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C-V, SHG를 이용한 pentacene FET의 전기적 특성 연구

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Study of electric properties of pentacene field effect transistor using C-V and SHG measurements

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Abstract : Analyzing pentacene field effect transistors (FETs) with Au source and drain electrodes as Maxwell-Wagner effect elements, electron and hole injection from the Au electrodes into the FET channel were examined using current-voltage (I-V), capacitance-voltage (C-V) and optical second harmonic generation (SHG) measurements. Based on these results, a mechanism of the hole and electron injection into pentacene from the Au electrodes and subsequently recombination mechanism with light-emitting in the pentacene layer are discussed, with taking into account the presence of trapped charges.

Key Words : pentacene FET, Maxwell-Wagner model, SHG, trapped charge

1. INTRODUCTION

In order to drive the field effect transistor (FET), we need to apply a high drain-source voltage V_{ds} and a gate bias voltage V_{gs} that are quite large compared with the driving voltage of the Si-FET [1,2]. The charge carriers forming the conducting channel of pentacene FETs are mainly holes injected from the Au source electrode [3]. Therefore, to realize organic FET (OFET) devices with a high efficiency, we need to fully understand the behavior of carriers injected from the Au source and drain electrodes into pentacene layer. Using pentacene FETs with Au source and drain electrodes, electron and hole injection from the Au electrodes into the FET channel were examined using capacitance-voltage (C-V) and optical second harmonic generation (SHG) measurements [4], where electric field induced SHG (EFISHG) is used effectively [5,6]. Results revealed that holes and electrons are injected from the Au source and drain electrodes and they are subsequently trapped in the pentacene. Based on these results, a mechanism of the hole injection assisted by trapped electrons in the pentacene is discussed in terms of the hystersis behavior of C-V curves.

2. EXPERIMENT

Figure 1 shows the device configuration of top-contact (TC) pentacene FET used here. Before deposition of the pentacene active layer, the SiO_2 gate insulator was subjected to the UV/ozone and octadecyltrichlorosilane ($C_{18}H_{37}SiCl_3$) (OTS) chemical treatments. The UV/ozone and OTS treatments were performed in the same manner as that done in our previous study [4]. Finally, we deposited Au electrodes (=80 nm) as source and drain electrodes. Their channel length L and width W were, respectively, 50 μm and 1.25 mm. We masked the FET sample, except the

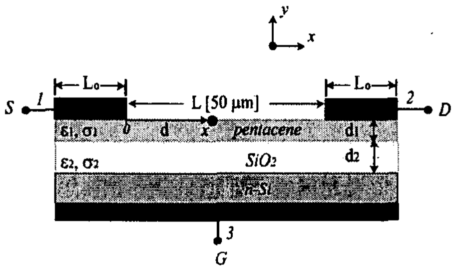

Fig 1. Schematic cross-sectional view of TC pentacene FET

channel and electrode regions during the deposition to avoid unnecessarily carrier diffusion. Using a source meter (type-2400; Keithley Instruments, Inc.) and an LCR meter (type-3522-50; Hioki E.E. Corp.), C-V measurements were carried out in laboratory ambient conditions where source and drain electrodes were electrically shorted (V_{ds} = 0). For SHG measurements, using reflection optical geometry, fundamental light was focused on the channel region of the OFET using a microscopic objective lens (50 ×, NA=0.42, WD=20.5 mm, M Plan Apo SL; Mitsutoyo Co. Ltd.). The spot size was approximately 20 μm for microscopic SHG measurements. The light source was an optical parametric oscillator (OPO, Surelite OPO; Continuum Inc.) pumped by the third-harmonic light of a

Q-switched Nd-YAG laser (Surelite II-10; Continuum Inc.). The wavelength was fixed at 1120 nm to probe the resonance enhancement of the EFISHG process from the pentacene, selectively. The SH light from the sample was detected using a photomultiplier tube (R3896; Hamamatsu Photonics KK). In this configuration, the polarization direction was chosen as that along the channel between the source and drain electrodes, i.e., in the x-direction (see Fig. 1). All SHG measurements were performed in the laboratory's ambient atmosphere.

3. RESULTS and DISCUSSION

In figure 2, the C-V characteristics show a hysteresis behavior that depends on gate-source (drain) stress biasing, V_{gs} (V_{gd}) [7]. Results suggest that the hysteresis behavior is attributable to injected carrier trapping in the FET channel, and that hole injection is suppressed after $V_{gs}<0$ stress biasing, whereas it is

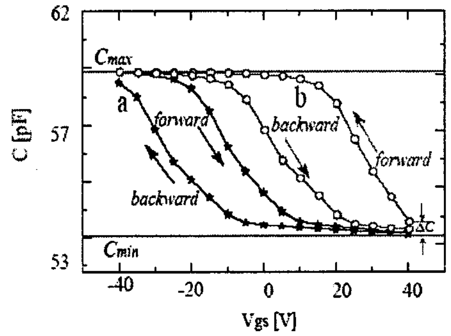

Fig 2. C-V characteristics in the region between V_{gs}=-40 V and +40 V. Curves a and b were taken before applied V_{gs}=-40 V and V_{gs}=+40 V for 30 min

assisted after $V_{gs}>0$. The modulation of the electric field along the FET channel by injected carriers was examined using SHG measurements. The enhanced SHG at the off state decayed gradually with a relaxation time of 10^3 s during the V_{gs} (=V_{gd})= +100 V stress biasing. Through evidence of hole and electron injection from Au source and drain electrodes, we propose the hole injection process assisted by trapped electrons in the pentacene FETs. Moreover, C-V and SHG measurements were shown to be helpful to clarify carrier injection that followed carrier trapping (see Fig.3). Furthermore, we expect that the phenomenon of electron-hole recombination leading to electroluminescence might occur in pentacene FETs with Au source and drain electrodes in a manner resembling that in tetracene FETs with Au source and drain electrodes.

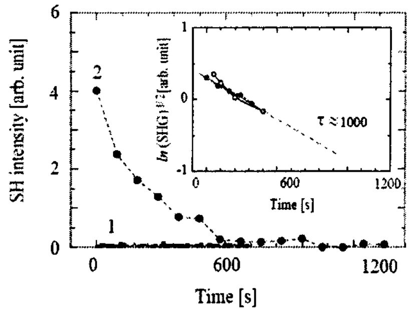

Fig 3. Results of microscopic SHG measurement vs. biasing time. Curve 1 represents the on state with V_{gs} = V_{gd} = -100 V, and curve 2 represents the off state with V_{gs} = V_{gd} = +100 V. The inset figure shows the plots of EFISHG(x) with time during V_{gs} = V_{gd} = +100 V at the off state with plotted from curve 2 and biasing time.

4. CONCLUSION

On the basis of C-V and modulated SHG signal results, we discussed hole and electron injecting process into pentacene from Au source and drain Hysteresis behavior was caused by injected carrier trapping; it depended on stress biasing time and charging conditions. Through evidence of hole and electron injection from Au source and drain electrodes in pentacene, we proposed the hole injection process assisted by trapped electrons in the pentacene FETs. Moreover, C-V and SHG measurements were shown to be helpful to clarify carrier injection that followed carrier trapping. Also, these FET mechanism was discussed in greater detail by analyzing the FETs as Maxwell-Wagner effect elements.

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