Supplementary Information

For

A High responsivity $CsPbBr_3$ Nanowire Photodetector induced by $CdS@Cd_xZn_{1-x}S$ gradient alloyed Quantum Dots

Ying Wei, [a] Xiao Liu,*[a] Yu Miao,[b] Yuxin Liu[a], Chuanglei Wang, [a] Xiangjing Ying,[a] Gaotian Zhang[a], Huaimin Gu[a], Menglong Zhang*[a] and Hongyu Chen*[a]

Affiliations:

[a]School of Semiconductor Science and Technology, South China Normal University, Guangzhou 510631, P.R. China

[b]Laboratory of Quantum Engineering and Quantum Material, School of Physics and Telecommunication Engineering, South China Normal University, Guangzhou 510006, P.R. China

E-mail: (liuxiao@m.scnu.edu.cn, mlzhang@m.scnu.edu.cn, chenhy@m.scnu.edu.cn)

Contents:

1. Materials and sample preparation

Synthesis of CdS QDs: 1 mmol of S powder was completely dissolved in 10 ml of ODE by sonicate to form S-ODE. 0.2 mmol of $CdSt_2$,0.4 mmol of stearic acid and 6 ml of ODE were placed in the three-necked flask. After 10 minutes of argon at room temperature, the temperature was raised to 250°C， and then the 0.4 ml S-ODE was quickly injected into the three-necked flask. After 10 minutes of reaction, S-ODE was added dropwise to three-necked flask every 30 seconds. It was until to the growth of QDs to be a predetermined size, the heating was stopped and the reaction temperature was lowered to room temperature.

Synthesis of CdS@ZnS QDs: The prepared purified CdS nanocrystals were ready for the growth of ZnS shells. First, 2 mL of oleylamine solution was added to the flask and the reaction mixture was heated to 120°C. Second, 0.48 ml of each solution containing the Zn and S precursors were injected to the containing CdS core solution at 5 min intervals via syringe. Subsequently, the temperature was immediately increased to 220°C and kept for 20 minutes to prepare the growth of a ZnS monolayer. Finally, the reaction temperature was lowered to room temperature.

2. Figures

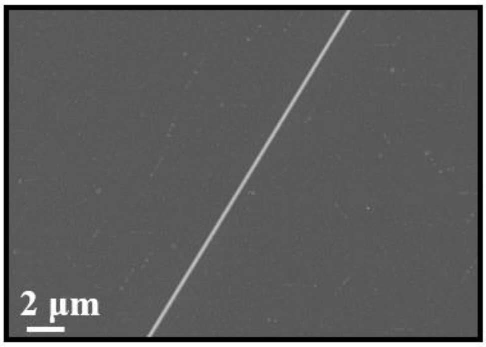

Figure S1. The SEM micrograph of $CsPbBr_3$ NW.

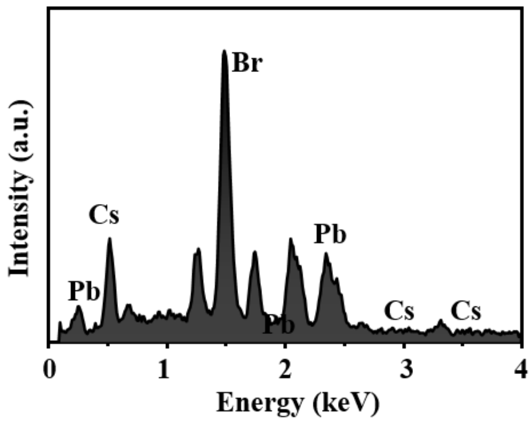

Figure S2. The EDS data of $CsPbBr_3$ NW.

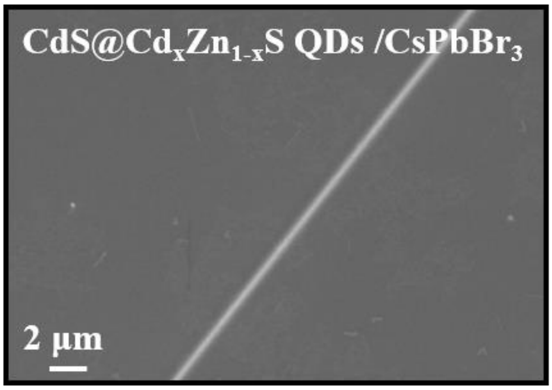

Figure S3. The SEM micrograph of $CsPbBr_3$ NW after CdS@Cd_xZn_{1-x}S QDs deposition.

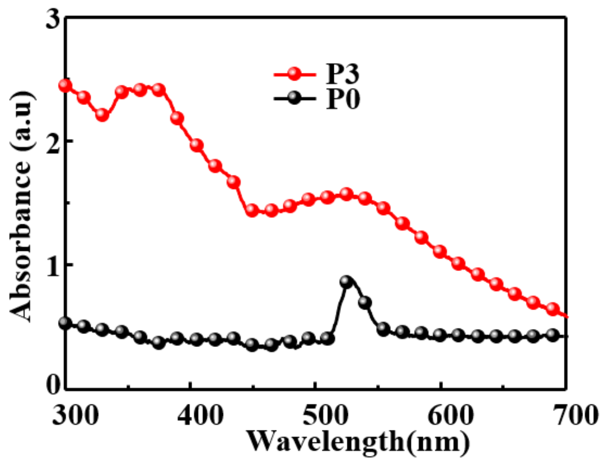

Figure S4. The absorption spectra of the P0 and P3.

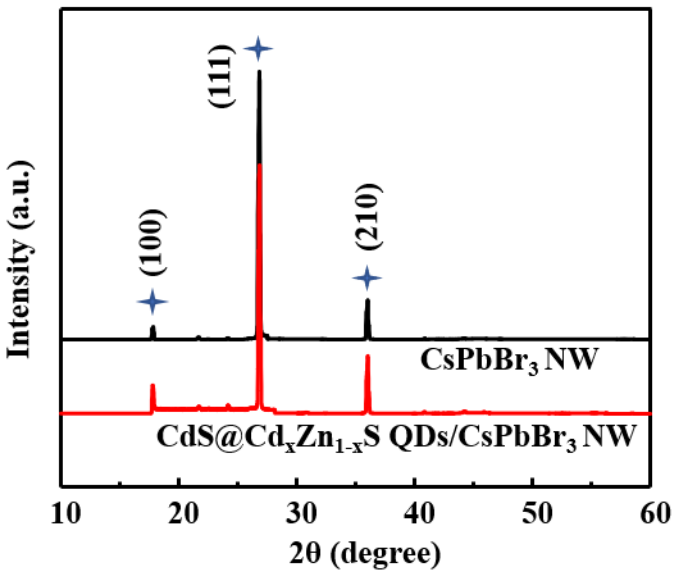

Figure S5. The XRD pattern of $CsPbBr_3$ NW and CdS@Cd_xZn_{1-x}S QDs/$CsPbBr_3$ NW.

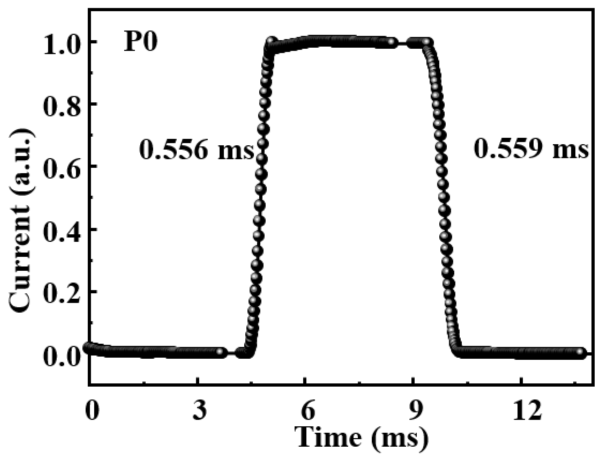

Figure S6. One cycle of the photoresponse under 405 nm laser at 19 μW/cm² for the P0 device.

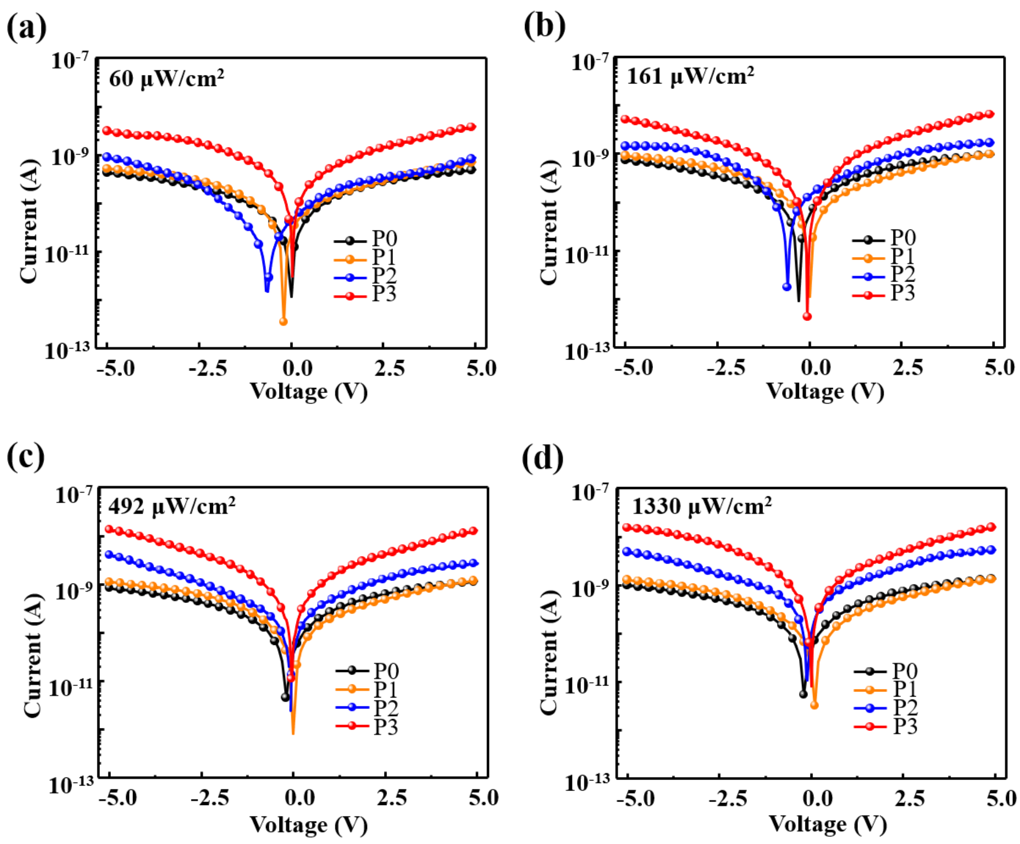

Figure S7. (a-d) Typical curves of P0 and P1, P2, P3 hybrid devices under 405 nm laser with

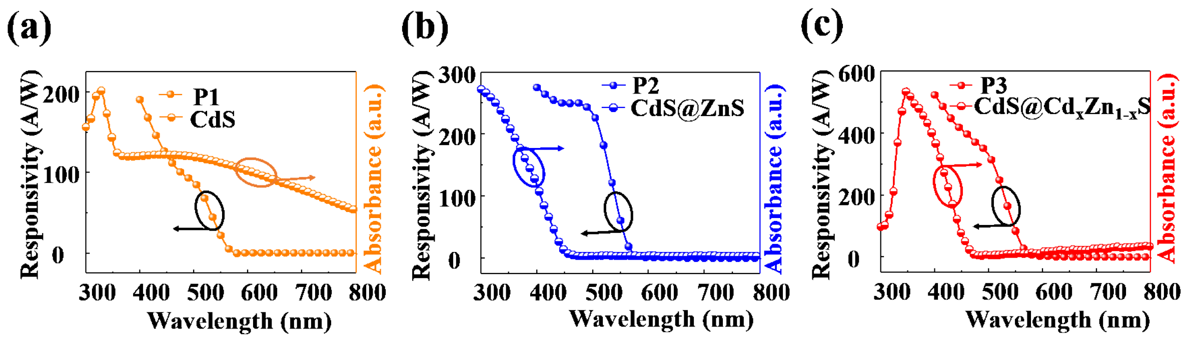

Figure S8. Photoresponsivity of P1, P2, P3 devices and the absorption curves of CdS QDs (a), CdS@ZnS QDs (b), CdS@$Cd_xZn_{1-x}S$ QDs (c) at wavelengths from 400 nm to 800 nm regions.

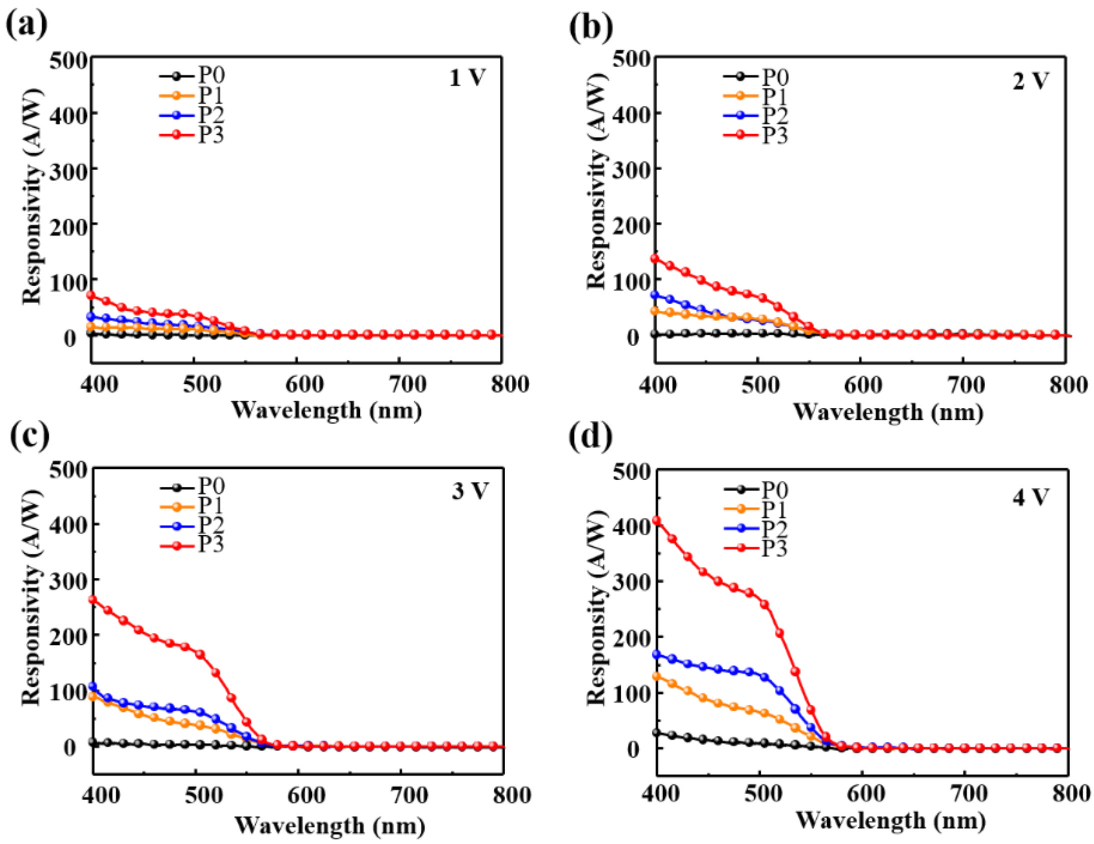

Figure S9. Photoresponsivity of P0, P1, P2, P3 devices at wavelengths from 400 nm to 800 nm regions under the increasing voltages of 1 V (a), 2 V (b), 3 V (c), and 4 V (d).

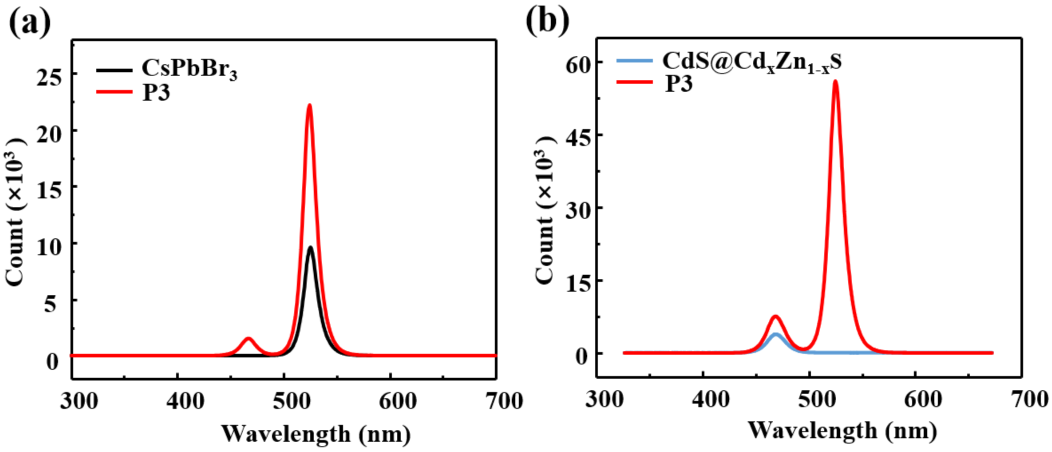

Figure S10. (a) The PL spectra of pure $CsPbBr_3$ NW and P3. (b) The PL spectra of pure $CdS@Cd_xZn_{1-x}S$ QDs and P3.

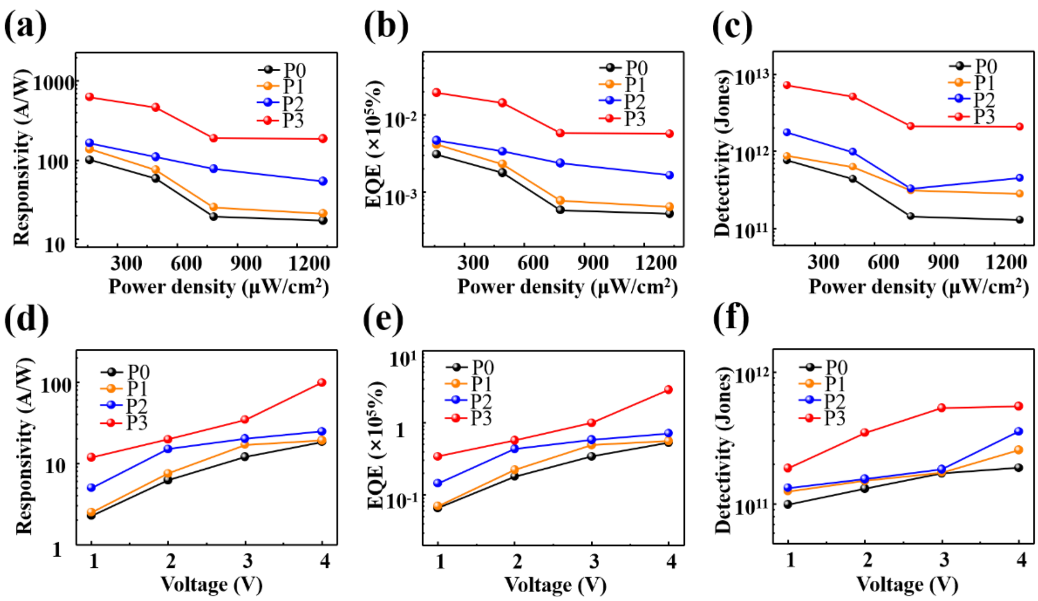

Figure S11. Photoresponsivity (a), EQE (b), and specific detectivity (c) of P0 and P1, P2, P3 devices under different light intensities and a voltage of 5 V. Photoresponsivity (d), EQE (e), and specific detectivity (f) of P0 and P1, P2, P3 devices with the light intensity of 19 μW/cm^2 under different voltages.

3. Tables

Table S1. Photoluminescence lifetimes fitted by exponential decay function for pure $CsPbBr_3$ NW, $CdS@Cd_xZn_{1-x}S$ QDs and $CdS@Cd_xZn_{1-x}S$ QDs-$CsPbBr_3$ NW.

Sample	τ_1	A_1	τ_2	A_2
$CsPbBr_3$	7.078 ns	100%		
$CdS@Cd_xZn_{1-x}S$ QDs	5.093 ns	100%		
$CdS@Cd_xZn_{1-x}S$ QDs-$CsPbBr_3$ NW	1.158 ns	40%	6.429 ns	60%

Table S2. Comparison of characteristic parameters with the $CsPbBr_3$-based photodetectors and other previously reported photodetectors on related materials heterostructure.

Classification	Device structure	*R* (A/W)	*D** (Jones)	Response time (ms)	EQE (%)	Wavelength (nm)	Ref
Single $CsPbBr_3$	$CsPbBr_3$ Microwires	20	9.38×10^{-10}	0.25/0.29	7540	325	1
	$CsPbBr_3$ Single-Crystal	0.028		<100	7	450	2
	$CsPbBr_3$ Microwire	118	8×10^{12}	38/36	1×10^{4}	500	3
Hetero-junction	$CsPbBr_3$/ZnO	0.0115		409/17.9		405	7
	$CsPbBr_3$/InGaZnO	3.794		2/2		365	8
	$CsPbBr_3$/GeSn	0.129		26/26		532	9
	$CsPbBr_3$: ZnO	0.0038	1.6×10^{-11}	58.59/593		405	11
	$CsPbBr_3$/2D CdS_xSe_{1-x}	289	1.28×10^{-14}			405	12
	$CsPbBr_3$ with Au	0.01004	4.56×10^{-8}	0.2/1.3	1254	532	6
	$CsPbBr_3$@Au	~4.2	9.9×10^{-8}	4/15	11.5	532	10
QDs decoration	PbS QDs/$CsPbBr_3$	0.100	8×10^{10}	2/1.5		500	4
	$CsPbBr_3$ QDs/$CsPbBr_3$	0.88	2.5×10^{12}	8.1×10^{-3}/ 27.2×10^{-3}		409	5
	MoS_2/$CuInSe_2$ QDs	74.8	7.1×10^{11}	1.5×10^{3}/ 1.2×10^{3}		1064	13
	MoS_2/PbSe QDs	1.9×10^{-6}		$\approx0.2\times10^{3}$/ 0.5×10^{3}		1200	14
	ReS_2/CdSe-CdS-ZnS QDs	654		3.2×10^{3}/ 2.8×10^{3}		532	15
This work	$CsPbBr_3$	116.9	0.92×10^{12}	0.556/0.559	358.87	405	
	CdS QDs/$CsPbBr_3$	172.03	1.73×10^{12}	0.29/0.5	526.21	405	
	CdS@ZnS QDs/$CsPbBr_3$	306.6	2.22×10^{12}	0.28/0.48	941.53	405	
	CdS@$Cd_xZn_{1-x}S$ QDs/$CsPbBr_3$	1442	1.62×10^{13}	0.34/0.33	4400	405	

4. References

1 Y. Yang, F. Gao, Q. Liu, J. Dong, D. Li, X. Luo, J. Guo, J. Shi, Y. Lin, W. Song, X. Wang and S. Li, *J. Phys. Chem. Lett.,* 2020, **11,** 7224.

2 J. Ding, S. Du, Z. Zuo, Y. Zhao, H. Cui, X. Zhan and *J. Phys. Chem. C,* 2017, **121,** 4917.

3 P. Gui, Z. Chen, B. Li, F. Yao, X. Zheng, Q. Lin and G. Fang, *ACS Photonics* 2018, **5,** 2113

4 J. Navarro Arenas, A. Soosaimanickam, H. Pashaei Adl, R. Abargues, P. P. Box, P. J. Rodriguez-Canto and J. P. Martinez-Pastor, *Nanomaterials,* 2020, **10,** 1297.

5 S. Yan, S. Tang, M. Luo, L. Xue, S. Liu, E. E. Elemike, B. S. Bae, J. Akram, J. Chen, Z. Zhao, Z. Zhu, X. Zhang, W. Lei and Q. Li, *J. Mater. Chem. C,* 2021, **9,** 10089

6 Y. Dong, Y. Gu, Y. Zou, J. Song, L. Xu, J. Li, J. Xue, X. Li and H. Zeng, *Small,* 2016, **12,** 5622

7 C. Li, C. Han, Y. Zhang, Z. Zang, M. Wang, X. Tang and J. Du, *Sol. Energy Mater. Sol. Cells,* 2017, **172,** 341.

8 M. Sun, Q. Fang, Z. Zhang, D. Xie, Y. Sun, J. Xu, W. Li, T. Ren and Y. Zhang, *ACS Appl. Mater. Interfaces,* 2018, **10,** 7231.

9 H. Cong, X. Chu, F. Wan, Z. Chu, X. Wang, Y. Ma, J. Jiang, L. Shen, J. You and C. Xue, *Small Methods,* 2021, **5,** 2100517.

10 Z. Yang, M. Jiang, L. Guo, G. Hu, Y. Gu, J. Xi, Z. Huo, F. Li, S. Wang and C. Pan, *Nano Energy,* 2021, **85,** 105951.

11 P. Tang, S. Yang, J. Hu, Z. Zhang, Y. Jiang, M. Sulaman, L. Tang and B. Zou, *J. Alloys Compd.* 2021, **896,** 163022.

12 M. Peng, Y. Ma, L. Zhang, S. Cong, X. Hong, Y. Gu, Y. Kuang, Y. Liu, Z. Wen and X. Sun, *Adv. Funct. Mater.,* 2021, 31, 2105051.

13 T. Shen, F. Li, Z. Zhang, L. Xu and J.Qi, *ACS Appl. Mater. Interfaces,* 2020, **12,** 54927.

14 J. Schornbaum, B. Winter, S. P. Schießl, F. Gannott, G. Katsukis, D. M. Guldi, E. Spiecker and J. Zaumseil, *Adv. Funct. Mater.,* 2014, **24,** 5798.

15 J. K. Qin, D. D. Ren, W. Z. Shao, Y. Li, P. Miao, Z. Y. Sun, P. A. Hu, L. Zhen and C. Y. Xu, *ACS Appl. Mater. Interfaces,* 2017, **9,** 39456.