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Acoustic wave propagation at a 3-layered graphene/$LiNbO_3$ interface

3 層グラフェン/ $LiNbO_3$ 界面における音波伝搬特性

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1. Introduction

Graphene/$LiNbO_3$ structure, which contains a graphene/ferroelectric interface, is a key component for electronic applications such as surface acoustic wave (SAW) filters, field-effect transistors(FETs), and nonlinear optical devices. Because graphene possesses high electrical conductivity and is also the thinnest and lightest material that can be easily processed using photolithography, it is a promising candidate for high-frequency SAW filters. Mayorov et al. fabricated a SAW filter based on graphene interdigitated transducers (G-IDTs) on a $LiNbO_3$ crystal substrate and demonstrated that the G-IDTs were sensitive to temperature and impurity doping in the graphene film electrodes.

2. Experimental

A 128° Y-X $LiNbO_3$ SAW device with dimensions, 30 × 10 × 0.5 mm^3, was used in this study. The device consists of two identical, uniform, double-electrode input/output transducers with an aperture of 16 mm and a resonant frequency of 50 MHz at room temperature. A graphene film composed of three single layers was transferred onto the $LiNbO_3$ surface between the two transducers in a clean room. The dimensions of the graphene layers on the $LiNbO_3$ substrate were 10×10mm^2. The structure of the SAW device is shown in Fig. 1. A d.c. pulse with a frequency of 100Hz and an amplitude varying from zero to ± 10Vwas used as the input signal, and the output pulse with a resonant frequency of 50 MHz was detected using the output transducer.

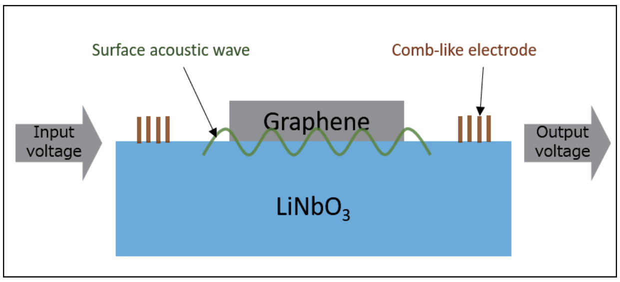

Fig. 1 Surface acoustic wave passing through graphene/$LiNbO_3$ structure.

The graphene layers on the $LiNbO_3$ substrate were characterized by Raman measurements and the obtained spectrum is presented in Fig. 2. The characteristic G band at 1590 cm^{-1} and 2D band at 2696 cm^{-1} were observed using a green laser with a wavelength of 532 nm. The intensity ratio of these two bands (I_G/I_{2D}=1.62) confirmed that the graphene film consisted of several layers of graphene.

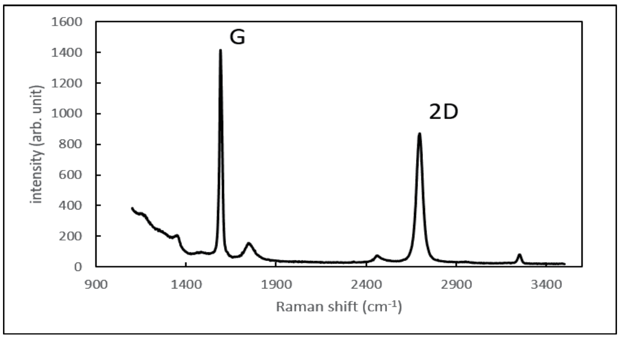

Fig. 2 Raman spectrum of the three graphene layers on the $LiNbO_3$ substrate.

3. Results and Discussion

3.1 Experimental results

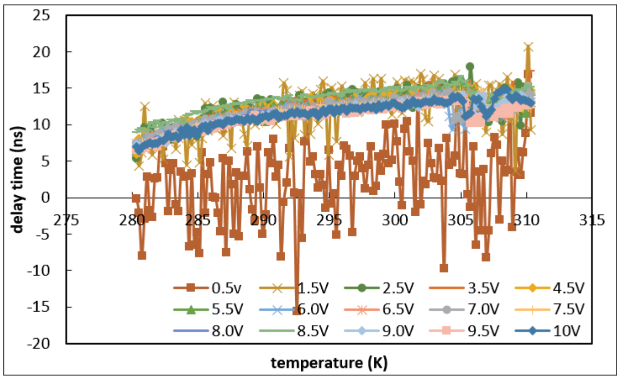

Fig.3 Temperature dependence of the delay time.

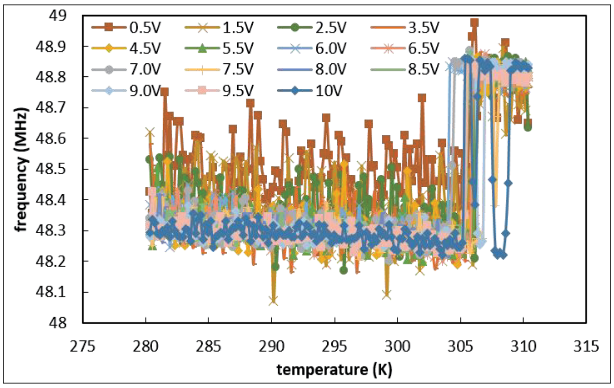

Fig.4 Temperature dependence of resonant frequency.

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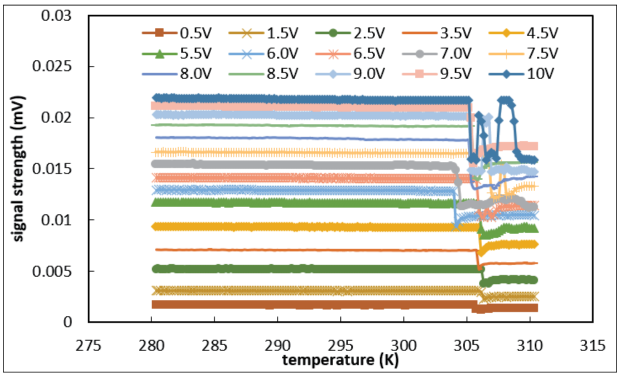

Fig5. Temperature dependence of the acoustic wave output signals.

Figure 3 shows the temperature dependence of the delay time for the propagation of the SAW packet along the interface for an input voltage from 0.5V to 10V. Also, Figure 4 shows the temperature dependence of the resonant frequency of the SAW device with the graphene layers, and Figure 5 shows the temperature dependence of the root-mean-square (RMS) output signal strength.

3.2 Discussion

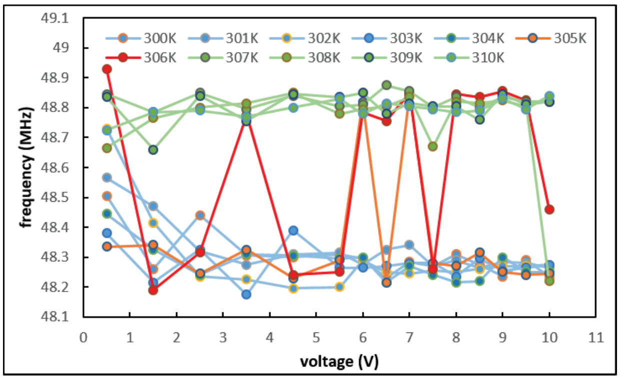

Fig.6 Resonant frequencies of the SAW device with the graphene layers at temperatures of 300.0 - 310.0 K as a function of input voltage.

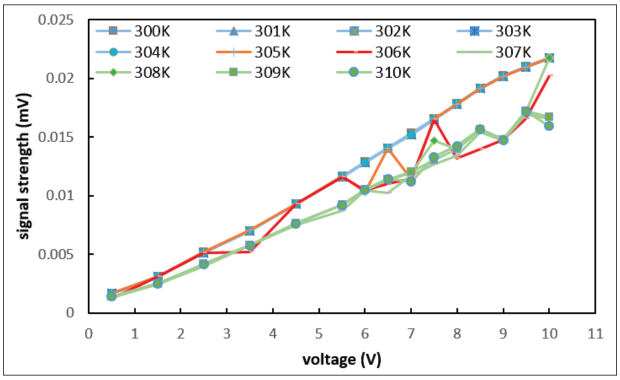

Fig.7 Signal strength of the SAW packet at temperatures of 300.0 - 310.0 K as a function of input voltage.

The interaction between the SAW packet and the stresses can be altered by controlling the input voltage amplitude and characterized by analyzing the output signal characteristics such as resonant frequency, RMS signal strength, and delay time. The resonant frequencies of the SAW device with the graphene layers at temperatures of 300.0, 301.0, 302.0, 303.0, 304.0, 305.0, 306.0, 307.0, 308.0, 309.0, and 310.0 K are plotted in Fig. 6 as a function of input voltage amplitude. Three types of voltage dependences on the resonant frequency were observed, corresponding to the three interfacial states of tensile stress, stress-free, and compressive stress. In the same way, the SAW amplitudes are plotted in Fig. 7 as a function of input voltage. Similar to the results observed for the resonant frequency, three types of voltage dependences on the signal strength could be observed, corresponding to the three interfacial states of tensile stress, stress-free, and compressive stress.

4. Conclusions

We have characterized the acoustic wave propagation properties of the graphene/$LiNbO_3$ structure formed by transferring three graphene layers onto a $LiNbO_3$ substrate at 306.0 K by examining the SAW packet over the temperature range of 280–310 K. The strong coupling of the elastic waves with stresses in the structure led to drastic changes in the temperature dependences of the resonant frequency, amplitude, and velocity of the SAW.

References

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