GRAPHENE AND 2DM VIRTUAL CONFERENCE & EXPO

Graphene online 2020 October 19-23

Intrinsic Properties and Environmental Effects in Time-Resolved Photocurrent in CVD MoS_2 Monolayer.

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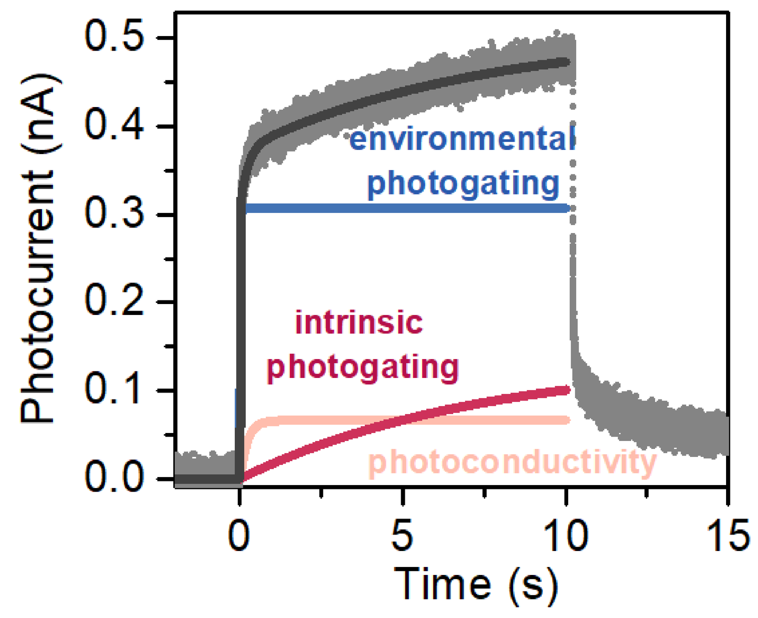
Abstract

With molybdenum disulfide's (MoS_2) interest as a two-dimensional direct band-gap semiconductor for optoelectronic applications, a significant attention was paid to the time dependence of photocurrents in MoS_2 based photodetectors. Studies of temporal response have been especially useful to distinguish photogating and photoconductive effects. We propose a new versatile model of the photocurrent response of MoS_2-monolayer-based devices with a description that distinguishes 3 exponential components. We studied a device subjected to different environments and under repeated illumination. We found that time constants obtained in our model differ by an order of magnitude between each other and stay relatively constant under any conditions. Current amplitudes, however, change significantly suggesting that photogating can be a result of two origins. Based on our study, we attributed obtained components to photoconductivity, environmental photogating and photogating due to intrinsic mechanisms. This study is the first time that photogating effect was distinguished in such a manner. We also showed that the rising signal of photocurrent may be a useful carrier of physical information about the sample.[1]

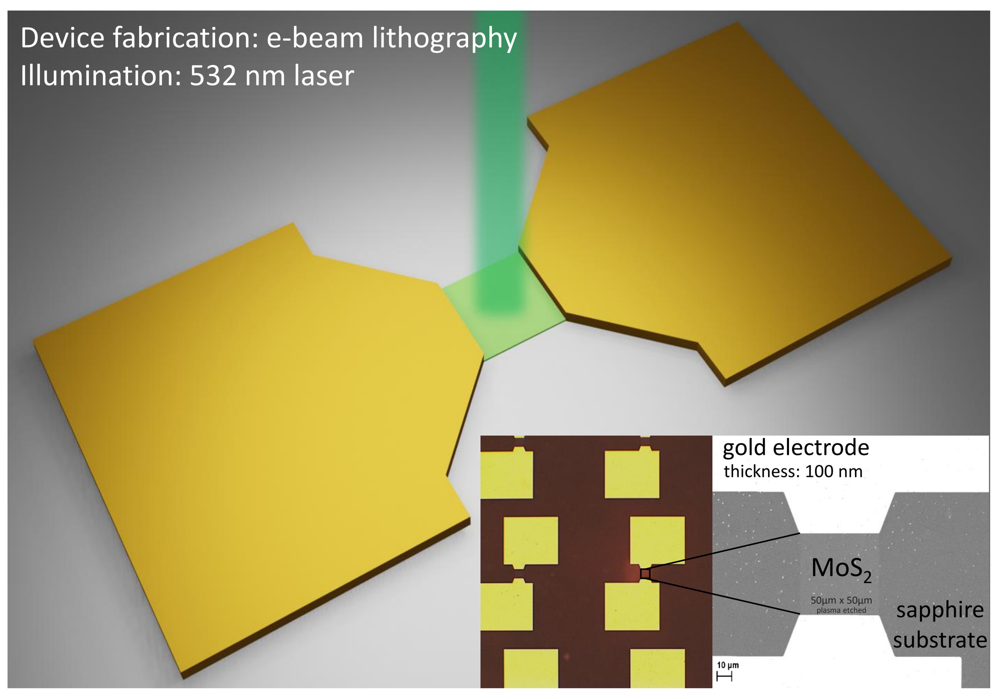


Methods

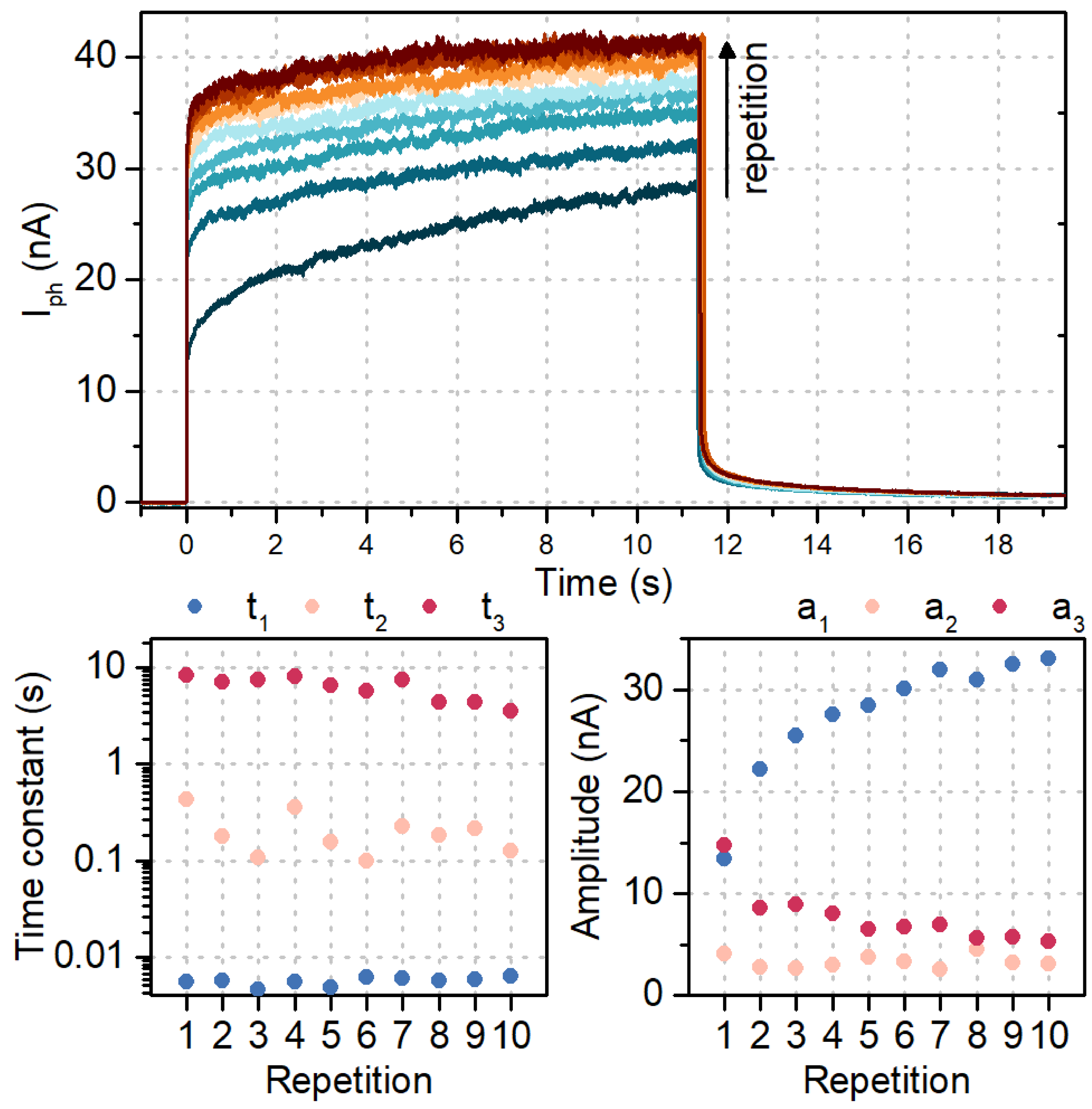
We fabricated the devices on a CVD continous MoS_2 on a dielectric sapphire substrate to minimize any effects that could affect their performance. They were measured applying 5V source-drain bias and illuminated. The measurements were conducted in two ways:

- changing the environment (air and direct argon flow)
- 10 consecutive measurements with repeated illumination (in air).

This way we obtained photucurrent signal in time domain with typical rapid increase (decrease) of the signal and then much slower, steady rise (decay) until plateu when the illumination was turned on (off).



10 consecutive measurements on the same device

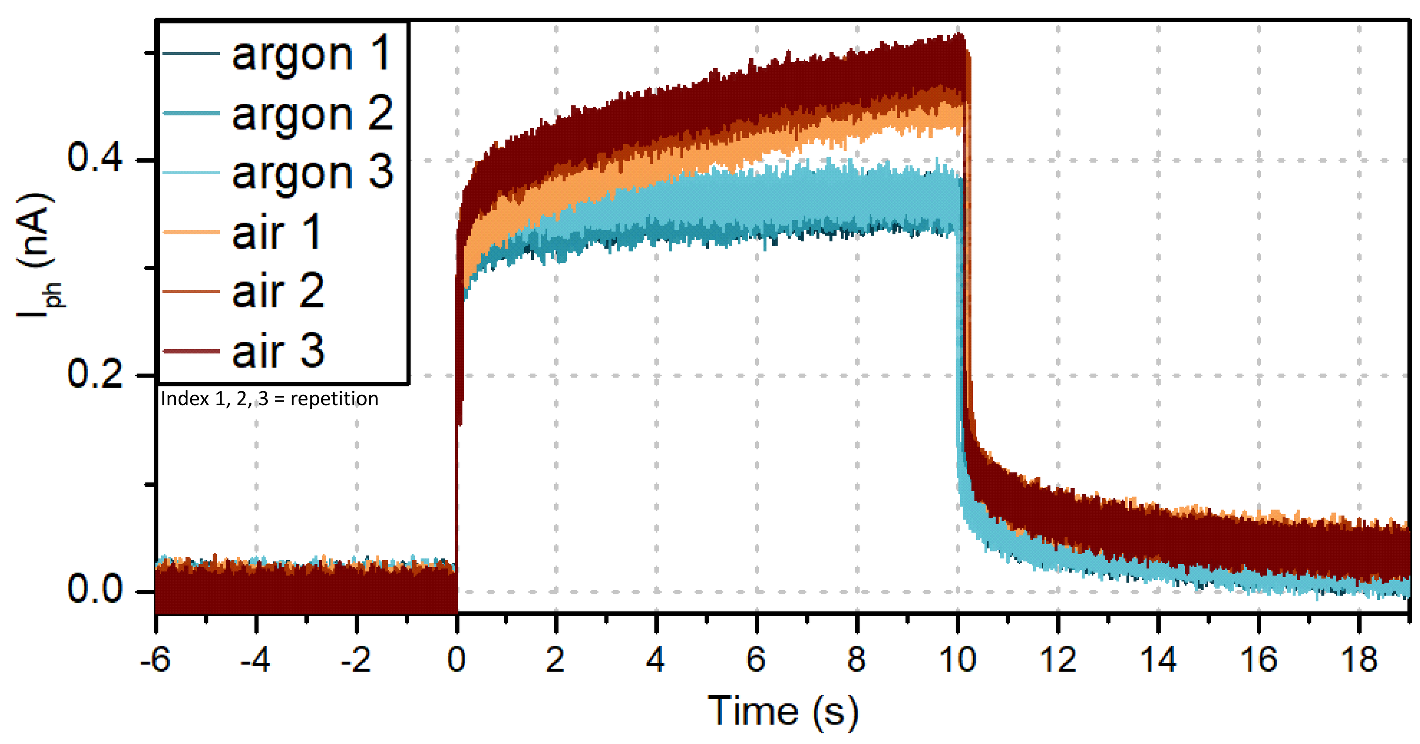


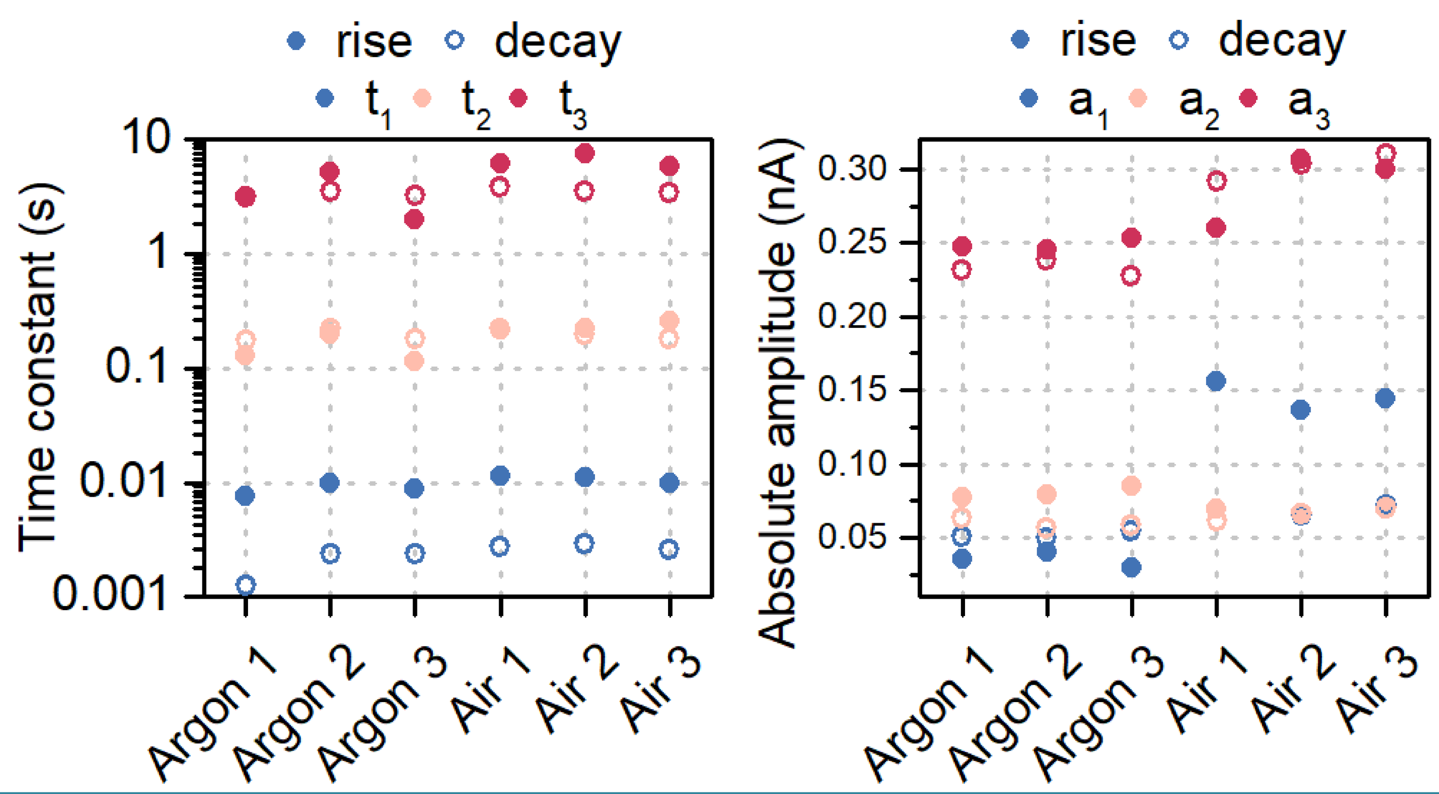
Results

After obtaining the data in the two previously described ways, we fit an equation below to the photocurrent signal. This resulted in a perfect fit to our data and gave us 3 components of time constants τ_k: t_1, t_2, t_3 and current amplitudes I_k: a_1, a_2, a_3 as seen in the figures.

$$I(t) = I_{dark} + I_{ph} = I_{dark} + \sum_{k=1}^{3} I_k\left(1 - e^{\frac{-t}{\tau_k}}\right)$$

Environmental change of rise and decay signal components





Conclusions

So far, photogating and photoconductive effects have been distinguished with a fit of two exponentials, where slow time constant was attributed to photogating and fast one to photoconductivity[2,3,4]. Our model proposes a versatile tripple-exponential fit in which we find the following characteristics:

- Time components are almost constant under any circumstances and differ by an order of magnitude between each other.
- a_1 increase with subjection to air[3] and its logarithmic rise[4] with repetition suggest environmental photogating.
- a_3 deacrease and slight t_3 decrease reflect faster saturation of the photocurrent and can be a result of photogating due to intrinsic properties of MoS_2 layer.
- The constant a_2 and t_2 components for all measurements suggest photoconductive effect.
- Rising signal shows changes in components that do not appear in decaying one. It is also less affected by change of doping with laser illumination[3].

Acknowledgements

This work was supported by the National Center for Research and Development, Poland, within Project No. Lider/180/L-6/14/NCBR/2015 and by TECHMATSTRATEG1/347012/3/NCBR/2017 (HYPERMAT) and partially supported by the CHARMING project (EOS 30467715), funded by the Science Foundation-Flanders (project number G0F6218N).

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Graphene online 2020