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Persistent photoconductance in graphene ceramics

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Abstract

A study of persistent photoconductance has been investigated in a graphene ceramic. Graphene ceramic has been produced by using hot isostatic pressing of few-layer thick graphene nanoplatelets. The influence of laser beam power and wavelength was analyzed. A linear power dependence of photoconductance yield was observed as high as 129,5% for 1500 mW 975 nm irradiation. The photocurrent changes were attributed to the photo-induced bolometric effect.

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*Keywords:*Graphene; photoconductivity, ceramic

1. Introduction

Graphene exhibits unique electronic and optical properties [1,2], making it an interesting candidate for numerous optoelectronic applications [3-5]. As a 2D monolayer of hexagonally arranged carbon atoms it behaves as a zero-gap semiconductor with charge carriers described by massless Dirac equation [6]. Chemical modification [7] and introduction of multi-layered structure [8] allows for further tuning of its capabilities, such as introduction of an energy gap or asymmetry in the electron-hole mobility.

Photoconductance is a phenomenon in which electrical conductivity of a material changes as a consequence of light absorption, which leads to generation of mobile charge carriers within. If the photoconductive behavior is prolonged in time, a persistent photoconductance (PPC) [9] can be spoken of. Both positive and negative photoconductive effects

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can be spoken of, as light excitation in different conditions and structures can either increase or decrease the conductance of the material.

PPC was observed in single- and few-layered graphene [10,11], yielding promising results. Manufacturing price of monolayer pure CVD graphene, however, is a serious issue for its potential applications. This factor is especially critical in the field of photovoltaics, where the relation between cost and efficiency determines whether a given technology will ever be implemented or rejected completely.

A graphene ceramic is proposed as a candidate for cost-effective optoelectronics. Composed of sintered graphene nanoplatelets (GNPs, as shown in Figure 1a), its internal structure is far more complex than that of monolayer graphene, what allows for observation of various photoelectric effects associated with structural defects. The nanoplatelets are composed of a few (up to five in case of higher quality GNPs, as used in the experiment) graphene layers, are several nanometers thick and have a large surface area of hundreds of square millimeters per gram. Primarily used as an additive in powder form used to increase electrical and/or thermal conductivity in composite materials with polymers [12], in this study the GNPs are the sole component of the material used in the photoconductance measurement.

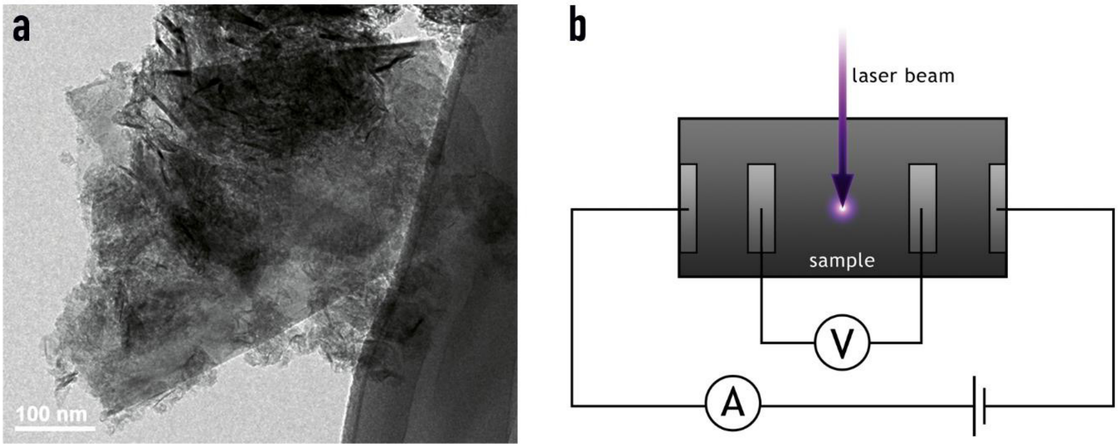

Fig. 1. (a) TEM image of graphene nanoplatelets (b) Photoconductance measurement setup in a four-terminal sensing configuration

2. Materials and methods

Graphene ceramics were prepared by using hot isostatic pressing of few-layer thick graphene nanoplatelets in powder form. The sintering was performed under the pressure of 8 GPa at 773K. The resulting material is a solid black cylindrical tablet, which is then polished and cut into desired dimensions. Due to the nature of the process, it is believed that the resulting ceramic is porous to a significant degree [13], a fact that should not be overlooked when interpreting the results and suggesting different phenomena possibly occurring within the photoconducting sample.

For the conductance measurement, a 4-wire setup (Figure 1b) was used for obtaining accurate resistance characterization of the highly conductive sample. Four golden wires were attached to the surface of the graphene ceramic, with the outer leads serving as the force electrodes and the inner ones used as sense probes. The sample was then illuminated with focused laser light, allowing for observation of irradiation-related resistance fluctuations. The power source current applied in the measurement was 10 mA. The experiment was carried out in ambient air.