Terahertz detection with optically gated vertical graphene nanowalls

Petr A. Obraztsov[1], Vassilis Papadakis[2] ,Yuri Svirko[1], Alexander N. Obraztsov[1]

[1]Institute of Photonics, University of Eastern Finland, 80101 Joensuu, Finland

[2]XpectralTEK, Av. da Igreja 7, 4705-732 Braga, Portugal

petr.obraztsov@uef.fi

Efficient terahertz (THz) photoconductive detection demands an active medium with high absorptivity, ultrashort carrier lifetime, and high mobility of photo-excited charge carriers. Graphene, with its ballistic charge carriers, offers mobilities up to 15,000 $cm^2 \cdot V^{-1} \cdot s^{-1}$ at room temperature and ultrafast carrier relaxation times. Its gapless Dirac-cone electron band structure allows 2.3% optical absorption across a broad spectral range, enabling excitation with low-energy photons. These properties make graphene competitive with conventional materials used for THz photoconductive antennas, such as low-temperature grown or Cr-doped GaAs.

Despite various approaches for measuring THz radiation power with graphene, including bolometric response, photovoltaic and photothermoelectric effects, and graphene-based field-effect transistors, only on-chip coherent pulse detection and generation have been demonstrated so far. However, graphene's application for THz detection is hindered by two main limitations: low responsivity due to limited absorption in atomically thin layers and moderate lateral dimensions restricting scalability.

In this work, we report on the time-domain detection of THz radiation using optically gated vertical graphene nanowalls (VGNs) [1]. VGNs, also known as nanographite (NGF), consist of vertically oriented graphene-containing carbon nanosheets with few-layer basal graphene layers, chemically active defect sites, and edges. NGF's properties, including excellent electrical and thermal conductivity, chemical stability, and large specific surface area, are advantageous for various applications. Tailoring the NGF microstructure through growth process adjustments ensures high optical absorption efficiency, making it suitable for applications such as photodetectors and thermal sensors.

We fabricated and evaluated a set of THz photoconductive detectors using VGNs grown on Si substrates via the CVD method. A direct comparison of the coherent photocurrent response of these optically gated devices with those of graphene and widely used electro-optic detectors demonstrates VGNs' strong potential for THz time-domain detection. The mesoporous 2D material's enhanced sensitivity and robustness surpass those of single-layer graphene, paving the way for the mass production of ultrafast photoconductive detectors.

This research was funded by H2020 Programme (RISE project Chartist (101007896) and Academy of Finland (decision numbers 340831 (UPHYPE project).

[1] Obraztsov, P. A.; Chizhov, P.; Kaplas, T.; Bukin, V.; Silvennoinen, M.; Hsieh, C.-F.; Konishi, K.; Nemoto, N.; Kuwata-Gonokami, M., ACS Photon.2019, 6, 1780−1788.