CHARACTERIZATION OF GRAPHENE ELECTRICAL PROPERTIES BY COMBINED TERAHERTZ AND INFRARED SPECTROSCOPY METHODS

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Graphene is two-dimensional (2D) material, with many potential applications in the terahertz (THz) and infrared (IR) ranges, such as a absorber/modulator [1], transparent gate contact [2] and etc. Since synthesis, transfer of the graphene and its device fabrication are extremely sensitive to the technological steps involved in the process flow, the development of the non-destructive characterization methods of 2D materials electrical properties is very important [3].

In this work, we combine the THz time-domain spectroscopy (TDS) and Fourier-transform infrared (FTIR) spectroscopy methods for the characterization of graphene electrical parameters. The graphene samples were prepared by different wet-transfer techniques on various substrates [4] including a high resistivity (HR) Si wafers. Structural quality of the graphene was controlled by well adapted Raman spectroscopy [5]. The transmission spectra were numerically described in terms of high-frequency Drude conductivity, results of which were found to corelate with the electrical dc-conductivity estimated from Hall experiment [6], [7]. Developed remote characterization method allowed us to compare different graphene samples measuring the sheet resistance, carrier density and mobility values.

A CVD graphene synthesized on a copper foil was used for the sample fabrication onto a semi-insulating Si using wet-transfer technique. Dissolution-based removal of the supporting PMMA layer after transfer process was realized by chloroform (Si-Cl), acetone (Si-A), and alcohol (Si-IP) solutions. 2D material parameters were evaluated on base of Raman spectra and optical microscope images analysis, summary of the results is given in Table 1. All graphene films demonstrated narrow line of 2D mode and relatively high 2D/G mode ratios in Raman spectra.

A THz TDS system were used to investigate the transmission spectra of graphene in the range of 0.1-2.5 THz. Optical spectra at higher frequencies up to 18 THz were acquired by FTIR spectrometer. The obtained characteristics were fitted by Drude conductivity model to determine the sheet resistance, carrier density and mobility values in graphene. Traditional contact-based Hall effect measurements in Van der Pauw (VdP) configuration with contacts placed at edges of graphene film were fulfilled also. In Table 1, the sheet resistance obtained from TDS and Hall experiments are labeled as $R_{S\text{-}TDS}$ and $R_{S\text{-}VdP}$, respectively. For all samples, the $R_{S\text{-}VdP}$ values were much higher, than $R_{S\text{-}TDS}$, indicating, that carrier hoping dominates conductivity in the samples [8].

Table 1. Comparison of Raman spectra properties and sheet resistance for graphene under study.

Sample	2D FWHM (cm^{-1})	2D/G ratio	$R_{S\text{-}TDS}$ (Ω/sq.)	$R_{S\text{-}VdP}$ (Ω/sq.)
Si-Cl	29.5	2.5	846	2728
Si-A	31.5	3.1	845	2132
Si-IP	27.9	2.9	1114	3116

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