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Supporting Information

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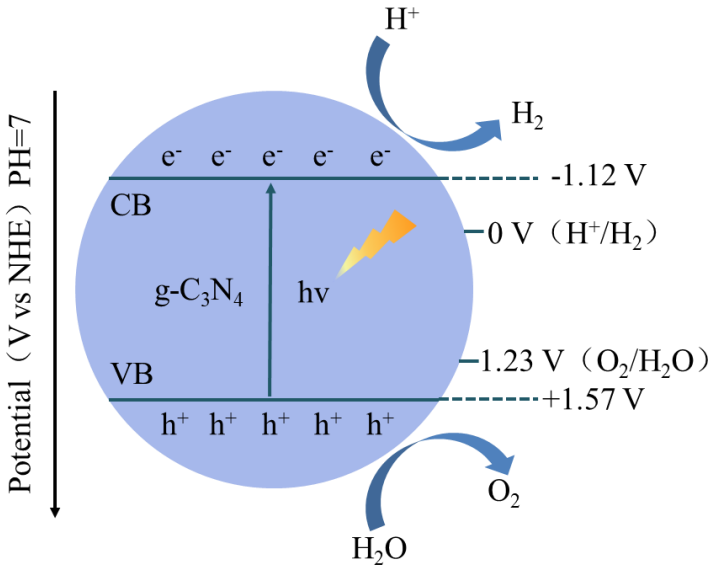

Figure S1. Schematic diagram of g-C_3N_4 photocatalytic hydrogen generation and energy band.

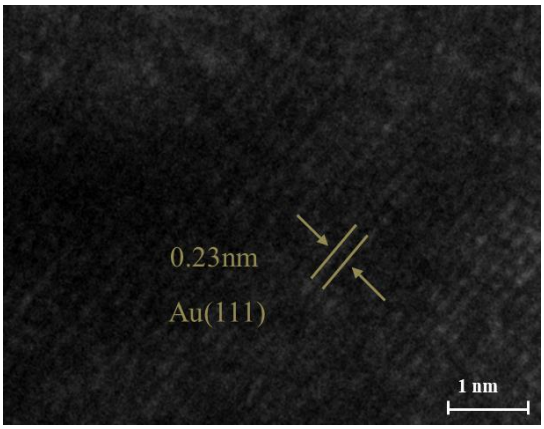

Figure S2. Magnified TEM image of the Au NPs.

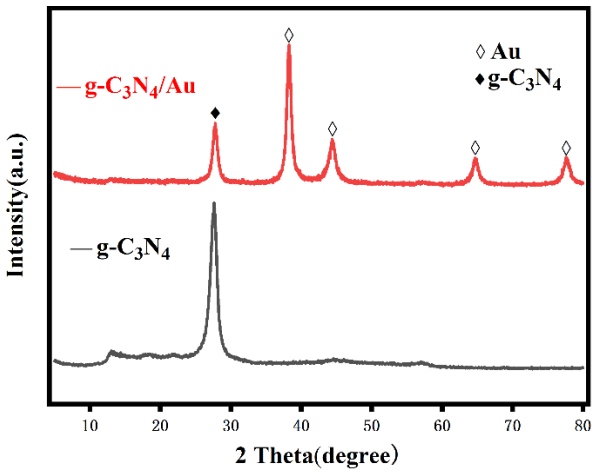

Figure S3. XRD patterns of Au/g-C_3N_4 and pure g-C_3N_4.

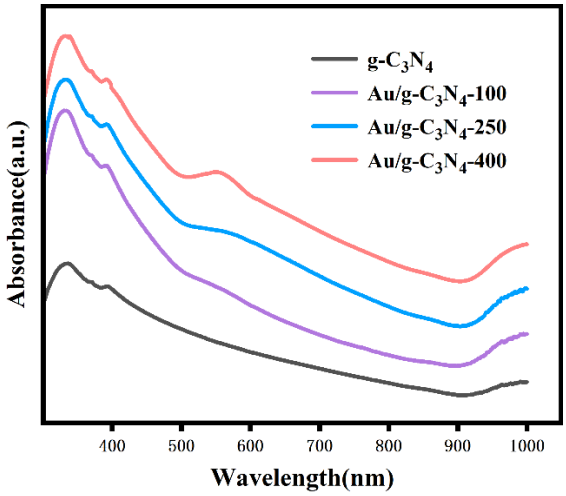

Figure S4. UV-vis spectra of pure g-C_3N_4 and Au/g-C_3N_4 synthesized with different contents of chloroauric acid (100, 250, 400 μL) in precursor solutions dispersions in deionized water.

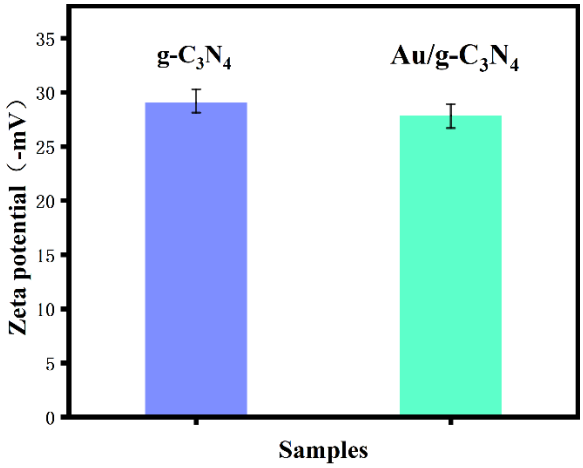

Figure S5. The Zeta potentials of g-C_3N_4 and Au/g-C_3N_4 dispersions in deionized water.

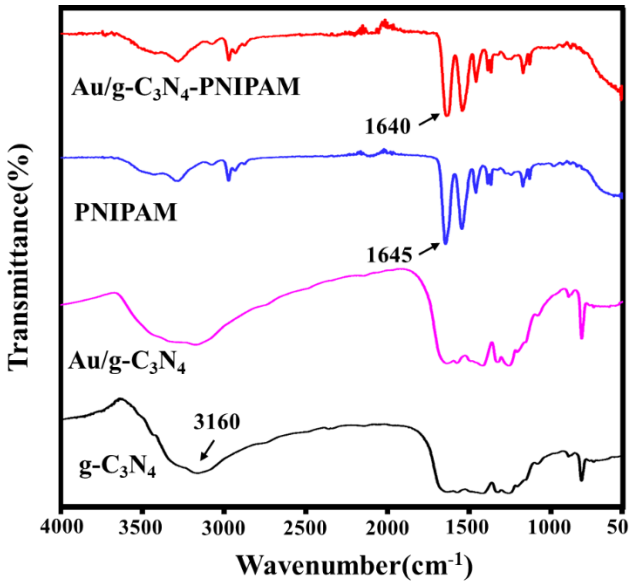

Figure S6. The FT-IR spectra of g-C_3N_4, Au/g-C_3N_4, PNIPAM, and the Au/g-C_3N_4-PNIPAM hydrogel.

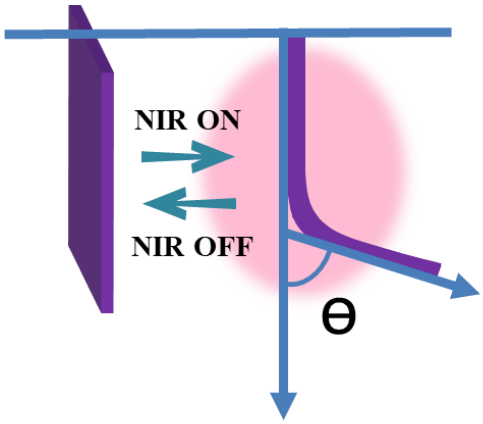

Figure S7. Schematic illustration of the gradient hydrogels bending angle (θ) under NIR light irradiation.

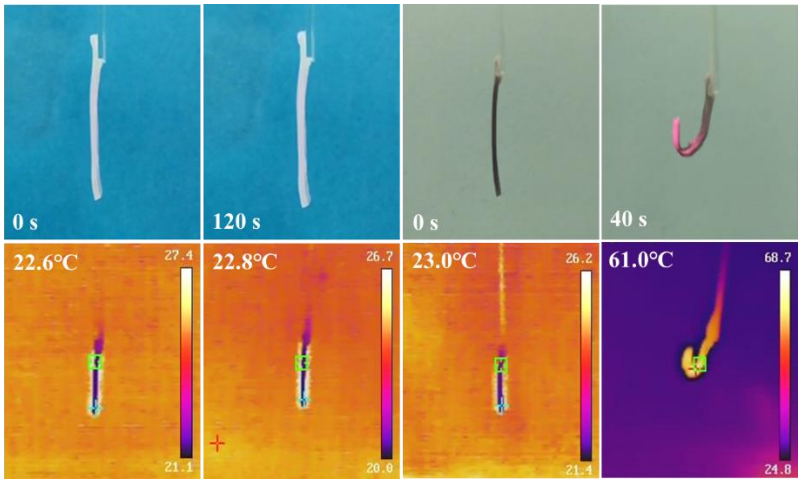

Figure S8. Real and infrared images of the $E_{2.5}C_{10}$ hydrogel actuator and the control sample undoped with Au NPs upon exposure to 808 nm NIR light (0.5 W cm^{-1}).

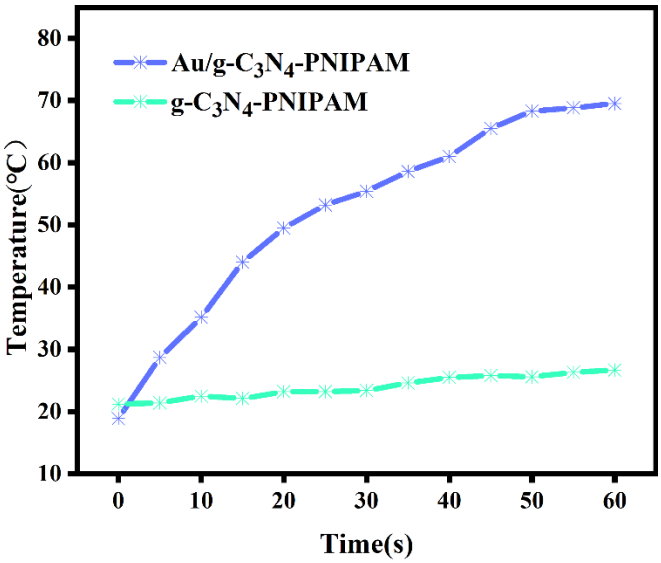

Figure S9. Temperature variation with an exposure time of the $E_{2.5}C_{10}$ hydrogel and g-C_3N_4-PNIPAM hydrogel under 808 nm NIR irradiation with 0.5 W cm^{-2}.

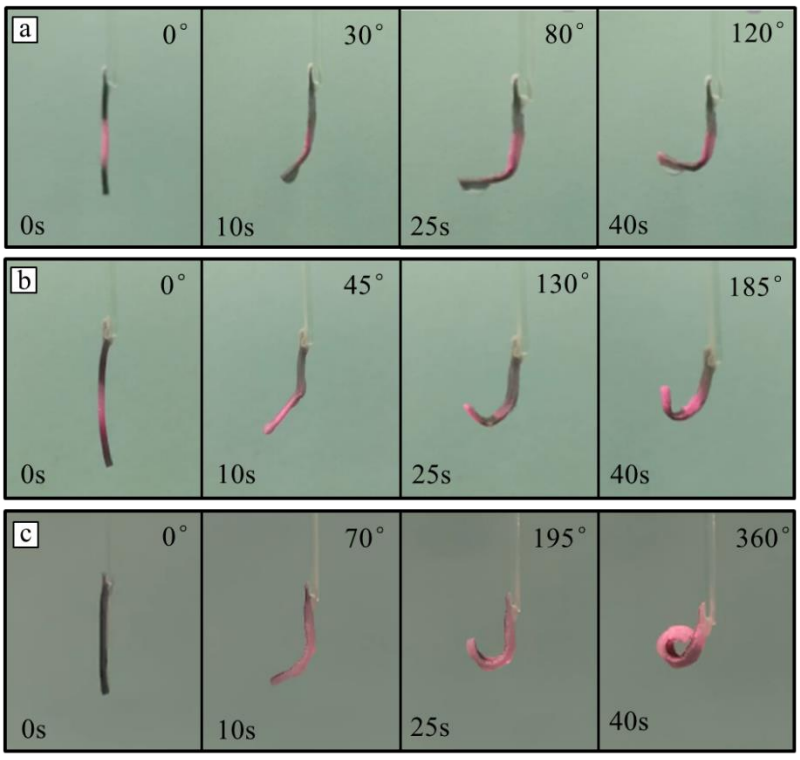

Figure S10. Actuation of gradient hydrogel actuators prepared at different voltages: (a) the E_2C_{10}, (b) the $E_{2.5}C_{10}$, and (c) the E_3C_{10} upon exposure to the 808 nm NIR light with 0.5 W cm^{-2}.

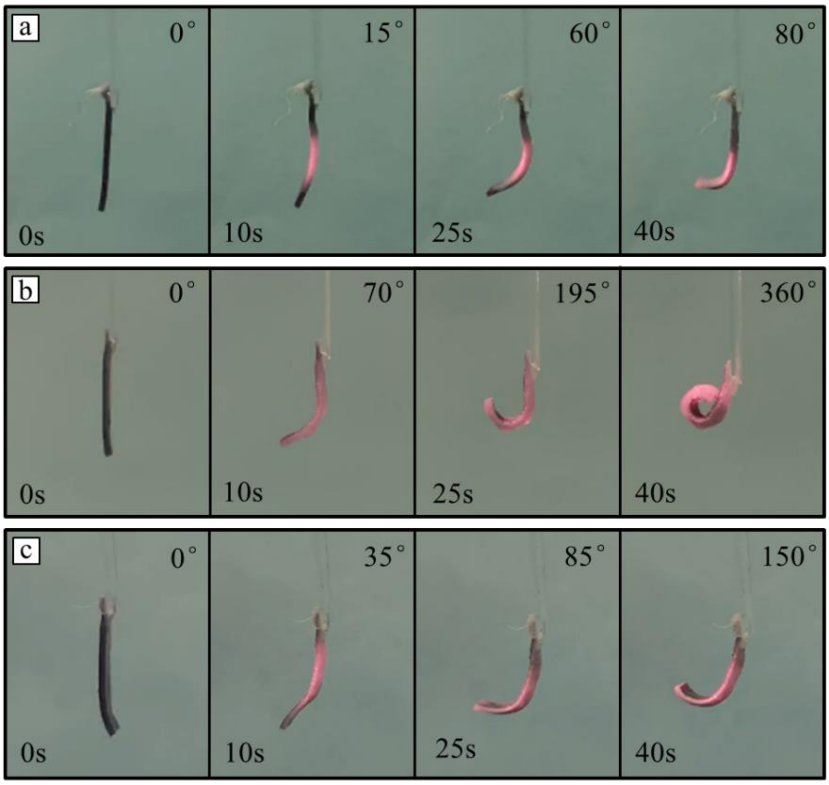

Figure S11. Actuation of gradient hydrogel actuators prepared with different Au/g-C_3N_4 concentrations: (a) the E_3C_5 (b) the E_3C_{10}, and (c) the E_3C_{15} upon exposure to the 808 nm NIR light with 0.5 W cm^{-2}.

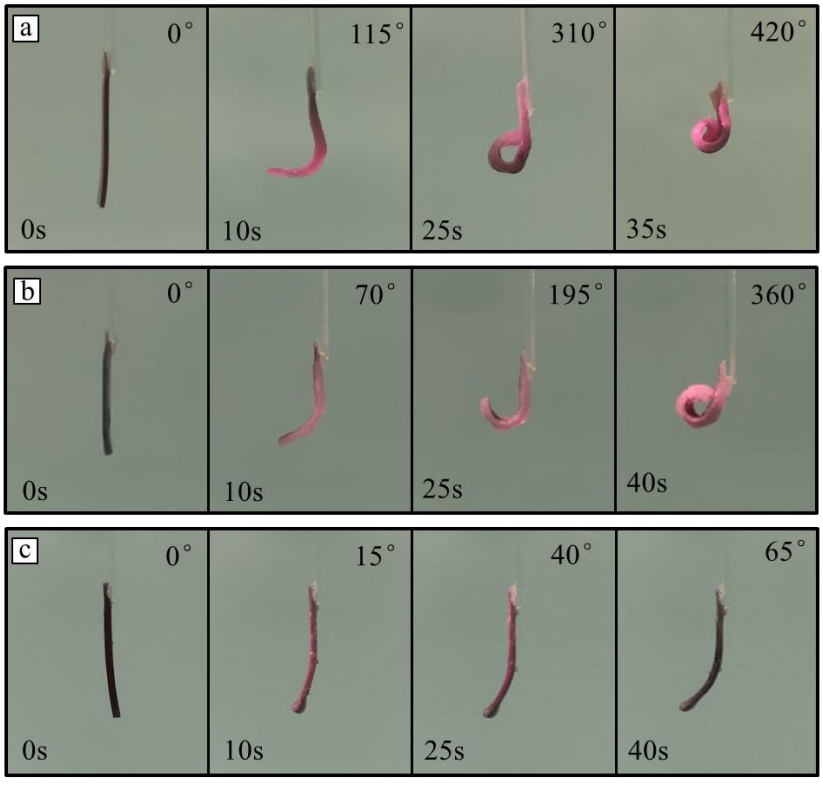

Figure S12. Actuation of gradient hydrogel actuators prepared with different

thicknesses: (a) 0.7, (b) 1.0, and (c) 1.4 mm upon exposure to the 808 nm NIR light with 0.5 W cm^{-2}.

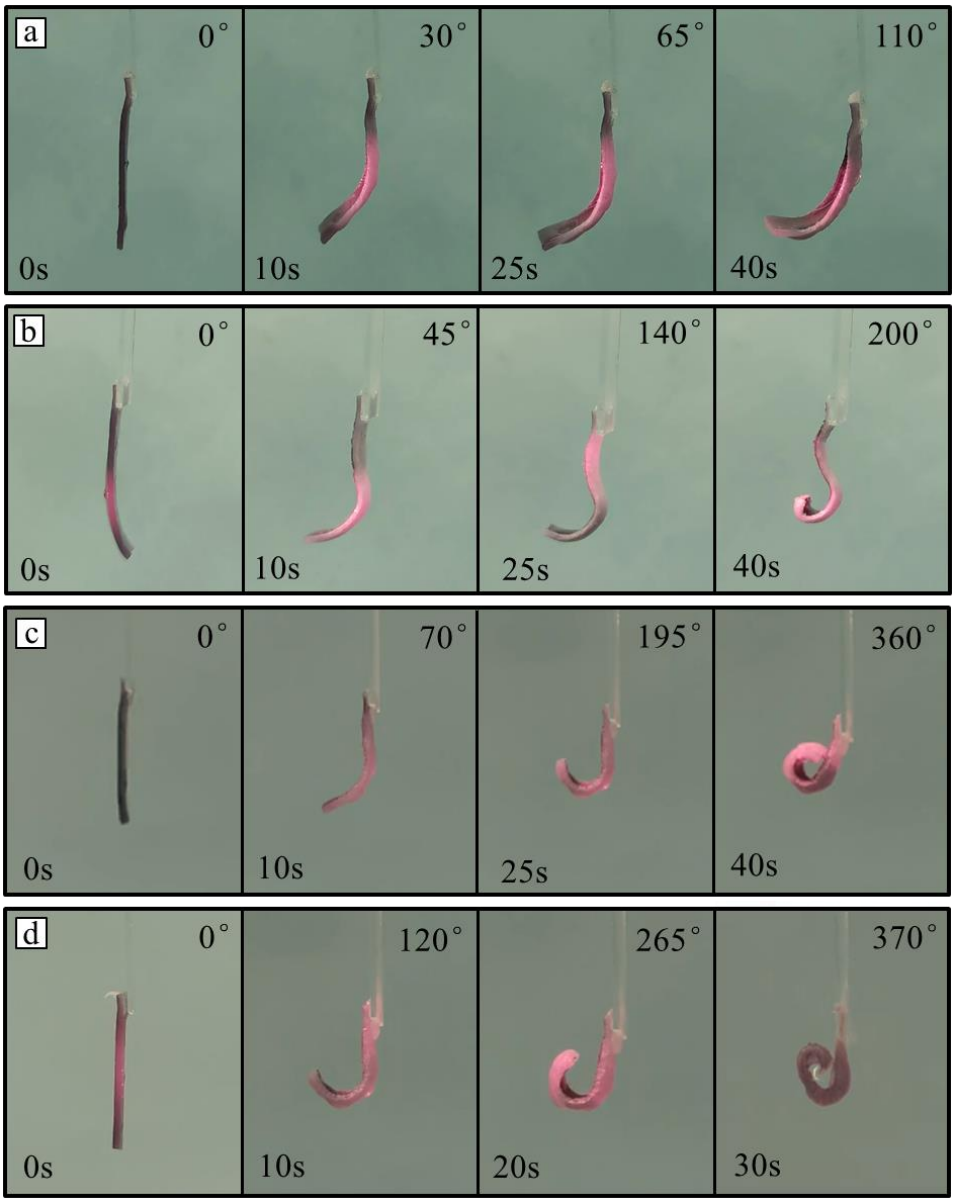

Figure S13. Actuation of the E_3C_{10} hydrogel actuators exposed to different power density: (a) 0.1, (b) 0.2, (c) 0.5 and (d) 0.8 W cm^{-2}.

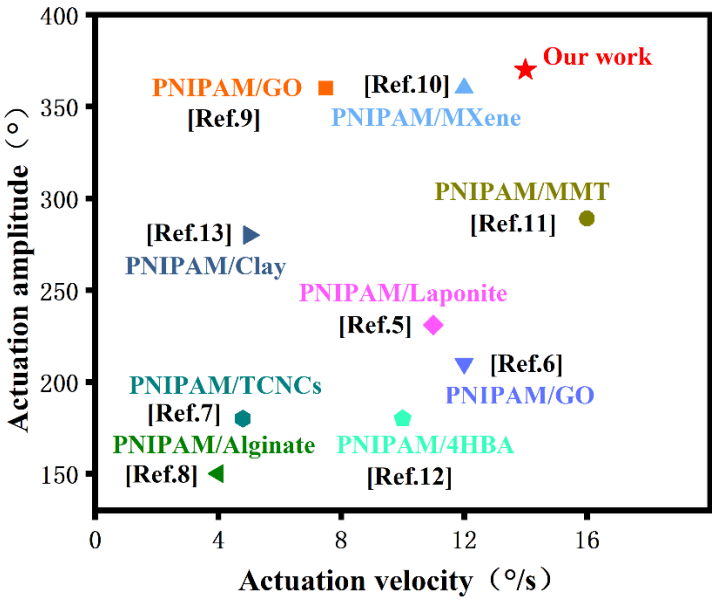

Figure S14. Comparison of actuation velocity and actuation amplitude of different hydrogel actuators. The detailed information is shown in Table S2.

Table S1. Comparison of g-C_3N_4-based 3D structures photocatalytic AQY performance

Sample	AQY(%)	Wavelength(nm)	Lamp power(W)	Ref(SI)
PNIPAM/g-C_3N_4	1.88	420	300W	1
3D porous C_3N_4	5.1	420	300W	2
PDMA/g-C_3N_4	1.0	405	50W	3
Porous fiber-like g-C_3N_4	2.42	420	500W	4
This work	5.39	420	150W	

Table S2. Comparison of actuation performance of different hydrogel actuators

Hydrogel	Actuation amplitude (°)	Actuation velocity (°/s)	Ref
PNIPAM-Laponite	231	11	5
PNIPAM-GO	210	12	6
PNIPAM-TCNCs	180	4.8	7
PNIPAM-Aliginate	150	4	8

PNIPAM-GO	360	7.5	9
PNIPAM-MXene	360	12	10
PNIPAM-MMT	289	16	11
PNIPAM-4HBA	180	10	12
PNIPAM-Clay	280	5	13
PNIPAM-Au/g-C_3N_4	370	13	This work

Supporting Movies:

Movie S1: Light-fueled flower-shaped hydrogel actuator in water under 808 nm NIR with 0.8 W cm^{-2} intensity.

Movie S2: Light-fueled soft end effector that grips and lifts a cargo in water when exposed to 808 nm NIR with 0.8 W cm^{-2} intensity.

Movie S3: Light-fueled hydrogel paddles enable the motion of a boat-like structure on the water under 808 nm NIR irradiation with 0.8 W cm^{-2} intensity.

Movie S4: Light-driven hydrogel walker on ratchet surface in water under 808 nm NIR irradiation with 0.8 W cm^{-2}.

Movie S5: The flower-shaped construct bends when exposed to the light source to maximize energy harvesting underwater.

Reference

[1] L. Lei, W. J. Wang, C. Wang, H. Q. Fan, A. K. Yadav, N. Hu, Q. Zhong and P. Muller-Buschbaum, *J. Mater. Chem. A*, 2020, **8**, 23812-23819.

[2] J. Xu, L. W. Zhang, R. Shi and Y. F. Zhu, *J. Mater. Chem. A*, 2013, **1**, 14766-14772.

[3] Q. Cao, J. Barrio, M. Antonietti, B. Kumru, M. Shalom and B. Schmidt, *ACS Appl. Polym. Mater*, 2020, **2**, 3346-3354.

[4] H. L. Dou, D. Long, S. H. Zheng and Y. P. Zhang, *Catal. Sci. Technol*, 2018, **8**, 3599-3609.

[5] Y. Tan, D. Wang, H. X. Xu, Y. Yang, W. L. An, L. N. Yu, Z. X. Xiao and S. M. Xu, *Macromol. Rapid Commun*, 2018, **39**, 6.

[6] X. M. He, Y. Sun, J. H. Wu, Y. Wang, F. Chen, P. Fan, M. Q. Zhong, S. W. Xiao, D. Zhang, J. T. Yang and J. Zheng, *J. Mater. Chem. C*, 2019, **7**, 4970-4980.

[7] K. W. Mo, M. He, X. D. Cao and C. Y. Chang, *J. Mater. Chem. C*, 2020, **8**, 2756-2763.

[8] W. J. Zheng, N. An, J. H. Yang, J. X. Zhou and Y. M. Chen, *ACS Appl. Mater. Interfaces*, 2015, **7**, 1758-1764.

[9] Y. Yang, Y. Tan, X. Wang, W. An, S. Xu, W. Liao and Y. Wang, *ACS Appl. Mater. Interfaces*, 2018, **10**, 7688-7692.

[10] P. Xue, H. K. Bisoyi, Y. H. Chen, H. Zeng, J. J. Yang, X. Yang, P. F. Lv, X. M. Zhang, A. Priimagi, L. Wang, X. H. Xu and Q. Li, *Angew. Chem.Int. Edit*, 2021, **60**, 3390-3396.

[11] J. Liu, W. Xu, Z. Kuang, P. Dong, Y. Yao, H. Wu, A. Liu and F. Ye, *J. Mater. Chem. C*, 2020, **8**, 12092-12099.

[12] R. C. Luo, J. Wu, N. D. Dinh and C. H. Chen, *Adv. Funct. Mater*, 2015, **25**, 7272-7279.

[13] H. Zhao, Y. M. Huang, F. T. Lv, L. B. Liu, Q. Gu and S. Wang, *Adv. Funct. Mater*, 2021, 31, 2105544.