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GRAPHENE FET ON SiC (0001) WITH CF_4 PLASMA TREATMENT

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We investigate the epitaxial graphene films grown on SiC with CF_4 plasma treatment and examine basic study of graphene devices. The surface roughness of the graphene films is reduced from 1.51 nm RMS to 0.75 nm RMS and carrier mobility of the graphene films is increased from 320 cm^2/Vs to 1960 cm^2/Vs by CF_4 plasma treatment, respectively. The epitaxial graphene devices on SiC exhibit the ambipolar characteristics.

I. Introduction

Graphene is a zero-bandgap semiconductor consists of monolayer carbon atoms. It has high mobility more than 200,000 cm^2/Vs [1)]. The best way to get good electrical properties is to use exfoliated graphene, however, the exfoliated graphene is not suitable for large scale device fabrication since the domain becomes μm-sized. One of the candidates to make large scale epitaxial graphene is high-temperature annealing of SiC substrate. In high temperature, Si atoms evaporate from substrate and thus, graphene is easily synthesized by C atoms after surface migration. In general, Ar gas atmosphere suppresses Si evaporation compared to UHV condition and it leads more equilibrated state on the surface. Therefore inert gas atmosphere makes better graphene than that made in UHV condition [2)].

On the other hand, We found that CF_4 plasma treatment suppress step bunching of the SiC substrate [3)]. In this work, we investigate the epitaxial graphene grown on SiC with CF_4 plasma treatment and examine basic study of graphene devices.

II. Experiments

A schematic cross section of the fabricated graphene devices is shown in Fig.1. The graphene films were grown on the silicon face of semi-insulating 4H-SiC substrates at 1500 °C in 10 kPa Ar ambient after CF_4 plasma treatment. CF_4 plasma treatment was given to the 4H-SiC for 1 min with an RF power of 400 W at a pressure of 0.4 Pa using ICP dry etching equipment, in which CF_4 gas flow rate was 30 sccm. The graphene films were isolated by O_2 plasma dry etching with photo-lithography. Source and drain electrodes were formed by

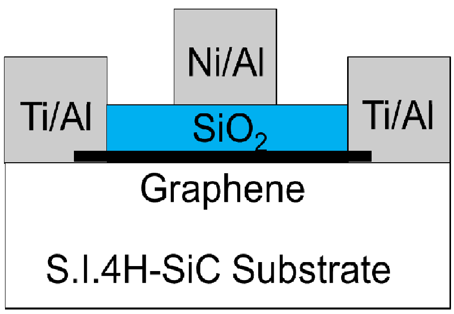

Fig. 1. Schematic cross section of fabricated graphene devices.

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depositing Ti/Al metals. A 50 nm thick SiO_2 gate dielectric film was deposited on graphene by sputtering. Finally, Ni/Al gate electrodes were formed by photo-lithography and lift-off process.

The graphene films were characterized using an Atomic-force microscopy (AFM) , Raman spectroscopy and Hall effect measurement at room temperature. The fabricated devices with the gate lengths of 10 um and a gate width of 100 um were evaluated. Current-voltage (I-V) characteristics were measured by the Keithley 4200-SCS semiconductor parameter analyzer at room temperature.

III. Results and Discussion

Figure 2 displays AFM images of the graphene films without and with CF_4 plasma treatment. The surface roughness was reduced from 1.51 nm RMS to 0.75 nm RMS by CF_4 plasma treatment. Figure 3 shows raman spectra of the graphene films and Fig.4 shows raman mapping of 2D-band FWHM without and with CF_4 plasma treatment. Using the ratio of peak intensities I_{2D}/I_G, I_{2D}/I_G of the graphene films with CF_4 plasma treatment is larger than that without CF_4 plasma treatment in Fig. 3. Figure 4 shows raman mapping of 2D-band FWHM. The graphene films without CF_4 plasma treatment have large 2D-band FWHM (40-80 cm^{-1}), but the graphene films with CF_4 plasma treatment have small 2D-band FWHM (40-60 cm^{-1}). The graphene films with CF_4 plasma treatment is more uniform than that without CF_4 plasma treatment.

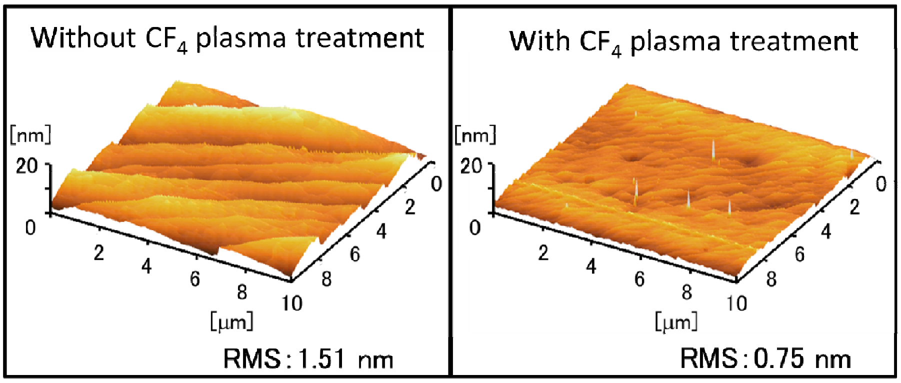

Fig. 2. AFM images of graphene films (a) without and (b) with CF_4 plasma treatment.

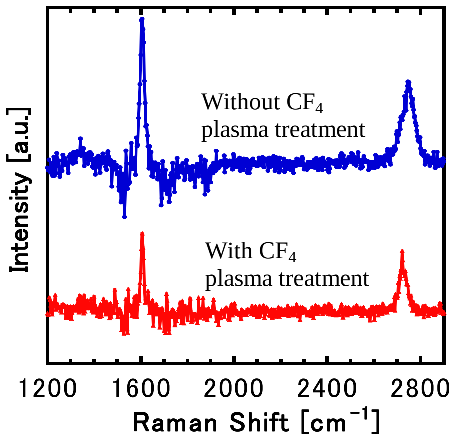

Fig. 3. Raman spectra of graphene films (a) without and (b) with CF_4 plasma treatment.

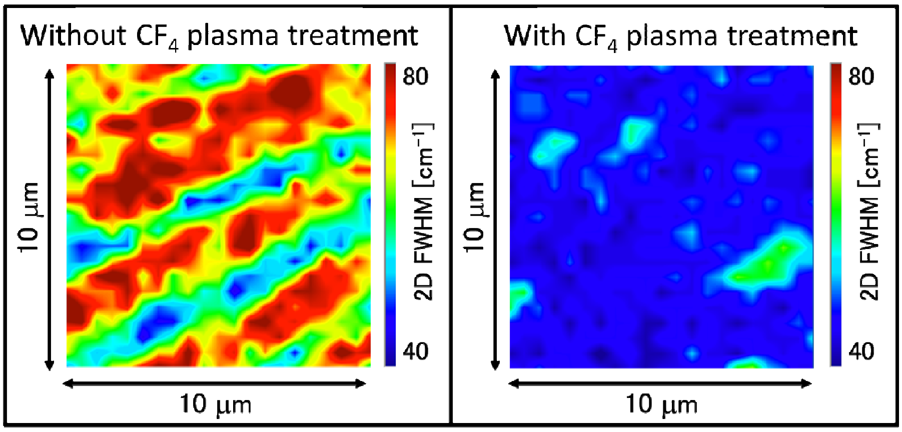

Fig. 4. Raman mapping of 2D-band FWHM (a) without and (b) with CF_4 plasma treatment.

Table 1 shows electrical properties of epitaxial graphene excluded SiC substrate using Hall effect measurement. The carrier mobility of the graphene films increased from 320 cm^2/Vs to 1960 cm^2/Vs and the sheet resistivity of the graphene films reduced from 11.7 kΩ/sq to 4.7 kΩ/sq by CF_4 plasma treatment. This is because the number of graphene layers with CF_4 plasma treatment are more uniform than that without CF_4 plasma treatment.

The typical I-V characteristics of graphene FETs are shown in Fig.5. The transfer characteristics exhibit the symmetry behavior, reflecting the ambipolar transport in graphene. Maximum drain current of 11.7 mA/mm at Vg = 26.7 V and maximum transconductance of 8×10^{-3} mS/mm were obtained for 10 um gate graphene FETs.

Table. 1. Electrical properties of the graphene excluded SiC substrate.

	Sheet Resistivity (kΩ/sq)	Carrier Mobility (cm^2/Vs)	Carrier Sheet Concentration (/cm^2)
Without CF_4 plasma tretmant	11.7	320	1.67×10^{12}
With CF_4 plasma treatment	4.7	1960	6.7×10^{11}

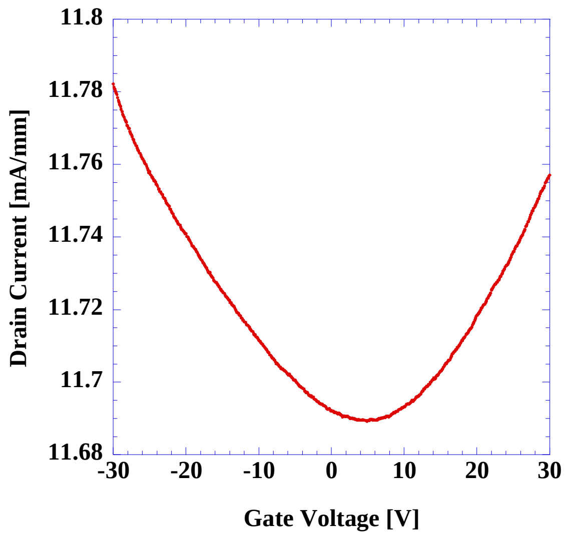

Fig. 5. Id-Vg characteristics of the fabricated graphene FETs with a gate length of 10 um and a gate width of 100 um.

IV. Conclusion

The number of graphene layers with CF_4 plasma treatment are more uniform than that without CF_4 plasma treatment and its carrier mobilities increased from 320 cm^2/Vs to 1960 cm^2/Vs by CF_4 plasma treatment. The graphene devices exhibit the ambipolar characteristics.

Acknowledgements

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