# Propagation properties of surface acoustic wave passing through graphene/LiNbO3 interface

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# 1P1-5

## Propagation properties of surface acoustic wave passing through graphene/$LiNbO_3$ interface

グラフェン/ $LiNbO_3$ 界面の弾性表面波伝搬特性評価


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### 1. Introduction

Graphene has been successfully exfoliated from graphite since 2004, and research on application to next-generation electronics, new materials, and semiconductor devices is proceeding.

Since there are a lot of advantages in terms of electronic, optical, thermal and mechanical properties such as its electron mobility is 100 times that of silicon, mechanical strength is more than 100 times that of iron, and thermal conductivity is more than 10 times that of copper. Therefore, graphene is able to manufacture a better battery, touch panel, and transparent electrode.

In order to discover the unknown properties of graphene, next-generation material, many results have been reported. In this study, we measured propagation properties of surface acoustic wave passing through graphene/$LiNbO_3$ at varous wave strength and temperature.

### 2. Experimental

#### 2.1 Measuring method

Five layer graphene film were transferred onto the surface of SAW device with resonant frequency of 50 MHz at room temperature. The sample obtained was set in vacuum chamber and measured in temperature range of 280 K to 300 K. Figure 1 shows

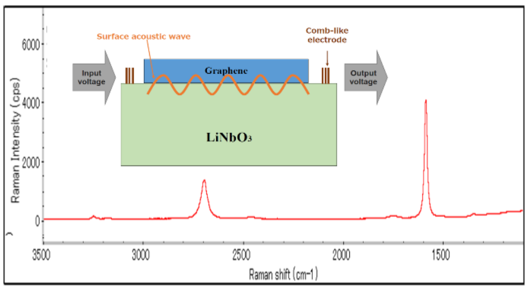


Fig. 1 Graphene sample and its Raman spectrum.

the measurement sample and Raman spectrum of the five layer graphene film.

#### 2.2 Measurement system

Measurement system used in this study is shown in Fig. 2. The system was controlled using SciLab program.

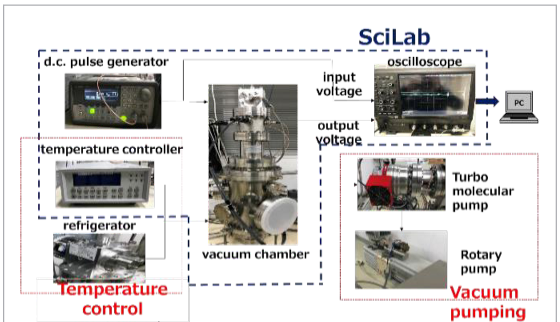


Fig. 2 measurement system

#### 2.3 Measurement condition

The measurement conditions used in this study were listed in Table 1.

Table 1 measurement condition

| | |
|---|---|
| sample size | 10[mm]×10[mm] 5 layer graphene (1layer=0.335[nm]) |
| measured temperature range | 15~300[K] (temperature rising and falling in 1 cycle) (0.2[K] step) |
| input pulse | 1[kHz] |
| output pulse | 50[MHz] |
| input voltage | 0.5 ~ 10[V] |

| | |
|---|---|
| piezoelectric substrate material | $LiNbO_3$ |
| piezoelectric substrate size | 30[mm] ×10[mm] ×0.5[mm] |
| electrode type | graphene interdigitated transducers (G-IDTs) |
| electrode width | 10[μm] |
| Number of electrode combs | 62 (31 pairs) |
| distance between both electrodes | 20[mm] |

### 3. Results and Discussion

#### 3.1 measurement results

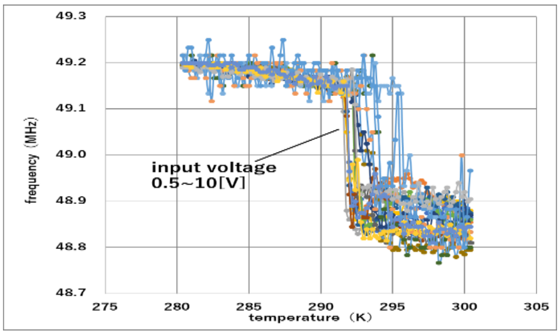


Fig. 3 Temperature dependences of resonant frequency of SAW device with graphene film at various input voltages

Temperature dependences of resonant frequency and the output signal strength are shown in Figs. 3 and 4. Also, the resonant frequencies of the SAW device with the graphene layers at temperatures of 281.0, 291.0, 292.0, 293.0 and 300.0 K, and the SAW


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amplitudes at temperatures of 281.0, 291.0, 292.0, 293.0, and 300.0 K are shown in Fig. 5 and 6 as a function of input voltage, respectively.

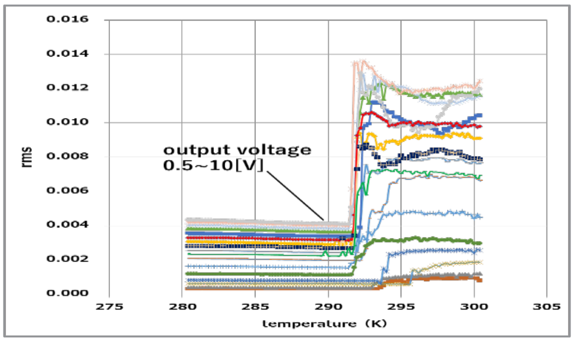


Fig. 4 Temperature dependence of output signal voltage

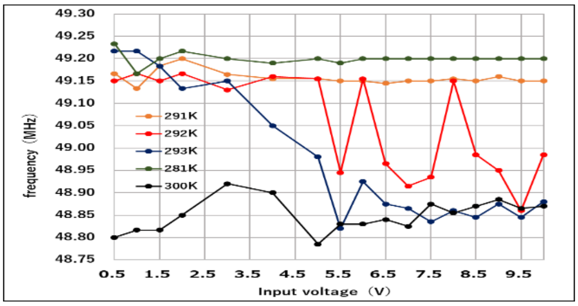


Fig. 5 Input voltage dependence of frequency

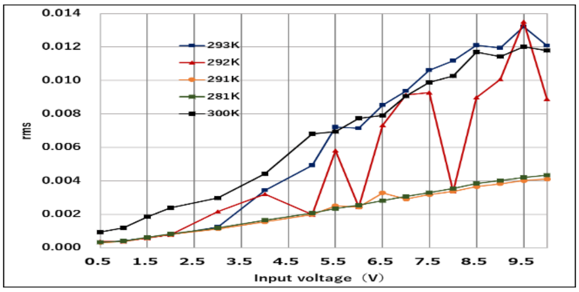


Fig. 6 Input voltage dependence of output signal

## 3.2 Discussion

As shown in Fig.6 and 7, there are suddenly change on frequency and amplitude nearby 292.0 K. The results might be related to difference between CTEs of graphene and $LiNbO_3$. Schematic diagram of 1 D model for directions of thermal stresses at the graphene/$LiNbO_3$ interface is shown in Fig. 7, where T is temperature, $l$ the lengths of the graphene/ $LiNbO_3$ sample along directions parallel to the interface, as well as slopes of $\alpha_G$ and $\alpha_L$ the CTEs, and ΔT the change on temperature, respectively. it has already been clarified by both theoretical and experimental studies that graphene has a negative CTE below a critical temperature depending on conditions such as the substrate-graphene interaction, the impurity doping and the number of the graphene layers. Since stress is easy to be detected by SAW, and 292 K (±1 K) is critical temperature between expansion and compression where stress is probably free.

On the other hand, temperature dependence of the amplitude may be related to Debye's relaxation. Schematic diagram of Debye's relaxation mechanism is shown in Fig. 8. When $\omega\tau < 1$, internal friction for loss of the wave decreases with decreasing frequency.

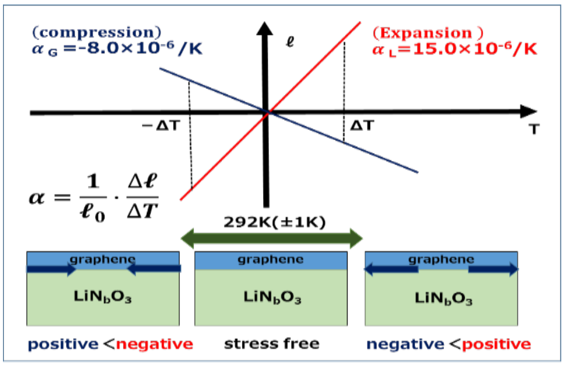


Fig. 7 CTE temperature dependences of graphene and LiNbO3 as well as interfacial stresses.

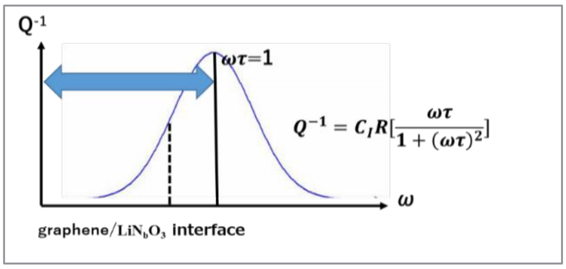


Fig. 8 Debye's relaxation mechanism

## 4. Conclusions

Propagation properties of SAW packet passing through graphene/$LiNbO_3$ interface are characterized in the range of 280~300 K. Interfacial stresses play an important role for attenuation of the SAW through Debye' relaxation mechanism. There is an interfacial stress free state, at temperature that graphene film was transferred onto the $LiNbO_3$ substrate. Therefore, the temperature can be memorized in the structure and be read out by using surface acoustic wave.

## References

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