# CdS/graphene hybrid photodetectors

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The application of graphene to photodetectors in the visible and near UV range suffers from low absorption of this gapless 2D material [1]. Among the different approaches to improve the performance in terms of responsivity, hybrid devices based on graphene and sensitizer materials have proved to be a promising solution to this problem. In particular, colloidal semiconductor nanocrystals are attractive because of the strong light absorption which can be tuned via composition and size over a wide spectral range [2]. Hybrid photodetectors based on these materials and graphene have given very good results in terms of photoconductive gain, but have a long response time which limits their use for high speed applications [3,4].

In this contribution, we will report on photodetectors fabricated with graphene and CdS nanocrystals showing high gain and capable to measure laser pulses up to a repetition rate of 2 kHz.

We use graphene grown by chemical vapor deposition [5] on a Cu substrate, and transferred onto a n-Si/$SiO_2$ wafer. On these samples, field effect transistors (FETs) are fabricated, exploiting the doped silicon layer as a back gate. The nanocrystals are synthetized according to the protocol in Ref. [6], dispersed in a chloroform-dichlorobenzene mixture, and deposited by spin coating on the graphene FETs. The sample is then mounted in a vacuum chamber, and the photoresponse is measured using a Xenon lamp and a pulsed laser at 349 nm.

The spectral response of the device follows the nanocrystals absorption, giving high sensitivity in the near UV range. In this hybrid system, the light is absorbed in the nanocrystals and excites charges, which are transferred to the graphene layer inducing a change in its conductivity. The photoconductive gain is the result of the short transit time in graphene (because of high carrier mobility) and the long relaxation time of the photogenerated charges [3]. Our device shows a maximum responsivity (photocurrent/light power) of about $3.4 \cdot 10^4$ A/W, corresponding to a gain of the order of $10^5$. The measured noise equivalent power (NEP) is of the order of pW $Hz^{-1/2}$.

The responsivity can be tuned via the charge density in graphene, using the backgate, as shown in left panel of fig. 1; the sign of the photocurrent can be switched from positive to negative, because of the ambipolar character of graphene.
As the light power is varied, we find that the maximum responsivity is achieved at the lowest power (right panel of fig.1).

We also have investigated the time response of our device. We measured a strongly non exponential decay of the photocurrent, with a time scale of the order of tens of seconds (fig.2, panel d). Indeed, the limiting factor in fast operation of this kind of devices is the long relaxation time of the photoexcited charges, which is important to achieve high responsivity. However, we found that our system response is a combination of fast and slow time scales, and the fastest ones are of the order of tenths of milliseconds. This feature allowed us to measure the laser pulses up to a repetition rate of 2 kHz (fig.2, panels a-c).

We explain the experimental response of the devices taking into account the role of surface states and adsorbed molecules on the nanocrystals [7-9]. This study allow us to gain insight in the charge transfer processes in the hybrid system [10].

## References


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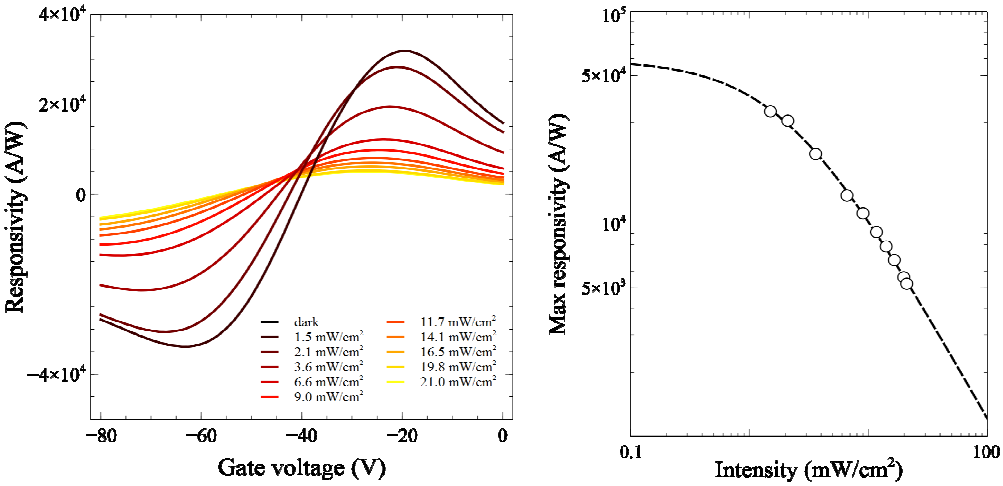


Figure 1: Left: Responsivity of the hybrid CdS/graphene photodetectors, measured with a laser at 349 nm, as a function of gate voltage. Right: dependence of the responsivity on the light power.

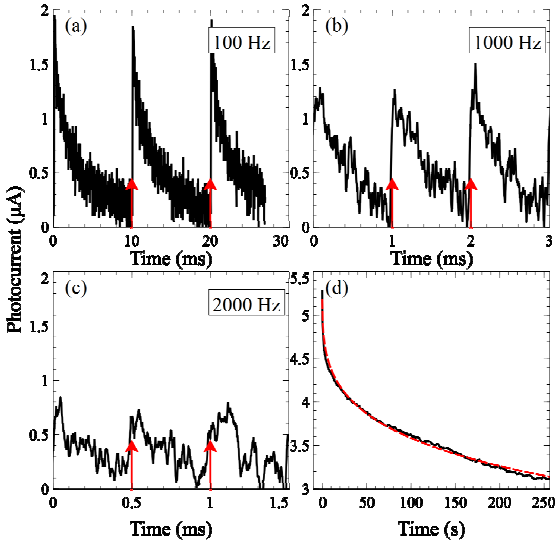


Figure 2: (a)-(c) Response of the photodetectors to ns-pulses at 349 nm, at different repetition rates. Red arrows mark the pulses. (d) Time response over a long period after turning off the laser.