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Analysis of graphene based transmission line in THz band

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ABSTRACT

Graphene nanoribbon transmission line (GNRTL) is considered as one of the most valuable structures which has been employed in many terahertz devices. A comprehensive analysis of GNRTL is reported by identification of the characteristic impedance and the propagation constant as secondary parameters of graphene nanoribbons transmission line. The impact of different physical and structural factors on the secondary parameters of GNRTL is discussed. Both characteristic impedance and propagation constant are analyzed to obtain an RLC equivalent circuit model which provides valuable insight into the design of terahertz component.

1. Introduction

Graphene is a two dimensional (2D) atomic layer of carbon with thickness of 0.34 nm which is discovered by Geim and Novoselov in 2004 [1–3]. This allotrope of carbon which has the ability to conduct high current density, is considered for several studies focusing on graphene nanoribbon which has been a candidate for both transistors [4] and interconnects [5–7]. High field confinement, tunability and lager phase constant compared with noble metals have attracted significantly at microwave, terahertz and optical frequencies [8–12]. The unique electromagnetic properties which include very high phase constant and controllable conductivity has triggered the study of wide variety of graphene based compact tunable integrated circuits including filter [13], coupler [14], phase shifter [15], attenuator [16] and antenna [17]. However, comprehensive analysis and appropriate modeling is not presented in these papers.

In microwave frequencies, the transmission line methods have been used for a wide range of microwave devices. In contrast, most of existing papers are based on commercial simulators, in this paper a theoretical investigation is performed to extract simple electrical models for graphene nanoribbons transmission line. The results are verified by a commercial full-wave simulator. The results of this paper could give new perspectives in analysis and are useful for the practical design of various terahertz components such as filters, couplers, phase shifters and other passive devices.

In this contribution, firstly the characteristic impedance is defined which will be used in transmission line model. Next, we study the impact of changing various nanoribbon parameters on the characteristic impedance, phase and attenuation constant of the GNRTL. Finally, the transmission line model is introduced and compared with commercial simulators.

2. Parametric study of graphene nanoribbons

Fig. 1 shows a graphene transmission line (TL) with graphene width *Wg* and thickness of substrate *hs*. In recent years, in order to calculate electromagnetic field and propagation constant or design devices, investigators have used numerical

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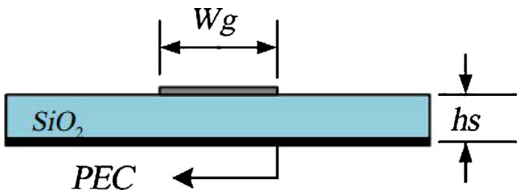

Fig. 1. Cross sectional view of graphene nanoribbon (GNR).

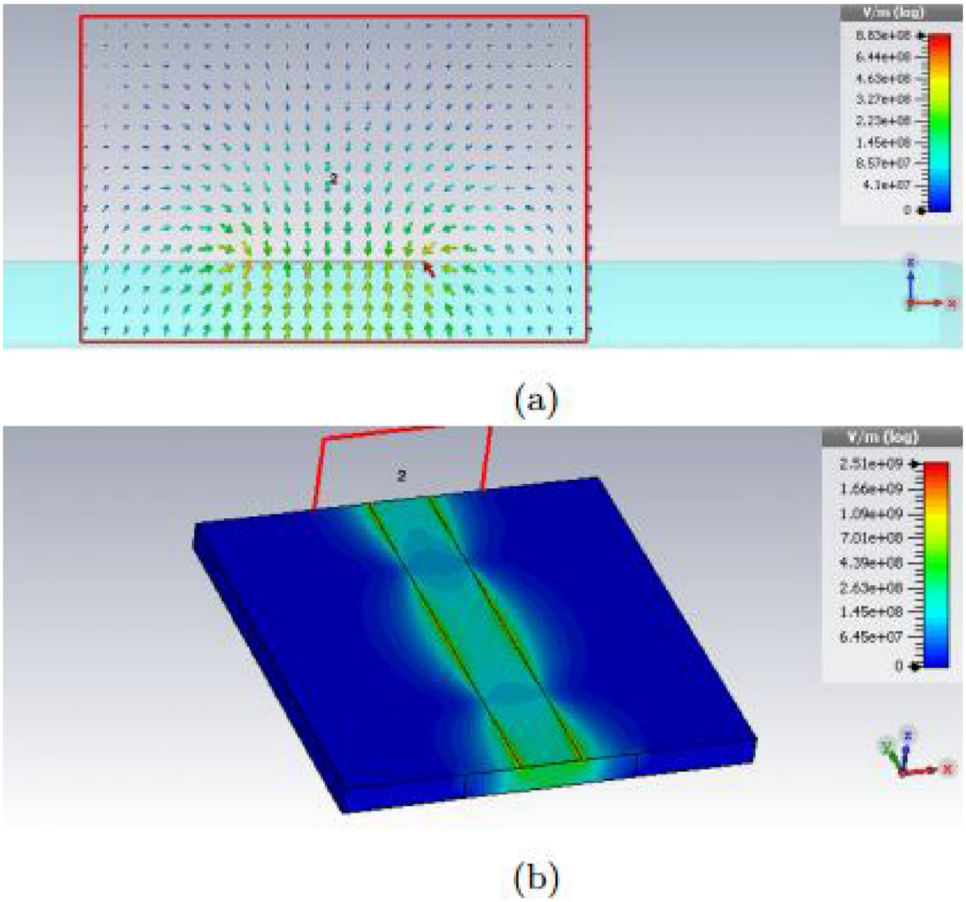

Fig. 2. E-field (a) in cross section (b) propagation along graphene strip.

approaches in the time and frequency domains [18,19]. Fig. 2 represents the E-field profile of GNRTL in cross sectional view and in the direction of wave propagation. Designing electromagnetic devices such as couplers and filters based on this GNRTL, in addition to consider the propagation constant, requires to identify the characteristic impedance. The characteristic impedance can be defined in three popular ways, which are power-current definition, voltage-current definition and power-voltage definition [20]. Generally, in the strip transmission lines due to non-uniform electric field distribution, it is not possible to have a unique voltage definition. So, the characteristic impedance based on the power-current definition is used in our article.

$$Z_0 = \frac{2S}{I^2} \tag{1}$$

where S is the complex power,

$$S = \iint_A (E_t \times H_t^*) .dA \tag{2}$$