Prototyping CMOS-compatible ultrasensitive photo detectors for visible and infrared light

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Abstract
Human beings are virtually blind during the night. Surveillance, military and car driver safety benefit enormously from the ability to observe in the dark. Currently there are different technologies available that enable people to see in the night. The most standard technology uses image intensifier tubes that amplify the remaining visible light. Image intensifier tubes are only sensitive to visible light and near infrared. With a camera that can detect short wave infrared radiation (SWIR), it is possible to benefit from illumination by night glow (also called air glow) [1]. Moreover fog is transparent for these wavelengths. A camera technology that combines responsivity in visible and SWIR spectral ranges would be enormously attractive. Current technologies relying on InGaAs cameras are prohibitively expensive for consumer electronics markets. Thus a need for low cost SWIR-Vis image sensors is immense.

Previously we demonstrated a hybrid graphene quantum dot photo detector that is sensitive to both visible light and short wave infrared radiation [2]. The broad spectral range combined with its extremely low noise-equivalent power smaller than a fW make it a promising sensing technology for future night vision devices. The high dynamic range enables imaging under day and night conditions. Recent developments make it possible to operate the detector at video frame rate. The detectors are fabricated by depositing PbS colloidal quantum dots on top of the graphene that induce a photogating effect when exposed to radiation. By tuning the size of the quantum dots, the band gap can be tuned and hence the absorption range. We have demonstrated absorption from the visible up to 1.6 µm (see Fig. 1b).

As a proof of concept for the robustness and facile integrability of the photo detection platform we have developed a demonstrator. We designed a custom read-out board with integrated amplification, video frame rate imaging capabilities. With this custom board we will perform a live demonstration of a single pixel ultrasensitive hybrid graphene quantum dot photo detector during the talk (see Fig. 1 for the setup). We will demonstrate for the first time a prototype photo detector device enabled by graphene's unique properties.

The hybrid graphene quantum dot photo detector is based on large area chemical vapour deposition (CVD) - graphene. Moreover the colloidal quantum dots are compatible with large volume synthesis wet-chemistry methodologies and can be deposited atop substrates using standard solution-processed large area deposition techniques. These factors make it possible to integrate the photo detectors at the end of the line of a CMOS fabrication process. This paves the way for volume production and commercialization

References

[1] M.P. Hansen and D.S. Malchow, Proc. SPIE, **6939** (March 2008). Overview of SWIR detectors, cameras, and applications.
[2] G. Konstantatos, M. Badioli, L. Gaudreau, J. Osmond, M. Bernechea,
F. P. Garcia de Arquer, F. Gatti and F. H. L. Koppens, Nature Nanotechnol., **7** (June 2012). Hybrid graphene-quantum dot detectors with ultrahigh gain.

Figures

Fig. 1: Demonstration setup with custom read-out board with integrated amplifier and signal visualized on an iPad. The chip with the detector is mounted in the chip carrier on read-out board.