Terahertz Nanocircuits Based on Active Graphene Transmission-Lines

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We propose here the concept and design of terahertz (THz) nanodevices based on three-terminal gated graphene parallel-plate waveguides (GPPWGs), which support tightly confined quasi-transverse electromagnetic (quasi-TEM) modes. The graphene PPWG consists of a locally gated graphene sheet, separated from the conducting ground plane by a dielectric layer. Graphene has a relatively high conductivity and its charge carrier density is much lower than the one of metals, due to its unique two-dimensional electronic configuration. This property makes graphene's chemical potential and associated surface conductivity readily tunable by chemical and/or electronic doping. It has been theoretically demonstrated that the deep-subwavelength GPPWG may provide comparable or even superior figure-of-merits than conventional thicker-walled metal-insulator-metal (MIM) heterostructures, and also provide tunable waveguiding properties at far-infrared and THz operating frequencies (G. W. Hanson, J. Appl. Phys. 104, 084314, 2008; P. Y. Chen, C. Argyropoulos, and A. Alù, IEEE Trans. Antenna Propagat., 2012, in press).

Based on this dynamic tunability with respect to the phase velocity, propagation constant and characteristic impedance of the guided mode, we have recently proposed on-chip THz phase shifters, switches and modulators (P. Y. Chen, C. Argyropoulos, and A. Alù, IEEE Trans. Antenna Propagat., 2012, in press). Since the nanolithgraphic patterning of very-large-area graphene interconnections and networks remains a challenging task, here we propose a *hybrid* scenario, in which a gated GPPWG is terminated by conventional MIM waveguides at its input and output ports, which also serve as the source (S) and drain (D) metal contacts for the graphene channel controlled by the gate electrode (G). We show that this *three-terminal* ac nanodevice may allow full control and tailoring of the phase variation and impedance along the graphene transmission-line, and therefore may serve a paradigm for active/passive THz circuits and optoelectronics, with potentially switchable and tunable functionalities. We theoretically demonstrate the possibility of realizing several relevant on-chip circuit components, including tunable and switchable band-pass and low-pass filters, narrowband and broadband impedance transformers and tapers, switches, and modulators. The integration of several nano-components into a single entity will enable the development of advanced THz nano-circuits and nano-systems. In our talk, we will present a fundamental step towards the design of architectures and protocols for THz intra/inter-chip communication, as well as unique applications in biomedicine, sensing and actuation.