continuous pressure to emit the jet, ultrasonic vibration is added to uniformly divide the liquid jet to a series of droplets using the Ryleigh instability. The flying particle is then deformed by the dielectric force and the eigen frequency of the droplet oscillation after the deformation gives the surface tension. Figure 4 shows the computer window of the software and the aspect of the measurement system.

The time resolution of the system is better than 100 μs, which is more than 100 times higher than the conventional method of dynamic surface tension measurement. The optional function of the system enables us to directly observe the behavior of liquid droplets on the solid substrate, such as the permeation of the inkjet ink to the paper.

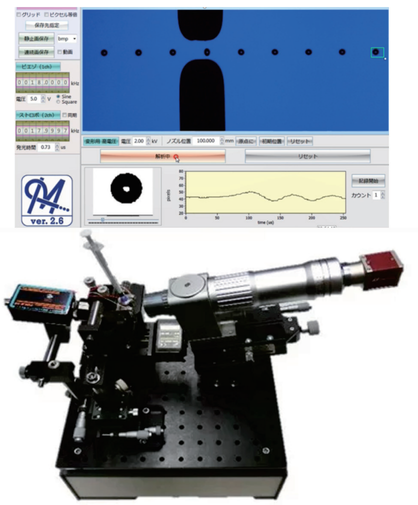

Fig. 4 Dynamic surface tensiometer. Image of software (above) and measurement system (below).

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