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Viscoelastic Analysis for Shear Horizontal Surface Acoustic Wave Biosensor on Quartz

水晶を用いた横波型弾性表面波バイオセンサの粘弾性解析

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1. Introduction

Recently, an innovation platform for the detection and identification of the infectious agents that can be used by the patients has been required. There are various important requirements for the sensor platform, such as portability, low cost per test, maximum achievable sensitivity and specificity, ease of use, and that can be used at or near patients.

Many systems have been realized as ease of use membrane based test strips, often enclosed by a plastic cassette. However, membrane-based test strips have disadvantages due to their visual read-out. On the other hand, immunoassay-based biosensor systems using a shear horizontal surface acoustic wave (SH-SAW) have been investigated [1]-[4]. The SH-SAW immunoassay-based biosensors can be disposable, inexpensive and suitable for mass production. A palm-sized electric reader connected to a sensor device for detecting antigen-antibody reactions has been realized. However, there are only few papers which have studied theoretical analysis of SH-SAW biosensors.

Numerical analysis of SH-SAW biosensors must be one of important factors for the commercialization of SH-SAW biosensors. In the analysis of the bio-reactions with mass loading, the sensitivities of SH-SAW biosensors were too small to confirm the experimental results [3]. In the analysis of the bio-reactions with viscosity sensitivity, the absolute values of velocity and attenuation changes of SH-SAWs agreed with the experiments [4]. However, a protein which used in SH-SAW biosensors is viscoelastic material. Therefore we analyze the bio-reactions as viscoelastic film of SH-SAW biosensors using a numerical calculation method.

2. Calculation

The numerical calculation has been proposed by an improved Campbell and Jones method [5] involving an influence of liquid in order to evaluate sensitivities of SH-SAW biosensors.

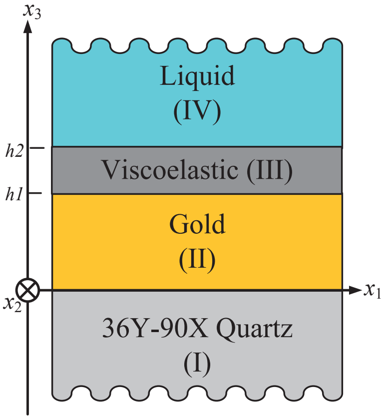

Fig. 1 Calculation model.

Figure 1 shows the structure model of the calculation. There are four layers: substrate (I), metal (II), bio-layer (protein) (III), and liquid (IV). The substrate layer (I) is 36Y-90X quartz, the metal layer (II) is gold film, the bio-layer (III) is assumed viscoelastic film, and the liquid layer (IV) is the Newtonian fluid. The SH-SAW propagates along the x_1 direction. The liquid layer and substrate are considered as semi-infinite layers while the gold and viscoelastic films are considered as a finite layer.

In the cases on layers (I) and (II), we can use a numerical calculation method proposed by Campbell and Jones [5]. In the case of layer (III), the elastic coefficients of isotropic viscoelastic materials have complex quantities, where the real part is the elastic storage modulus and the imaginary part is the dissipative loss modulus. In the case of layer (IV), we can use the numerical calculation method reported by Moriizumi et al., [6]. The boundary conditions between (I) and (II), (II) and (III), (III) and (IV) are the continuities of the displacement and stress x_3 direction.

3. Results and discussion

The velocity changes of SH-SAW were investigated as a function of thickness of the viscoelastic films. The material constants of viscoelastic films were selected from a paper reported by M. Weiss et al., [7]. A 250MHz

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delay-line SH-SAW biosensor [1] was used. We examined the effect of the differences in the parameters of the material constants of viscoelastic films. **Figure 2** shows the velocity changes of SH-SAW biosensor versus thickness of the viscoelastic films with different shear modulus of elasticity. The real parts of shear modulus of elasticity were estimated 0.3, 0.5, and 0.7 MPa, and imaginary parts of shear modulus of elasticity were estimated 2.5, 3.0, and 5.0 MPa. The density was estimated 1000 kg/m^3. In these results, local maximum velocity changes were observed. The amounts of local maximum velocity changes are increasing with amounts of the imaginary part of shear modulus of elasticity. Under the local maximum velocity change thickness, velocity changes show very similar characteristics without depending on real part of shear modulus of elasticity. Over the local maximum velocity change thickness, velocity changes are decreasing with the amounts of the real part of shear modulus of elasticity.

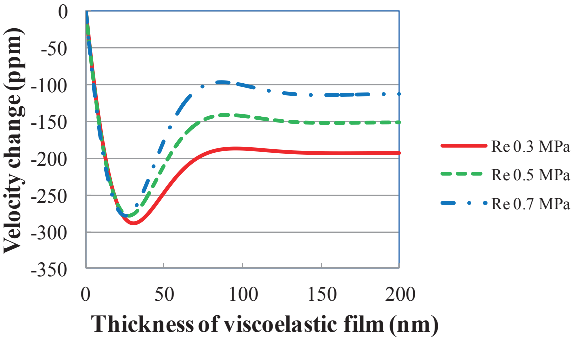
We will show experimental results and estimate the viscoelastic parameters of a protein using those calculation results in the near future.

4. Conclusion

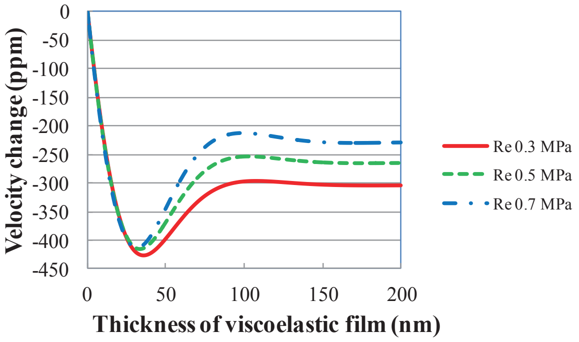
This paper shows theoretical results of SH-SAW biosensor using the viscoelastic model for the bio-layer. The velocity changes of SH-SAW biosensor were calculated as a function of the thickness of viscoelastic films. We examined the effect of the difference in real and imaginary part of shear modulus of elasticity. We will show experimental results and estimate the viscoelastic parameters of a protein in the near future.

References

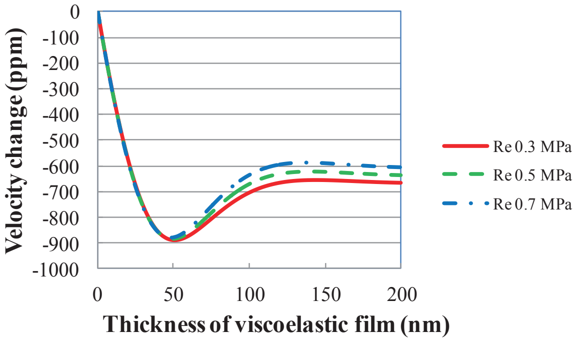
1. M. Goto, O. Iijima, T. Kogai, and H. Yatsuda: Proc. IEEE Ultrasonics Symp., 2010 p. 736.
2. H. Yatsuda, T. Kogai, M. Goto, and N. Yoshimura: Proc. IEEE Freq. Cont. Symp., 2014 p. 12.
3. M. Goto, H. Yatsuda, and J. Kondoh: Jpn. J. Appl. Phys. **52** (2013) 07HD10.
4. M. Goto, H. Yatsuda, and J. Kondoh: Proc. IEEE Ultrasonics Symp., 2012 p.2110.
5. J. J. Campbell and W. R. Jones: IEEE Trans. Sonics Ultrason. SU-17 (1970) 71-76.
6. T. Moriizumi, Y. Unno, and S. Shiokawa: Proc. IEEE Ultrasonics Symp., 1987, p. 579.
7. M. Weiss, W. Welsch, M. v. Schickfus, and S. Hunklinger: Anal. Chem., **1998,** 70, 2881-2887.



(a) 2.5 MPa of imaginary part.



(b) 3 MPa of imaginary part.



(c) 5 MPa of imaginary part.

Fig. 2 Velocity changes of SH-SAW biosensor as a function of thickness of viscoelastic film including different real and imaginary parts of shear modulus of elasticity.