Opto-Electronic Advances

Supplementary information

2021, Vol. 4, No. 7

DOI: 10.29026/oea.2021.200032

Boron quantum dots all-optical modulator based on efficient photothermal effect

Cong Wang[1†], Qianyuan Chen[2†], Hualong Chen[1], Jun Liu[1], Yufeng Song[1], Jie Liu[3], Delong Li[1], Yanqi Ge[1], Youning Gong[1*], Yupeng Zhang[1*] and Han Zhang[1]

[1]Collaborative Innovation Center for Optoelectronic Science & Technology, International Collaborative Laboratory of 2D Materials for Optoelectronics Science and Technology of Ministry of Education, Institute of Microscale Optoelectronics, Shenzhen University, Shenzhen 518060, China; [2]School of Physics and Technology, and MOE Key Laboratory of Artificial Micro-and Nano-Structures, Wuhan University, Wuhan 430072, China; [3]Shandong Provincial Engineering and Technical Center of Light Manipulation & Shandong Provincial Key Laboratory of Optics and Photonic Device, School of Physics and Electronics, Shandong Normal University, Jinan 250014, China.

[†]These authors contributed equally to this work.

[*]Correspondence: YN Gong, E-mail: youninggong@szu.edu.cn; YP Zhang, E-mail: ypzhang@szu.edu.cn

This file includes:

Supplementary information for this paper is available at https://doi.org/10.29026/oea.2021.200032

Section 1: Preparation of BQDs

In a typical procedure, 25 mg bulk boron powder was directly added into 50 ml dimethylformamide (DMF) solvent to form a suspension with the initial concentration of 0.5 mg/ml. The suspension was firstly sonicated by 700 W probe ultrasonication for 3 h at 5 °C, then centrifuged at 6000 rpm for 30 min to remove unexfoliated boron particles. Next, the obtained light brown dispersions in DMF were centrifuged at 15000 rpm for 1 h to concentrate the as-exfoliated boron sample. After that, the collected boron samples were further treated by high energy ball milling (Nanjing University Instrument Plant, QM-3SP2) with a rate of 500 rpm for 24 h. Finally, the resultant boron/DMF solution was centrifuged successively at 10000 rpm for 30 min and 13000 rpm for 60 min to obtain the final BQDs product.

Section 2: Determination of the absorption coefficient of BQDs dispersions

Typically, the as-prepared BQDs dispersion was further centrifuged at 15000 rpm for 1 h. The resultant solid product was collected, followed by drying under vacuum at 60 °C for 8 h. 3.5 mg of the solid BQDs product was then redispersed in 4 mL of deionized water (DIW) by 15 min sonication under a constant temperature of 10 °C. The obtained BQDs/DIW dispersion was used to determine the corresponding absorption spectra.

Section 3: Characterization

The morphology and microstructure of the samples were characterized via scanning electron microscope (SEM; Sirion, FEI, Netherlands), HRTEM (Tecnai G2 F30) and AFM (Dimension Edge, Bruker, America) equipped with an energy-dispersive X-ray spectrometer (EDS; Genesis 7000, EDAX Inc., USA). The elemental compositions were analyzed via X-ray photoelectron spectroscopy (XPS; AXIS-Ultra instrument, Kratos Analytical, England) with a monochromatic Al Kα X-ray beam (225 W, 15 Ma, 15 kV). The UV-Vis diffuse reflectance spectra (DRS) of the samples were measured with the diffuse reflectance accessory of UV-Vis spectrophotometer (UV-2550; Shimadzu, Kyoto, Japan), in which $BaSO_4$ was used as a background between 200–1200 scopes.

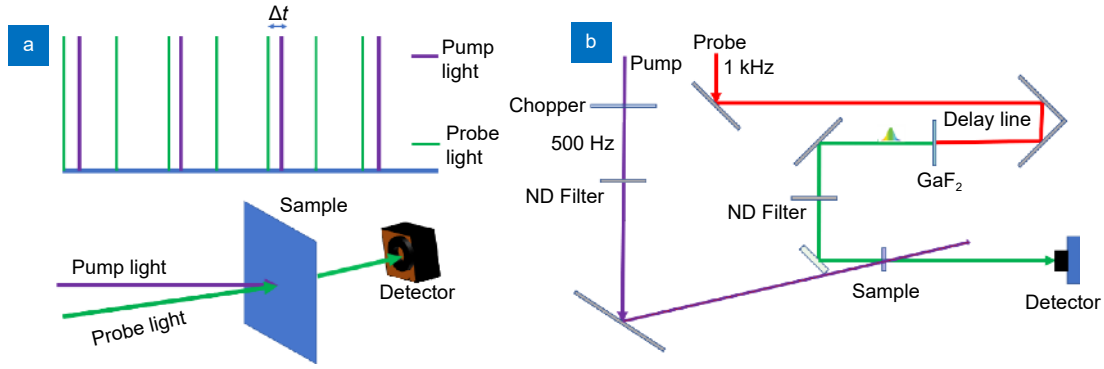

Fig. S1 | The work principle of pump probe setup. (**a**) The relationship between pump light and probe light in time domain and space domain. (**b**) The schematic diagram of pump probe setup.

Table S1 | The relaxation time constants of current state-of-the-art materials.

Materials	Wavelength (nm)	τ_1 (fs)	τ_2 (ps)	Ref.
BQDs	970	194	15.1	This work
Graphene	-	210	1.67	ref.[1]
$Cu_{2-x}S$	1300	315	34	ref.[2]
SnS	~1000	620	153	ref.[3]
WS_2	~564–689	1300	100	ref.[4]
Graphdiyne	~ 900	1400	24	ref.[5]

References

1. Bao QL, Zhang H, Wang Y, Ni ZH, Yan YL et al. Atomic‐layer graphene as a saturable absorber for ultrafast pulsed lasers. *Adv Func Mater* **19**, 3077–3083 (2009).
2. Guo QB, Yao YH, Luo ZC, Qin ZP, Xie GQ et al. Universal near-infrared and mid-infrared optical modulation for ultrafast pulse generation enabled by colloidal plasmonic semiconductor nanocrystals. *ACS Nano* **10**, 9463–9469 (2016).
3. Xie ZJ, Zhang F, Liang ZM, Fan TJ, Li ZJ et al. Revealing of the ultrafast third-order nonlinear optical response and enabled photonic application in two-dimensional tin sulfide. *Photonics Res* **7**, 494–502 (2019).
4. Vega-Mayoral V, Vella D, Borzda T, Prijatelj M, Tempra I et al. Exciton and charge carrier dynamics in few-layer WS_2. *Nanoscale* **8**, 5428–5434 (2016).
5. Guo J, Shi R, Wang R, Wang Y, Zhang F et al. Graphdiyne-polymer nanocomposite as a broadband and robust saturable absorber for ultrafast photonics. *Laser Photon Rev* **14**, 1900367 (2020).