Measurement of Mechatronic Property of Biological Gel with Micro-Vibrating Electrode

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ABSTRUCT

A new methodology to measure local mechatronic property of biological gel has been proposed, and measurement system has been designed with a micro-vibrating electrode. The designed system consists of two electrodes, where one of the electrodes vibrates with piezoelectric actuator. The component of variation at impedance between two electrodes with vibration of electrode is analyzed at the corresponding spectrum. The system was applied to measurement of impedance in saline solution and potassium chloride aqueous solution. The experimental results show that the component increases with amplitude of vibration of the electrode and with the impedance of solution.

Keywords: Bio-measurement, Mechatronic property, Biological gel, Micro-vibrating electrode, Frequency, Electric impedance

1. INTRODUCTION

A biological body includes various electrolytes. Several studies had been tried to estimate structures of the human body with electric impedance. Some studies tried to analyze the structure of organs with measurement of local electric impedance [1-5]. To avoid the change of structure by movement of ions with a direct current, an alternating current is applied to measure electric impedance of electrolyte solutions. In the present study, a new methodology to measure local mechatronic property has been proposed, and measurement system has been designed with a micro-vibrating electrode.

2. METHODS

Measurement principle

The impedance between two electrodes soaked in an electrolyte solution varies with the distance between them (Fig. 1). When the distance oscillates sinusoidally with a mechanically vibrating electrode, the impedance oscillates, too.

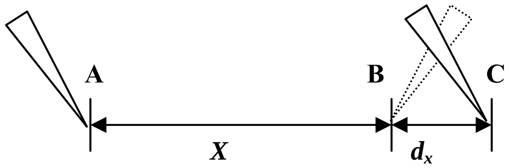

Fig. 1: One electrode is fixed at point A and the other electrode is vibrating between B and C.

The oscillation corresponds to the variation of impedance of the local space, where the electrode is mechanically vibrating (Fig. 2). The variation was analyzed with spectrum and the amplitude at the corresponding frequency was measured [6].

Electrodes

The electrode was made of a glass micro-capillary filled with a potassium chloride aqueous solution (3 mol/L). A platinum wire was inserted in the center of the capillary. The diameter of the tip of the capillary is 0.01 mm (Fig. 3). One of the electrodes was vibrated with a piezoelectric actuator.

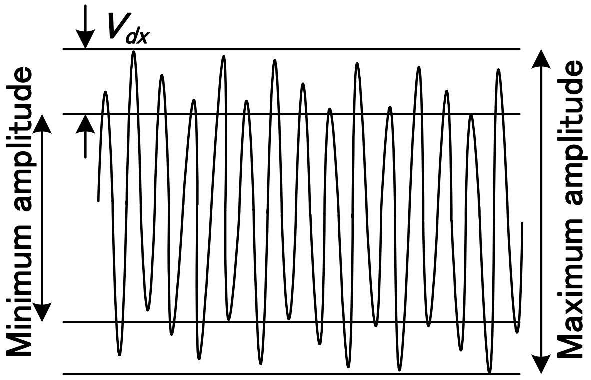

Fig. 2: An output electric alternating voltage signal (V_{out} in Fig. 4) oscillates with time. V_{dx} corresponds to impedance of the local space, where the electrode is mechanically vibrating.

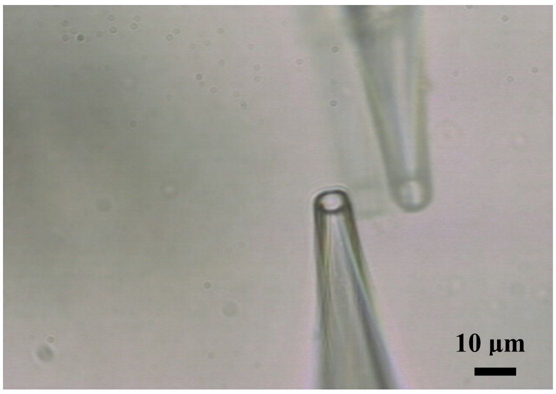

Fig.3: Electrodes. The upper electrode is vibrating.

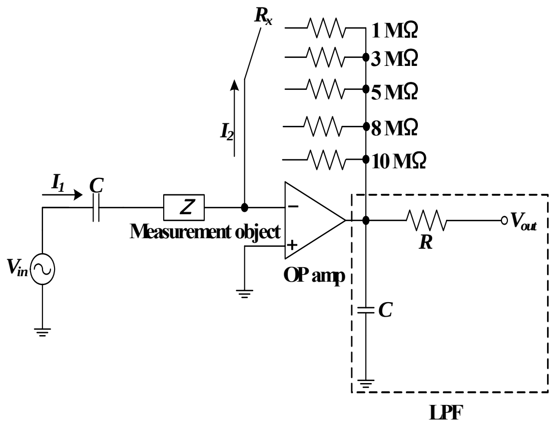

Fig. 4: Measurement circuit diagram. To cut high-frequency component, Low Pass Filter (LPF) is applied.

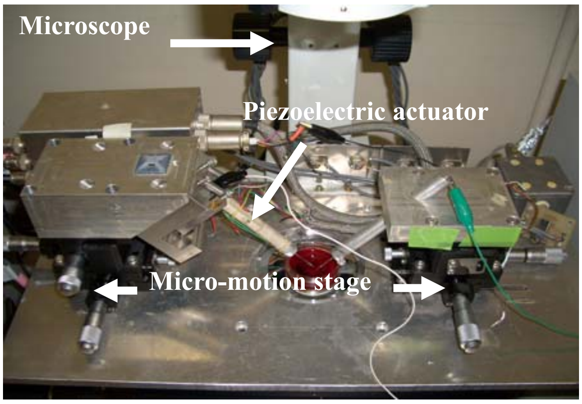

Fig.5: Microscope.

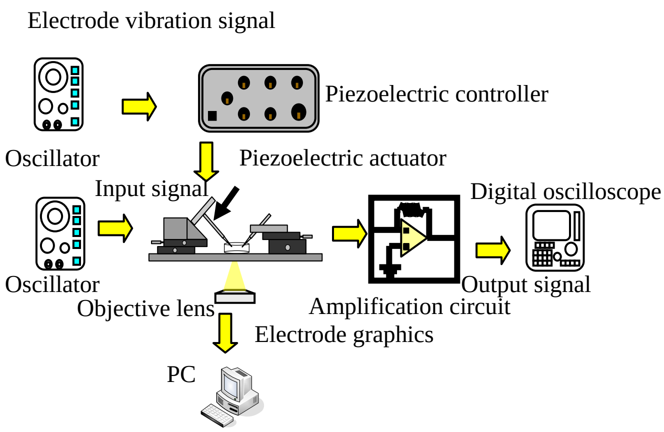

Fig. 6: Measurement system

Measurement system

The measurement system consists of an oscillator, an amplifier (Fig. 4), a spectrum analyzer, a phase-contrast optical microscope (Fig. 5), a charge-coupled device camera, a recorder, and a monitor (Fig. 6).

Experiments

The manufactured system was applied to measure electrolytes: a sodium chloride aqueous solution, a potassium chloride aqueous solution, and an egg. Variations were made in concentration (weight percentage of 0.1-9.0) of the sodium chloride aqueous solution. In sodium chloride aqueous solution of 0.5 percent, variations were made on amplitude of vibration of the electrode. In the test with an egg, one electrode was stuck into yolk and the other was set in the surrounding solution, while the impedance of surroundings was varied with potassium chloride. The performance was tested at 25 degrees centigrade.

3. RESULTS AND DISCUSSION

Figure 7 shows relation between the output voltage signal and concentration of sodium chloride aqueous solution, when the frequency of the input signal was varied between 100 and 500 Hz. The output voltage signal is standardized with that of 0.1 percent, so that the value is unity at 0.1 percent NaCl in Fig. 7. The output voltage signal without the amplifier was directly measured at the output resistance without vibration of the electrode in Fig. 7. Impedance is inversely proportional to the electric current, which is proportional to the output voltage signal. The experimental data show that impedance of the sodium chloride aqueous solution between two electrodes decreases with increase in the concentration of sodium chloride in the solution from 0.1 to 9.0 percent, and that impedance does not vary with frequency between 100 and 500 Hz.

Figure 8 exemplifies spectra of the output signal, when the amplitude of vibration (150 Hz) of the electrode is 0.023 mm. The spectra at 60 Hz and 100 Hz correspond to frequency of the electric power source and the input signal, respectively. The experimental data show that power spectrum at 150 Hz of output signal increases with the increase in the amplitude of vibration of the electrode to 0.023 mm (Table 1). The local impedance is proportional to output signal spectrum, which corresponds to the mechanically vibrating frequency of the electrode [6].

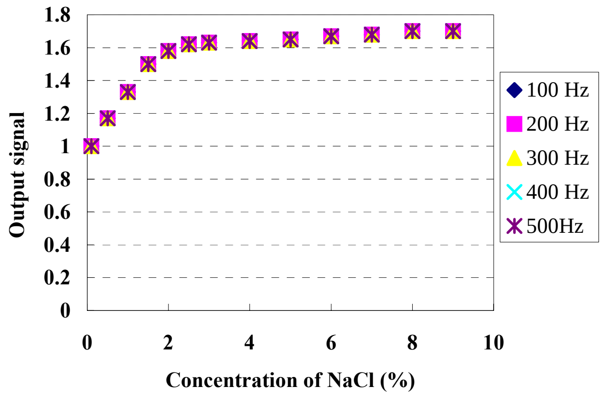

Fig. 7: Relation between output signal and concentration of NaCl.

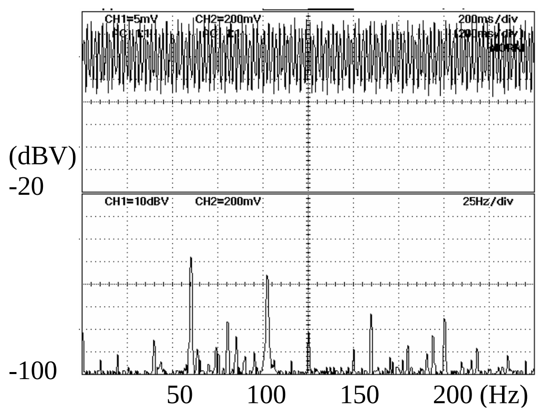

Fig. 8: Out put voltage (top) and its spectrum (bottom).

Table 1: Spectrum for each amplitude of mechanical vibration of electrode.

Amplitude mm	0	0.006	0.014	0.020	0.023
Spectrum	–96	–95	–90	–87	–87

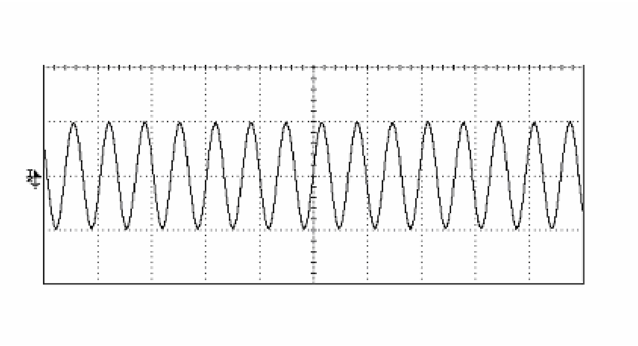

Fig. 9: Output voltage tracing. 10 ms/div for time scale.

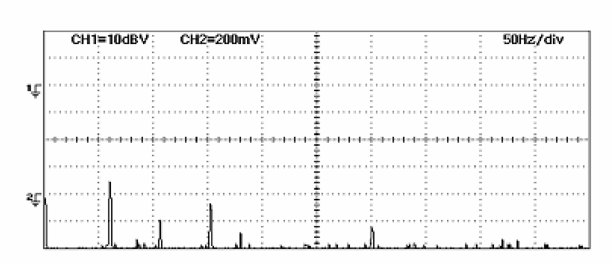

Fig. 10: Spectra of output voltage. 50 Hz/div for the axis of abscissas.

Table 2: Electric conductivity of aqueous solution.

	D (dBV)	V_{out} (mV)	κ ($\Omega^{-1}m^{-1}\times10^{-3}$)
KCl	–70.0	0.95	2.02
NaCl	–70.0	0.85	1.62

Output voltage tracing for the sodium chloride aqueous solution of 0.1 percent is exemplified in Fig. 9, where the electrode is vibrating at 100 Hz. Figure 10 shows spectra of the output voltage signal. The spectra at 60 Hz and 150 Hz correspond to frequency of the electric power source and the input signal, respectively. The experimental data show that power spectrum at 100 Hz of output signal varies with the electrolyte.

Table 2 shows experimental data for electric conductivity of two kinds of electrolyte solution. Conductivity is the inverse number of impedance. The results show that impedance depends on the variation of electrolytes and that the ratio of impedance between the potassium chloride (0.1 percent) and sodium chloride (0.1 percent) aqueous solutions is 0.80, which can be approximated to 0.83 calculated from electric conductivity of chronological scientific tables.

The experiment with an egg shows that the impedance is independently measured of that of the surroundings when the electrode stuck into the yolk is vibrating, while the impedance of the surrounding solution varies with the concentration of electrolyte. The output signal, however, depends on the concentration of electrolyte in the surrounding solution, when the electrode is not vibrating.

The results show that the local impedance at the vibrating electrode governs the output signal of the measurement system.

Several designs had been tried to analyze biological impedance. Spectra are applied to analysis of impedance [1]. Viscosity gives effects on output signals of a vibrating sensor [3]. In the previous study, the signal was also picked up as a function of viscosity, when the electrode was vibrated in the sodium chloride aqueous solution including dextran. The output signal depends on viscosity at higher frequency (>100 Hz), and on frequency at higher viscosity (>0.01 Pa s) [7].

4. CONCLUSION

The experimental data show that the designed system is effective to measure local mechatronic property of biological gel.

5. ACKNOWLEDGMENT

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6. REFERENCES

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