Planar four layers waveguide structure at sub-THz frequencies comprising metal and garphene: a complex scenery of coupled modes

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Abstract

In spite of the fact that graphene plasmons were investigated in a number of structures containing a few graphene monolayers or graphene bilayers, the case of coupled graphene plasmons with other types of structure modes (surface metal-plasmon or waveguide modes) has not been thoroughly examined. The coupling of graphene plasmons with surface metal plasmons in a structure containing a graphene layer and metal substrate separated by an air gap was studied [1]: the solution of the coupled plasmon mode shows a linear dispersion behavior in a specific parameter range.

We propose a multilayer structure containing a metal substrate, dielectric buffer layer, a monolayer of graphene, and air as the superstrate, aimed to unravel the complex solution space: coupled graphene-metal plasmons and waveguide modes which are supported by this structure.

Hereto we present interesting results for these plasmon modes, by employing analytical models [1], we described these plasmon modes behavior at the sub-THz range, to our knowledge, this could be the first study of its kind. The solution of the dispersion relation for the structure is explained in [2] [3].

We focused on the impact of the Fermi level in graphene and the geometrical parameters of the structure on the dispersion characteristics of various plasmonic solutions starting with a single frequency such as 300 GHz and then extending our model to different frequency values where we expect a strong coupling at sub-THz frequency range. This model has been verified numerically, where the surface plasmon characteristics of the multilayer structure under consideration have been analyzed for sub-THz frequencies [4],[5].

It was noted that the difference of decoupled metal surface plasmon and graphene surface plasmon wavevectors vanishes for low THz and GHz frequencies. Hence we may expect stronger coupling effects in this frequency range.

The TM surface plasmons are represented by metal-like and graphene-like branches depending on their behavior for very thick buffer layers.

For instance; for frequencies smaller than 0*.75 THz* (for the concrete structure under study), the metal-like surface plasmons split up into two branches depending on the graphene electron concentration: one of the branches exists in the whole range of the buffer thickness and being a short-range mode for small thicknesses, another one undergoes cutoff and exists only within a limited range of buffer thicknesses smaller than the cutoff thickness. Further increase of the surface plasmon frequency leads to the disappearance of the splitting effect for metal like surface plasmon, also the TM waveguide modes split up into two branches for small frequencies analogously to that of the metal-like surface plasmon [6].

The coupled graphene-metal plasmon modes and waveguide modes can depend very strongly on the electron concentration in the graphene layer, and the buffer layer thickness and this gives advantages to use in a wide range of applications in sub-THz frequency for example as sensors and modulators.

References

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