Random graphene metasurfaces as a perfect broadband THz absorber

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We present theoretical model and experimental investigation of THz metasurface made of an array of hemispheres made of defected multilayer graphene covered with a thin (100-200 nm) PMMA layer. The fabrication flow of the structure is sketched in Fig. 1 and involves ink-jet 3D printing, Ni sputtering and electroplating followed by chemical vapor deposition (CVD) of graphene on the top of Ni support, which shape reproduces that of the polymer 3D printed template.

The fabricated structure (Fig.2), i.e. a bubble wrap polymer nanomembrane covered with multilayered graphene, demonstrates extreme broadband and almost perfect absorption at THz frequencies and shows robustness against macroscopic random structural defects of the two-dimensional periodic lattice.

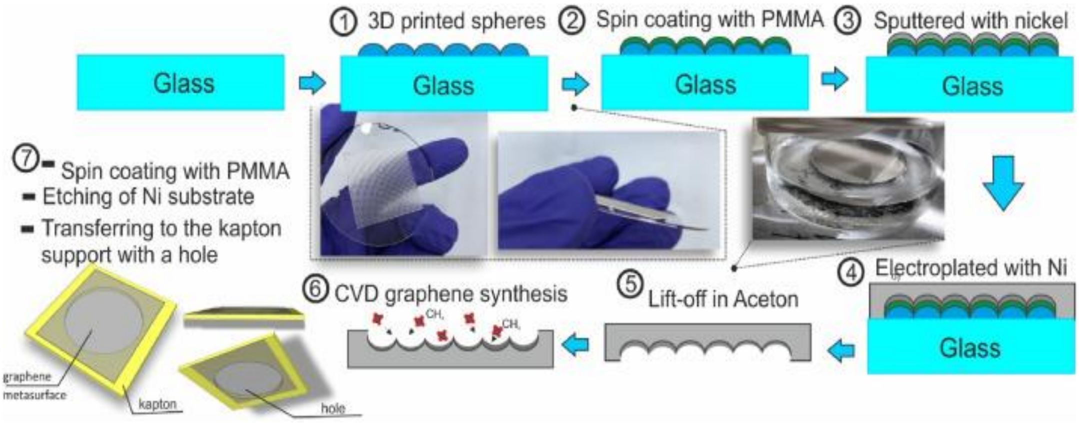

Fig. 1. Fabrication flow of free-standing graphene metasurface.

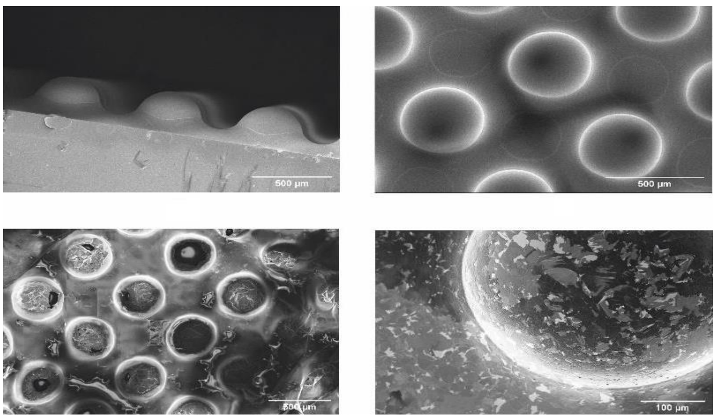

Fig. 2. (a), (b) SEM images of 3D printed polymer nanomembrane hemispheres on a silica substrate (polymer template). (c) SEM images of the graphene-based metasurface (“bubble wrap” polymer nanomembrane covered with graphene) and (d) hemisphere unit cell.

Moreover, these defects may result in the enhancement of the absorptance ability of the free-standing THz metasurface. The conductivity of graphene metasurface can be tuned by changing it’s the Fermi energy level by applying external stimuli including electrostatic doping. Full control of the graphene metasurface can be achieved if the voltage is independently applied to individual unit cells.

We propose a method that enables a closed-form description of a so-called random metasurface comprising unit cells randomly distributed on the planer substrate and having different properties.

[1] A. Paddubskaya, N. Valynets, S. Maksimenko, M. Kumar, M. Baah, M. Pekkarinen, Y. Svirko, G. Valusis, P. Kuzhir, THz photonics with graphene enhanced polymer hemispheres array, Nanomaterials 2021, 11(10), 2494

[2] A. Novitsky, A. Paddubskaya, I. A. Otoo, M. Pekkarinen, Y. Svirko, P. Kuzhir, Random Graphene Metasurfaces: Diffraction Theory and Giant Broadband Absorptivity, Phys. Rev Applied, 17, 044041 (2022)