UNIVERSITI TEKNOLOGI MARA

ACCURACY ISSUES OF RF PROBING OF GRAPHENE TRANSMISSION LINES

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ABSTRACT

The primary purpose of this research is to increase the accuracy of characterizing graphene which is a new conductive material. Graphene transmission lines are measured at microwave frequencies using an alternative on-wafer calibration method. This would then contribute to a more accurate characterization of graphene at elevated frequencies, hence enhancing the understanding of this novel material to assist RF integrated circuit designers. As the dimensions of integrated circuits scale down to nanometers, the conductor resistance at high frequencies increase due to skin effect, and therefore the performance of RFICs degrade. Graphene is therefore proposed in this study as a new material for RFIC due to its promising electrical properties including high current densities, high mobility, low noise and negligible skin effect. Co-planar transmission lines were constructed using graphene by applying techniques compatible with semiconductor processing. Graphene films were grown on Ni-coated Si wafers using a modified thermal CVD method, whereby the Ni acted as the growth catalyst. The consequent structure was then etched layer-by-layer using a modified process to remove the Ni layer, thus offering easy process control. The microstructure of graphene films was ascertained using optical, SEM, FESEM and EDS for microstructure analysis, and the crystallinity was determined using Raman spectroscopy. The Raman results showed samples had well-graphitized carbon structures. The resistivity was measured using a two-point probe station and revealed a dc resistivity of 1.2×10^{-7} Ω.m. The constructed co-planar graphene transmission lines were modeled using *CST* electromagnetic simulator to predict the RF performance and characterized from 2 to 20 GHz. The structures were then fabricated using standard semiconductor processing steps, and their characteristics later measured using *Cascade Microtech* probe station connected to a vector network analyser (VNA). Prior to this study, graphene devices have been characterized predominantly using the SOLT method, since the 50 Ω load required for calibration is readily achievable and is well-understood for reference conductors such as gold and copper. Such conditions may not be applicable to or suitable for specialized and emerging materials, such as graphene. Improved accuracy was obtained using Thru-Reflect-Line (TRL) calibration technique, as opposed to the more common SOLT method. The microwave properties of graphene were then extracted using curve-fitting of the measured data with *CST*, and RLC lumped-element circuit modeling using *Advanced Design System (ADS),* respectively. The modelling determined graphene to have an RF conductivity of 9.0×10^{3} S/m, which is better than those reported by other researchers. Even though very thin layers of graphene were used in this work, the skin effect was found to be negligible compared to Au or Cu. There is therefore significant potential for graphene to be used as an interconnecting material in RFICs, by acting as a monolithic interconnection between various active and passive devices with little loss of current at higher frequencies.

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