Graphene-Based Transparent Photodetector Array for Multiplane Imaging

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Abstract: We report a transparent photodetector array using graphene as both the active pixel and interconnect material. We demonstrate imaging at multiple focal planes with these arrays. Further applications of position tracing will also be discussed.

1. Introduction

Monolayer graphene is highly transparent material that absorbs only several percent of incident light [1]. Hence it is a promising candidate for transparent electrodes used in various applications [2][3]. Moreover, it can also be made into photodetectors with high responsivity from visible to mid-infrared by leveraging the photogating effect in a phototransistor structure [4]. These properties of graphene allow us to build paradoxically transparent photodetectors that absorb only a few percent of incident light yet give a significant photoresponse [5]. Here we report the first transparent imaging arrays with both the active devices and interconnects made of graphene. We stack these arrays along the optical axis of a camera, as shown in Fig.1 (c). When an object is imaged by the lens, the light beams pass the detector planes mostly unperturbed, so that we can simultaneously capture images of an object in multiple planes almost as if the other planes do not exist. For a proof of concept demonstration, we test the performance of our multiplane imaging system with a point source as the object. The images from multiple sensor planes carry more information than a single plane in a typical camera. Using proper signal processing techniques, one can extract the depth information of the object. This opens the possibility of recovering the 3D information of objects from the readout of transparent arrays. We believe these transparent photodetector arrays, combined with proper computational techniques, would lead to applications as a compact, high quality light-field camera. This type of light-field camera is potentially useful for emerging technologies such as autonomous vehicles and unmanned aero vehicle navigation.

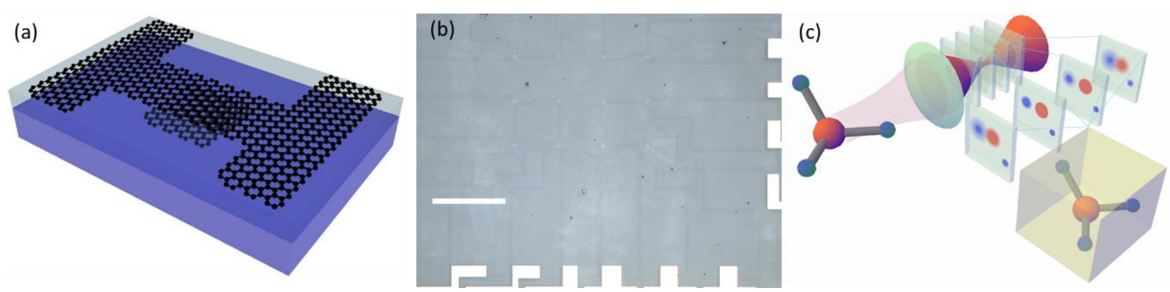

Figure 1. (a) Schematic of a single graphene phototransistor. (b) Image of a transparent array under optical microscope, scale bar: 500 µm. (c) A conceived diagram of the arrangement of the imaging planes in a camera. Depth information of objects is captured by multiple detector planes.

2. Device fabrication and optical characterization

Fig.1 (a) shows a schematic of a single pixel. We used graphene grown by CVD method on copper foil and used standard wet transfer in our process. We first transferred a layer of graphene onto a glass substrate; this was patterned into patches as the floating gate of a phototransistor [4][5] using oxygen plasma. Then we sputtered 6 nanometers of undoped silicon on top as a tunneling barrier. Finally, another layer of graphene was transferred and patterned into interconnects and channels of devices. We fabricated a 4 by 4 array of phototransistors. The devices are wired separately and connected to metal pads. The pads are then wire-bonded and connected to a customized signal readout circuit.

We fabricated two such sensor arrays and mounted them along the optical axis, separated at a distance, to form a stack of imaging planes. Fig. 1 (c) shows the optical setup. For a simple demonstration, we used a convex lens to focus a 532 nm laser beam and used the beam focus as a point source object. The object-generating lens was mounted on a motorized stage so that we can change the position of the object in a controlled manner. To remove drifting and hysteresis effect when measuring the current across the photo transistor, we chopped the beam at 500 Hz and captured the AC photocurrent using a lock-in amplifier.

Fig. 2 shows the measurement results. We recorded images from both the front plane and back plane. As we move the point source along the optical axis, the planes are gradually brought in or out of focus, indicating that depth information of object is captured in such imaging system. Details on subsequent data processing, including an artificial intelligence technique that can recover the object position from these images, will be presented in the conference.

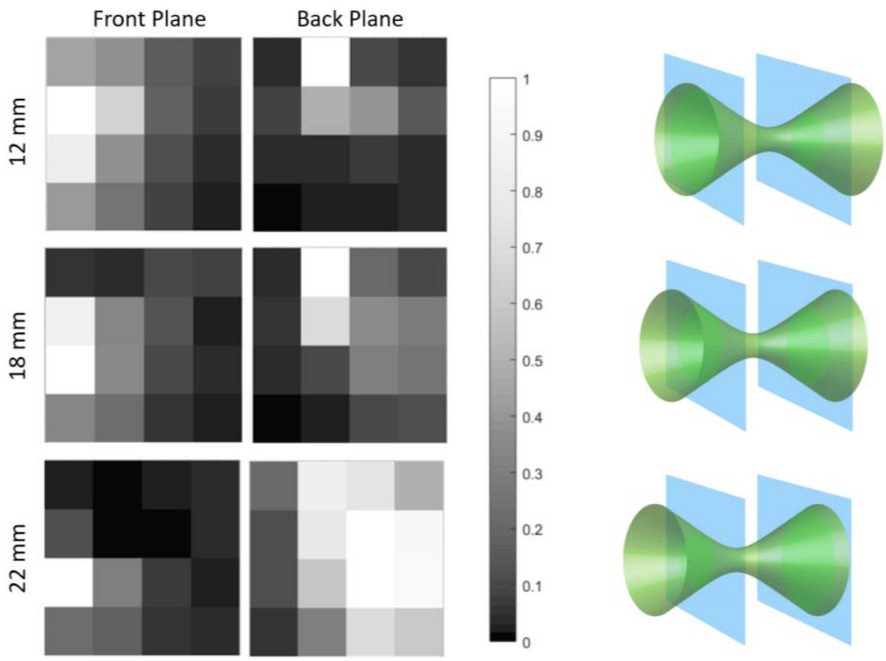

Figure 2. Images captured by both photodetector planes with object at three different positions along the optical axis (12 mm, 18 mm, 22 mm respectively), the intensity is normalized and shown with arbitrary unit. The right panel are the corresponding illustrations of the beam profile and the imaging planes of the left panel.

3. References

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4. Acknowledgement

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