Evaluation of the microwave frequency multiplication effects in microstrip gaps with graphene layers exfoliated from graphites with a different angular spread of the crystallite c-axes.

S. Ver Hoeye[1], F. Rodríguez[2], R. Menéndez[3], P. Álvarez[3], G. Hotopan[1], R. Camblor[1], C. Vázquez[1], M. Fernández[1], F. Las Heras[1]

[1]University of Oviedo, Campus Universitario de Gijón, Gijón, Spain
[2]Universidad de Alicante, Departamento de Química Inorgánica, Alicante, Spain
[3]Instituto Nacional del Carbón-CSIC,Oviedo, Spain
sverhoeye@tsc.uniovi.es

In this work, the frequency multiplication effect predicted in [1-2] is analyzed in a microwave microstrip gap covered with graphene layers exfoliated from graphites showing optically flat basal plane surfaces with different values for the angular spread of the crystallite c-axes. Three graphite samples have been used, two samples with a respective angular spread of the crystallite c-axes of 2.6º and 3.2º, and a third sample of less oriented graphite. The used microwave structure consists of two microstrip lines with tapered tips towards a gap of 0.15 mm that is covered with the exfoliated graphene layer (Fig. 1). The nonlinear behavior of the graphene layer is evaluated by applying on one side of the circuit an input signal at the fundamental frequency f_0 and measuring on the other side the third harmonic component that is generated at $3f_0$. The output power P_{out} of the third harmonic component at $3f_0$ (30 MHz to 10 GHz) has been measured when varying of the input frequency f_0 from 10 MHz to 3.33 GHz, and for different values of the input power P_{in} between 1 dBm and 10 dBm. The resulting ratio between the obtained output power $P_{out}(3f_0)$ and the input power $P_{in}(f_0)$ is shown in Fig. 2. With the used microstrip circuit, higher values for the output power have been obtained when using graphene layers exfoliated from less oriented graphites. From Fig. 2, it can also been observed that for higher values of P_{in} the output power slightly saturates. The measured third harmonic power has an almost flat frequency response along the whole frequency range.

References

[1] S.A. Mikhailov, K. Ziegler, “Nonlinear electromagnetic response of graphene: frequency multiplication and the self-consistent-field effects”, Journal of Physics: Condensed Matter, 20 (2008) 384204.
[2] S.A. Mikhailov, “Electromagnetic response of electrons in graphene: Non-linear effects”, Physica, E40 (2008), 2626-2629.

Figures

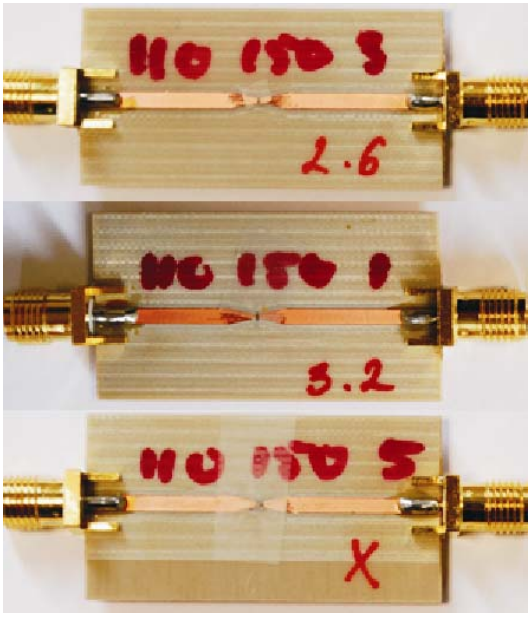

Fig. 1. Tapered microstrip line structures with a 0.15 mm gap covered with exfoliated graphene layers.

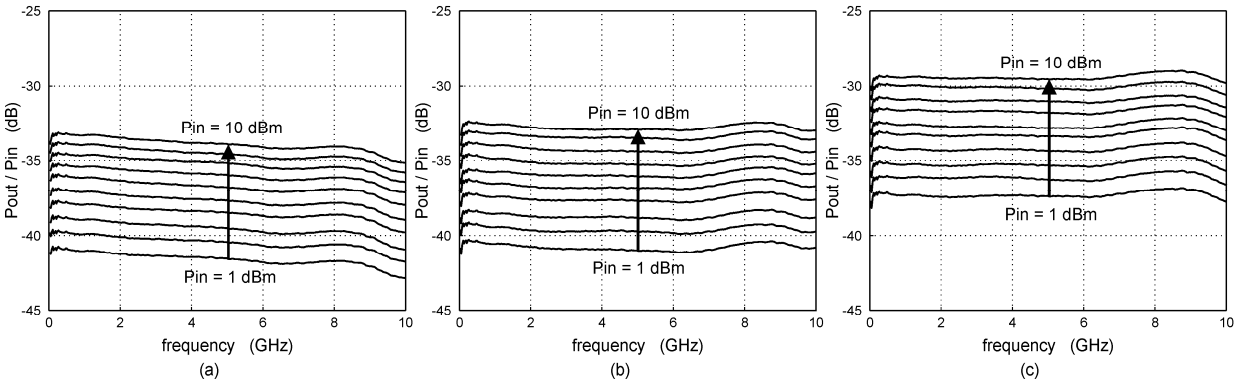

Fig. 2. Relation between the provided input power Pin at the fundamental frequency f_0 and the measured output power Pout at the third harmonic component at $3f_0$, for three types of graphites with corresponding angular spread of the crystallite c-axes: (a) 2.6º, (b) 3.2º, and (c) less oriented graphite.