1Pa-29
Proceedings of Symposium on Ultrasonic Electronics, Vol. 31 (2010) pp. 73-74
6-8 December, 2010

Viscoelasticity Meter Using $LiTaO_3$ Shear-wave Resonator
$LiTaO_3$ 圧電すべり波振動子をセンサ素子とした粘弾性測定装置の開発

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1. Introduction

There are many reports on the response of shear-wave resonators in a viscous liquid.[1-4] $LiTaO_3$ chip-type resonators were investigated as sensors for viscoelasticity meters.[5-6] Because electromechanical coupling factor is high, mechanical loss is small, shear-wave velocity is high, and density is also high, the resonators have great potential for application as miniaturized, temperature stable and disposable sensors.

2. Chip-type $LiTaO_3$ shear-wave resonator

Figure 1 shows a schematic chip-type $LiTaO_3$ shear-wave resonator. The direction of particle displacement, driving electrode and the 4 MHz chip size are shown in the figure. Each resonator is installed directly on a ceramic plate. There is infiltration space for liquid on the back surface of the resonators. Both sides of the resonators are bound to the liquid. The electromechanical equivalent circuit of the resonator is shown in Fig. 2. [5-6] These resonance characteristics have high Q values and no spurious response in the measuring frequency range. The influence of shear-wave generation in viscous liquid is introduced as radiation impedance Z_L for the resonator. It causes increase of resonant resistance and decrease of resonant frequency for the resonator.

3. Measuring resonant frequency and resonant resistance

Using frequency sweep, we measure resonant characteristics and find the frequencies of the minimum impedance value (*fr*) and the minimum impedance (*Rr*). *fr* decreases and *Rr* increases with the viscoelasticity of the liquid. The range of resonance frequency change is 1% and the range of resonance resistance is from 50 to 100 kΩ . The sensor element on a ceramic plate is so small as shown in Fig.1 that we can use the compact holder on a Peltier device. The holder contains a reference element and an element with liquid sample. The microprocessor controls electric driving resonator at MHz range, detecting resonator current, setting holder temperature from -20 to 100℃, and deriving *fr* and *Rr* as a viscoelasticity meter.

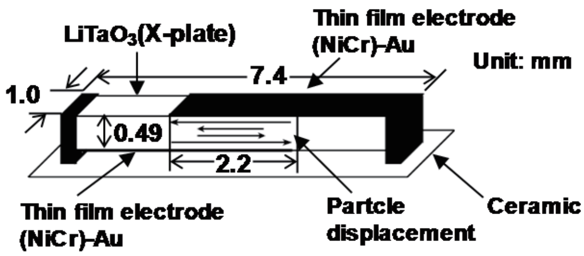


Fig. 1. A chip-type $LiTaO_3$ shear-wave 4MHz resonator.

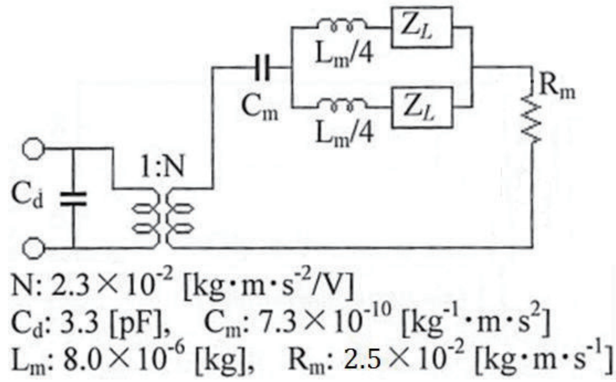
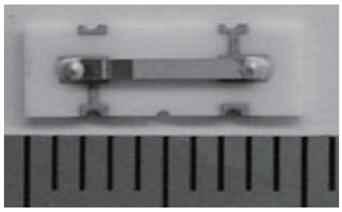
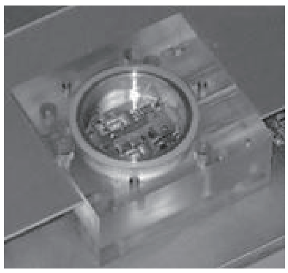


Fig. 2. Equivalent circuit of a typical $LiTaO_3$ shear-wave 4MHz resonator.



(a) Shear-wave resonator.



(b) Sample holder for temperature measurement.
Fig. 3. A sensor element and a sensor holder.

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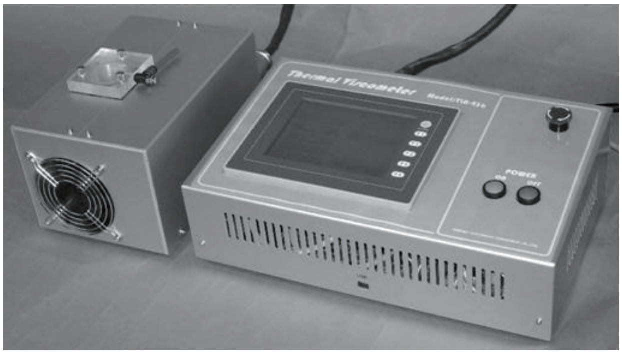
Figure 4(a) shows a portable viscoelasticity meter with a flexible probe. A sensor unit is disporsable. Figure 4(b) shows a desktop meter with a temperature control unit. Both meters can be used as a stand-alone. Conventional PCs are also applicable for scheduled measuring and data processing with USB terminal.

(a) Portable viscoelasticity meter with a flexiable probe.



(b) Desk-top viscoelasticity meter with a temperature control unit.

Fig. 4. Two types of viscoelasticity meter using $LiTaO_3$ shear-wave resonator.

4. Measured temperature characteristics of standard material glycerin

Glycerin is typical standard material for viscosity measurement because it is a pure substance. Figure 5 shows the temperature dependency of viscosity measured by the newly developed meter and reported values. Virtical axis scales of measured resonant resistance data of 4 MHz and 6 MHz were linearly adjusted to the temperature characteristics of 100% glycerin. The resonant resistances show good agreement with the viscosities measured by a conventional rotational viscosity meter and thermal water bus.

5. New application of disposable viscoelasticity meter

The sensor element is so simple, so small and so economical that the element is disposable after measurement. Figure 6 shows the typical stiffening phenomenon of the bonding material observed by the viscoelasticity meter. It shows the possibility of new applications for the timely and temperature controlled contentious measurement for chemical and physical transient phenomena related to viscosity and elasticity.

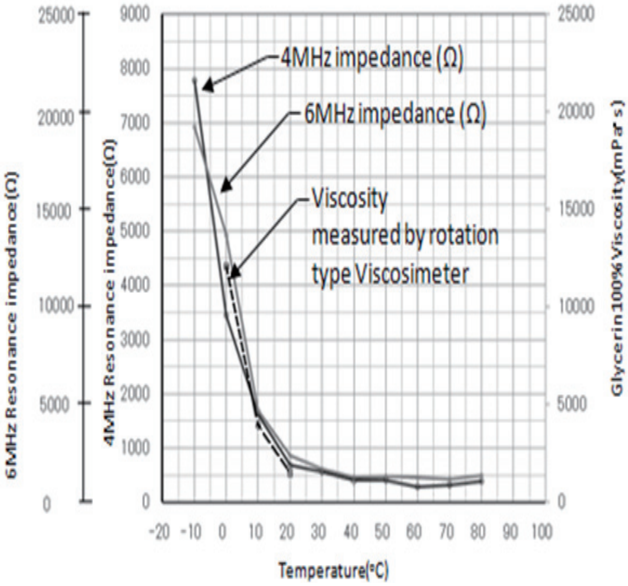


Fig. 5. Temperature dependency of viscosity of 100% glycerin measured by the developed meter and reported values.

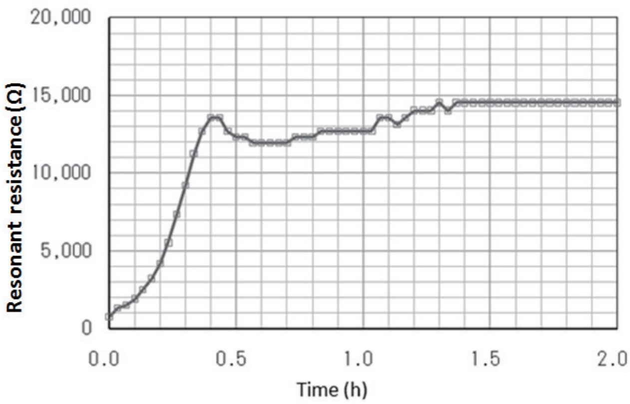


Fig. 6. Typical stiffening phenomenon of the bonding material observed by viscoelasticity meter.

Acknowledge

Authors show our thanks to Mr. A. Nakatsuka of Industrial Technology Institute, Miyagi Prefectural Government for his valuable advices.

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