

Recent advances in the applications of porous organic cages

Dingyue Hu,^{‡a, b} Jinjin Zhang ^{‡b} and Ming Liu ^{*a, b}

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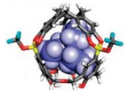
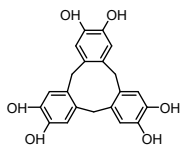
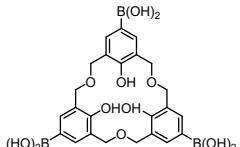
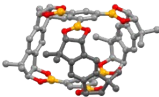
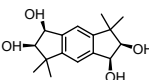
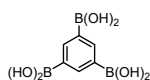
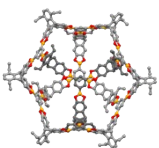
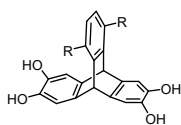
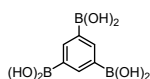
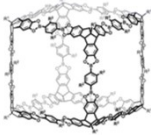
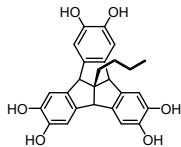
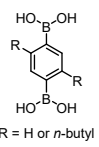
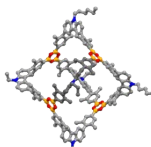
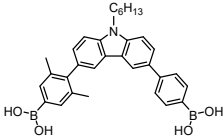
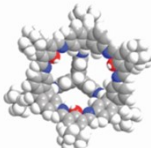
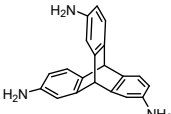
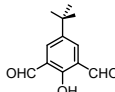
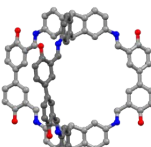
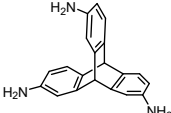
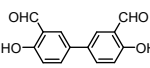
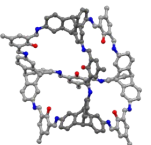
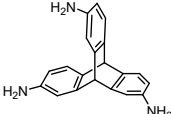
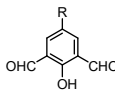
^b. *Hangzhou Global Scientific and Technological Innovation Center (HIC), Zhejiang University, Hangzhou 311200, China.*

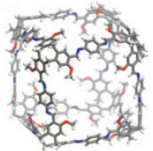
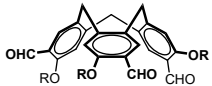
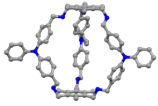
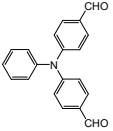
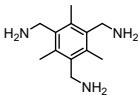
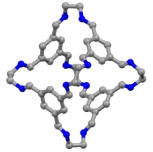
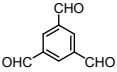
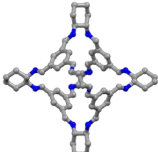
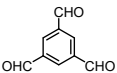
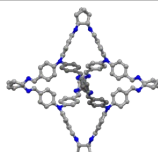
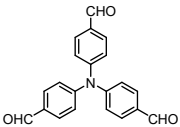
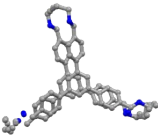
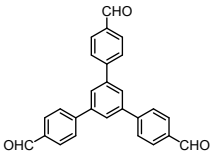
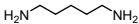
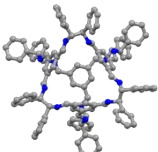
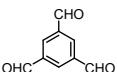
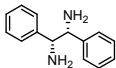
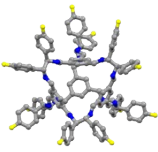
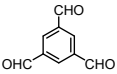
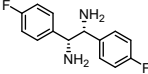
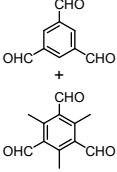
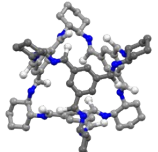
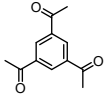
[‡]*Dingyue Hu and Jinjin Zhang contributed equally to this work.*

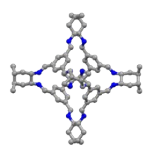
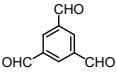
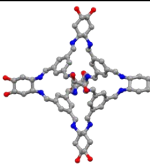
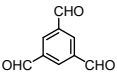
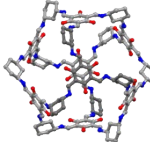
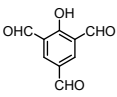
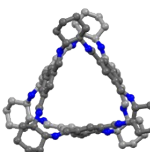
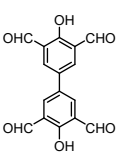
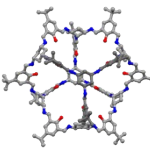
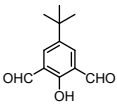
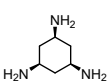
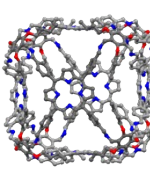
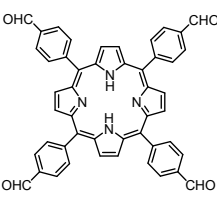
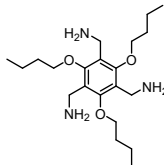
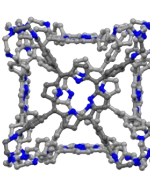
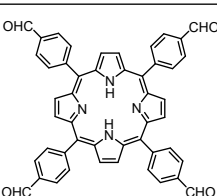
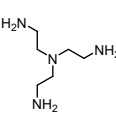
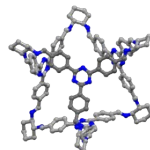
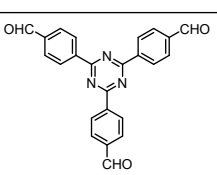
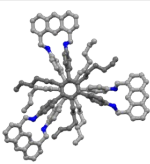
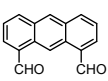
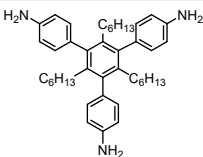
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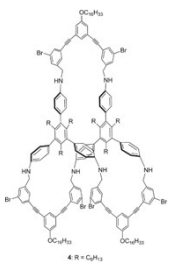
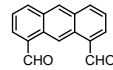
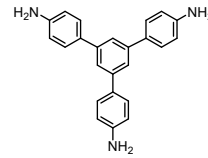
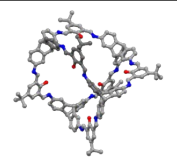
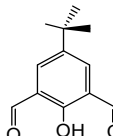
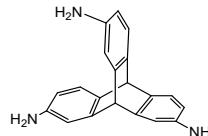
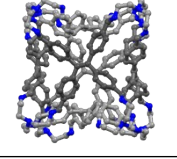
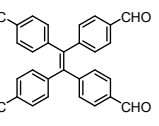
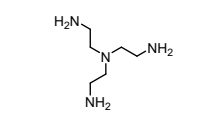
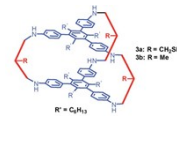
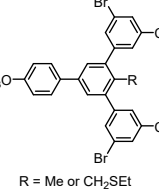
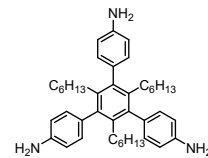
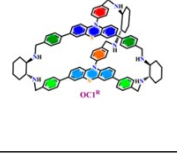
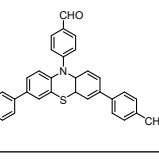
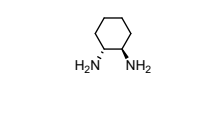
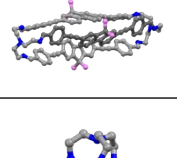
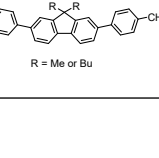
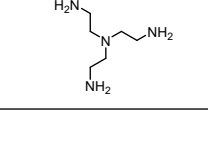
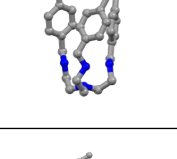
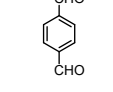
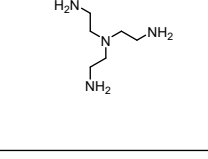
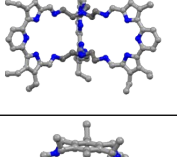
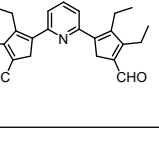
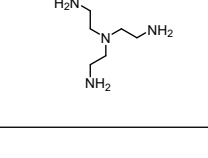
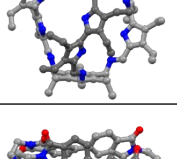
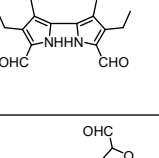
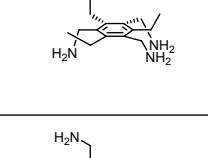
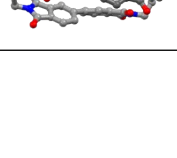
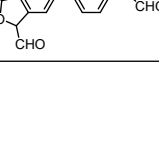
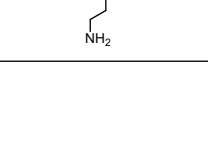
Table S1. A summary of reported porous organic cages.

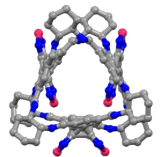
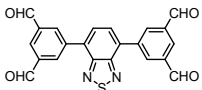
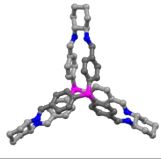
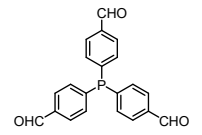
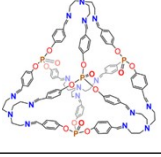
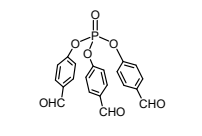
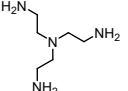
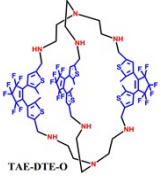
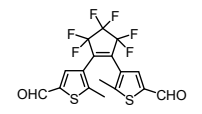
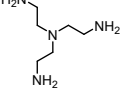
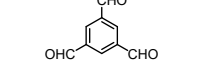
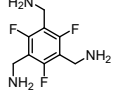
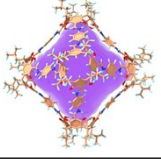
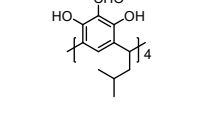
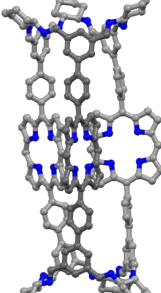
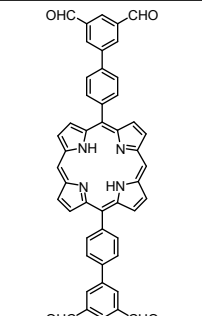
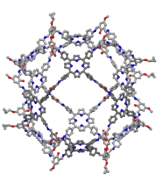
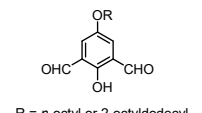
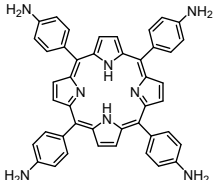
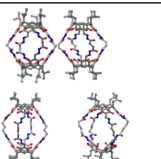
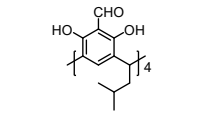
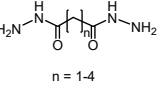
C (grey), O (red), N (blue), Cl (green), B (orange), F (yellow), P (purple), S (rose red).

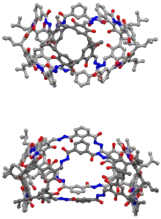
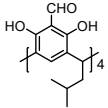
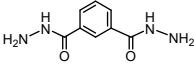
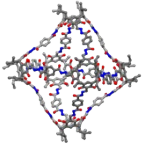
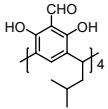
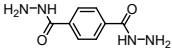
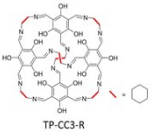
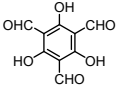
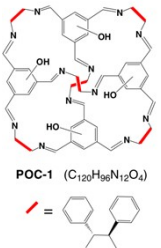
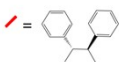
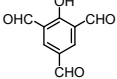
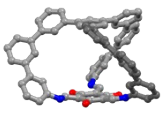
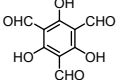
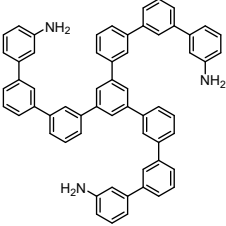
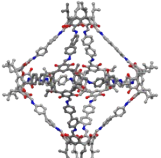
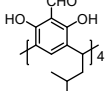
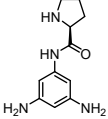
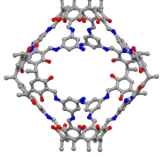
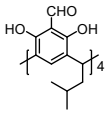
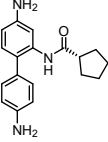
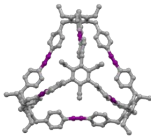
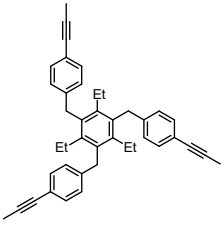
Name	Structure	Building block 1	Building block 2	SA _{BET} [m ² g ⁻¹]	Reference
The dehydration-condensation reaction of boric acid and alcohol.					
1				_a	1
homo-C				_a	2
Cage 3a & 3b 3a R = H 3b R = ethyl				3758	3
4	 4 a R ¹ = <i>n</i> -butyl, R ² = H b R ¹ = <i>n</i> -butyl, R ² = <i>n</i> -butyl		 R = H or <i>n</i> -butyl	_a	4
6-mer				_a	5
The condensation reaction of amine and aldehyde compounds.					
				_a	6
3a				744	7
[4+6] cage 3				~700	8

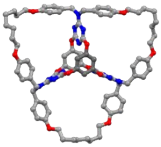
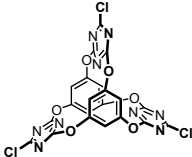
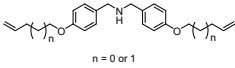
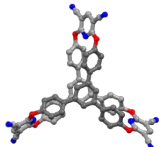
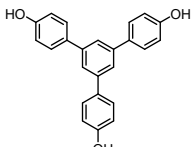
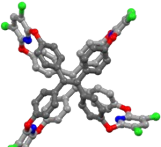
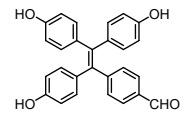
1a				$\text{-}a$	9
Cage 4				$\text{-}a$	10
CC1				$\text{-}a$	11
CC3				624	11
CC5				1333	12
CC6				99	13
CC9				501	14
CC10				460	14
CC14-R				$\text{-}a$	15
CC15-R				$\text{-}a$	15

CC16- <i>R</i>				1023	16
CC17- <i>R</i>				423	16
[8+12] Cage				1752	17
NC1				802	18
cuboctahedral imine cage 3				<i>a</i>	19
PB-1				1370	20
PB-2				935	20
Trazine-based cage 1				1181	21
6				<i>a</i>	22

Cage compound 4				--_a	23
Salicylbisimine cage compound 4				1377	24
TPE-(6M)-1				--_a	25
Cage 3a-CS				--_a	26
OC1^R				--_a	27
Cage 2-OL				--_a	28
COC-PA				12.8	29
1-CC				279	30
2-CC				111	30
NKPOC-1				--_a	31

MTC1				$\sim a$	32
PPOC				$\sim a$	33
[4+4] imine OMC				<10	34
TAE-DTE				$\sim a$	35
FC-1				536	36
CPOC-301				1962	37
PTC-1(2H)				$\sim a$	38
Cage 3- Chem				$\sim a$	39
HPOC-101 HPOC-102 HPOC-103 HPOC-104				373 563 523 552	40

HPOC-201 HPOC-301				218	40
HPOC-401				474	40
TP-CC3-R				<i>a</i>	41
POC-1	 POC-1 (C ₁₂₀ H ₁₅₀ N ₁₂ O ₄) 			<i>a</i>	42
DC-1				<i>a</i>	43
CPOC-302-Pro				648	44
CPOC-401-Pro				861	44
Metathesis reaction					
Ta				<i>a</i>	45

5-JACS			 $n = 0 \text{ or } 1$	26	46
S_NAr reaction					
1-OL				– ^a	47
TOC				8	48

^aNot reported.

References

1. K. Kataoka, T. D. James and Y. Kubo, *J. Am. Chem. Soc.*, 2007, **129**, 15126-15127.
2. H. Takahagi, S. Fujibe and N. Iwasawa, *Chem. - Eur. J.*, 2009, **15**, 13327-13330.
3. G. Zhang, O. Presly, F. White, I. M. Oppel and M. Mastalerz, *Angew. Chem., Int. Ed.*, 2014, **53**, 1516-1520.
4. S. Klotzbach, T. Scherpf and F. Beuerle, *Chem. Commun.*, 2014, **50**, 12454-12457.
5. K. Ono, K. Johmoto, N. Yasuda, H. Uekusa, S. Fujii, M. Kiguchi and N. Iwasawa, *J. Am. Chem. Soc.*, 2015, **137**, 7015-7018.
6. M. Mastalerz, *Chem. Commun.*, 2008, 4756-4758.
7. M. W. Schneider, I. M. Oppel and M. Mastalerz, *Chem. - Eur. J.*, 2012, **18**, 4156-4160.
8. M. W. Schneider, I. M. Oppel, H. Ott, L. G. Lechner, H. J. S. Hauswald, R. Stoll and M. Mastalerz, *Chem. - Eur. J.*, 2012, **18**, 836-847.
9. D. Xu and R. Warmuth, *J. Am. Chem. Soc.*, 2008, **130**, 7520-7521.
10. K. Acharyya and P. S. Mukherjee, *Chem. Commun.*, 2014, **50**, 15788-15791.
11. T. Tozawa, J. T. Jones, S. I. Swamy, S. Jiang, D. J. Adams, S. Shakespeare, R. Clowes, D. Bradshaw, T. Hasell and S. Y. Chong, *Nat. Mater.*, 2009, **8**, 973-978.
12. J. T. Jones, T. Hasell, X. Wu, J. Bacsá, K. E. Jelfs, M. Schmidtman, S. Y. Chong, D. J. Adams, A. Trewin and F. Schiffman, *Nature*, 2011, **474**, 367-371.
13. S. Jiang, J. Bacsá, X. Wu, J. T. Jones, R. Dawson, A. Trewin, D. J. Adams and A. I. Cooper, *Chem. Commun.*, 2011, **47**, 8919-8921.
14. M. J. Bojdys, M. E. Briggs, J. T. Jones, D. J. Adams, S. Y. Chong, M. Schmidtman and A. I. Cooper, *J. Am. Chem. Soc.*, 2011, **133**, 16566-16571.
15. A. G. Slater, P. S. Reiss, A. Pulido, M. A. Little, D. L. Holden, L. Chen, S. Y. Chong, B. M. Alston, R. Clowes and M. Haranczyk, *ACS Cent. Sci.*, 2017, **3**, 734-742.
16. P. S. Reiss, M. A. Little, V. Santolini, S. Y. Chong, T. Hasell, K. E. Jelfs, M. E. Briggs and A. I. Cooper, *Chem. - Eur. J.*, 2016, **22**, 16547-16553.

17. B. Teng, M. A. Little, T. Hasell, S. Y. Chong, K. E. Jelfs, R. Clowes, M. E. Briggs and A. I. Cooper, *Cryst. Growth Des.*, 2019, **19**, 3647-3651.
18. L. Zhang, L. Xiang, C. Hang, W. Liu, W. Huang and Y. Pan, *Angew. Chem.*, 2017, **129**, 7895-7899.
19. P. Skowronek, B. Warżajtis, U. Rychlewska and J. Gawroński, *Chem. Commun.*, 2013, **49**, 2524-2526.
20. S. Hong, M. R. Rohman, J. Jia, Y. Kim, D. Moon, Y. Kim, Y. H. Ko, E. Lee and K. Kim, *Angew. Chem., Int. Ed.*, 2015, **54**, 13241-13244.
21. H. Ding, Y. Yang, B. Li, F. Pan, G. Zhu, M. Zeller, D. Yuan and C. Wang, *Chem. Commun.*, 2015, **51**, 1976-1979.
22. Y. Jin, B. A. Voss, R. D. Noble and W. Zhang, *Angew. Chem.*, 2010, **122**, 6492-6495.
23. Y. Jin, B. A. Voss, A. Jin, H. Long, R. D. Noble and W. Zhang, *J. Am. Chem. Soc.*, 2011, **133**, 6650-6658.
24. M. Mastalerz, M. W. Schneider, I. M. Oppel and O. Presly, *Angew. Chem., Int. Ed.*, 2011, **50**, 1046-1051.
25. H. Qu, Y. Wang, Z. Li, X. Wang, H. Fang, Z. Tian and X. Cao, *J. Am. Chem. Soc.*, 2017, **139**, 18142-18145.
26. L. Qiu, R. McCaffrey, Y. Jin, Y. Gong, Y. Hu, H. Sun, W. Park and W. Zhang, *Chem. Sci.*, 2018, **9**, 676-680.
27. B. Mondal and P. S. Mukherjee, *J. Am. Chem. Soc.*, 2018, **140**, 12592-12601.
28. N. Cao, Y. Wang, X. Zheng, T. Jiao and H. Li, *Org. Lett.*, 2018, **20**, 7447-7450.
29. R. K. Gajula, R. Kishor and M. J. Prakash, *ChemistrySelect*, 2019, **4**, 12547-12555.
30. F. Wang, E. Sikma, Z. Duan, T. Sarma, C. Lei, Z. Zhang, S. M. Humphrey and J. L. Sessler, *Chem. Commun.*, 2019, **55**, 6185-6188.
31. Z. Wang, N. Sikdar, S.-Q. Wang, X. Li, M. Yu, X.-H. Bu, Z. Chang, X. Zou, Y. Chen and P. Cheng, *J. Am. Chem. Soc.*, 2019, **141**, 9408-9414.
32. N. Sun, C. Wang, H. Wang, L. Yang, P. Jin, W. Zhang and J. Jiang, *Angew. Chem.*, 2019, **131**, 18179-18184.
33. Z. Wang, C. B. Reddy, X. Zhou, J. J. Ibrahim and Y. Yang, *ACS Appl. Mater. Interfaces*, 2020, **12**, 53141-53149.
34. G.-F. Feng, J. Geng, F.-D. Feng and W. Huang, *Sci. Rep.*, 2020, **10**, 4712.
35. A. Singh, P. Verma, D. Samanta, A. Dey, J. Dey and T. K. Maji, *J. Mater. Chem. A*, 2021, **9**, 5780-5786.
36. T. Kunde, E. Nieland, H. V. Schröder, C. A. Schalley and B. M. Schmidt, *Chem. Commun.*, 2020, **56**, 4761-4764.
37. K. Su, W. Wang, S. Du, C. Ji and D. Yuan, *Nat. Commun.*, 2021, **12**, 3703.
38. C. Liu, K. Liu, C. Wang, H. Liu, H. Wang, H. Su, X. Li, B. Chen and J. Jiang, *Nat. Commun.*, 2020, **11**, 1047.
39. J. Koo, I. Kim, Y. Kim, D. Cho, I.-C. Hwang, R. D. Mukhopadhyay, H. Song, Y. H. Ko, A. Dhamija and H. Lee, *Chem*, 2020, **6**, 3374-3384.
40. M. Yang, F. Qiu, E.-S. M. El-Sayed, W. Wang, S. Du, K. Su and D. Yuan, *Chem. Sci.*, 2021, **12**, 13307-13315.
41. C. Dai, H.-L. Qian and X.-P. Yan, *J. Hazard. Mater.*, 2021, **416**, 125860.
42. H.-X. Li, T.-P. Xie, K.-Q. Yan, S.-M. Xie, B.-J. Wang, J.-H. Zhang and L.-M. Yuan, *Microchim.*

Acta, 2020, **187**, 269.

43. X. Liu, Z. Shi, M. Xie, J. Xu, Z. Zhou, S. Jung, G. Cui, Y. Zuo, T. Li and C. Yu, *Angew. Chem., Int. Ed.*, 2021, **60**, 15080-15086.
44. N. Xu, K. Su, E.-S. M. El-Sayed, Z. Ju and D. Yuan, *Chem. Sci.*, 2022, **13**, 3582-3588.
45. S. Lee, A. Yang, T. P. Money Penny and J. S. Moore, *J. Am. Chem. Soc.*, 2016, **138**, 2182-2185.
46. Q.-Q. Wang, N. Luo, X.-D. Wang, Y.-F. Ao, Y.-F. Chen, J.-M. Liu, C.-Y. Su, D.-X. Wang and M.-X. Wang, *J. Am. Chem. Soc.*, 2017, **139**, 635-638.
47. Z. Wang, Y. Luo, T.-L. Zhai, H. Ma, J.-J. Chen, Y. Shu and C. Zhang, *Org. Lett.*, 2016, **18**, 4574-4577.
48. Z. Wang, H. Ma, T. L. Zhai, G. Cheng, Q. Xu, J. M. Liu, J. Yang, Q. M. Zhang, Q. P. Zhang and Y. S. Zheng, *Adv. Sci.*, 2018, **5**, 1800141.