Supplementary Information

Biomimetic Silicon Nitride Skeleton with Oriented Microstructures in Epoxy Resin for High Thermal Conductivity and Low Thermal Expansion

Xu Hao[1], Song-song Xu[1], Xiao-Nan Zhou[1], Jia-Xin Li[1], Han Jia[1], Zhi-Lei Wei[1], Qiang Zhi[2], Jian-Feng Yang[1], Bo Wang[1*], Kozo Ishizaki[3]

[1]State Key Laboratory of Porous Metal Materials, Xi'an Jiaotong University, Xi'an, 710049, China

[2]School of Materials Engineering, Xihang University, Xi'an, 710077, China

[3]Department of Mechanical Engineering, Nagaoka University of Technology, Nagaoka, 940-2188, Japan

[*]Corresponding author. E-mail: wangbo_1@mail.xjtu.edu.cn (B. Wang)

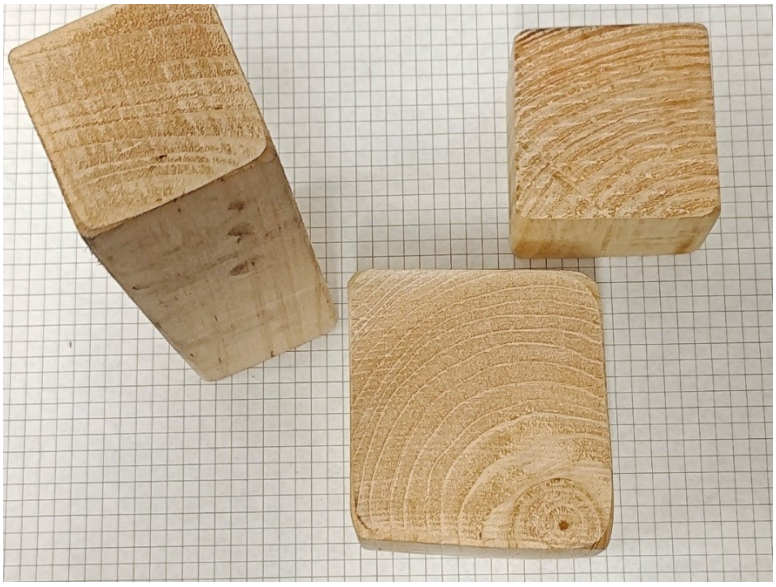

Fig. S1 Digital photos of spruce

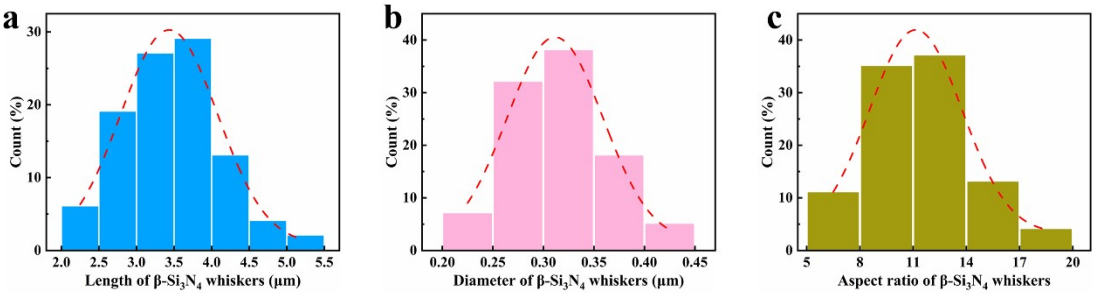

Fig. S2 (a) Length; (b) diameter and (c) aspect ratio of β-Si_3N_4 whisker measured from SEM images.

Table S1. Comparison of thermal conductivity data with other representative polymer composites form the literature.

Sample	Filler content (Vol.%)	TC ($W \cdot m^{-1} \cdot K^{-1}$)	Ref
BN-SiC/EP	40	5.77	[1]
40-SiC/EP	40	3.15	[2]
SiC/EP	40	1.87	
28-SiC/EP	28	1.23	[3]
36-Al_2O_3/EP	36	3.17	[4]
43-Al_2O_3/EP	43	4.36	[5]
Al_2O_3/EP	25	6.71	[6]
25-Al_2O_3/EP	25	3.01	
AlN-Fe_3O_4/EP	41	3.14	[7]
45-Si_3N_4/EP	45	1.75	[8]
35-Si_3N_4/EP	35	1.55	
40-Si_3N_4/EP	40	1.4	[9]
23-Si_3N_4/EP	23	3.8	
16-Si_3N_4/EP	16	1.8	
22-Si_3N_4/EP	22	3.89	
15-BNNs/EP	15	5.19	[10]
9-BNNs/EP	9	2.85	[11]
13-BNNs/EP	13	5.05	[12]
10-BNNs/EP	10	3.13	[13]
4-BNNs/EP	4	1.56	
G/MLG/EP	10	5.1	[14]
GNP/EP	25	6.44	[15]
Al particle/EP	48	1.47	[16]
AgNW/EP	4	0.9	[17]
Bio-Si_3N_4/EP	38	8.26	This work

Table S2. Material properties used in the finite element simulations.

Properties	**Si_3N_4**	**EP**
Thermal conductivity ($W \cdot m^{-1} \cdot K^{-1}$)	COMSOL Multiphysics Material Library (β-Si_3N_4, c-axis)	0.18
Density ($g \cdot cm^{-3}$)		1.8
Heat capacity ($J \cdot kg^{-1} \cdot K^{-1}$)		1.4
Young's modulus (GPa)		2.5
Poisson's ratio		0.38
Coefficient of thermal expansion (K^{-1})		74.3×10^{-6}

Table S3. The average displacement of each surface of the models.

Model	Direction	Surface	Displacement (μm)	Size (μm)	Linear expansivity (%)
A single unit	x	left	-0.0016098	22.0	0.01465
		right	0.0016138		
	y	front	-0.00090103	17.0	0.01062
		back	0.00090383		
	z	bottom	-0.0010804	19.5	0.01106
		top	0.0010758		
Multiple units	x	left	-0.015915	200	0.01434
		right	0.015919		
	y	front	-0.0095787	200	0.00861
		back	0.0095788		
	z	bottom	-0.018078	200	0.01629
		top	0.01808		

References

1. K. Kim, H. Ju and J. Kim, Compos. Sci. Technol., 2016, 123, 99–105.
2. K. Kim, M. Kim, J. Kim and J. Kim, Ceram. Int., 2015, 41, 12280–12287.
3. A.-j. Ma, H. Li, W. Chen and Y. Hou, Polym.-Plast. Technol. Eng., 2013, 52, 295–299.
4. Y. Hu, G. Du and N. Chen, Compos. Sci. Technol., 2016, 124, 36–43.
5. L.-C. Hao, Z.-X. Li, F. Sun, K. Ding, X.-N. Zhou, Z.-X. Song, Z.-Q. Shi, J.-F. Yang and B. Wang, Compos. Part A Appl. Sci. Manuf., 2019, 127, 105648.
6. G. Pan, Y. Yao, X. Zeng, J. Sun, J. Hu, R. Sun, J.-B. Xu and C.-P. Wong, ACS Appl. Mater. Interfaces, 2017, 9, 33001–33010.
7. K. Kim and J. Kim, Compos. Part B Eng., 2016, 93, 67–74.
8. H. He, R. Fu, Y. Han, Y. Shen and X. Song, J. Mater. Sci., 2007, 42, 6749–6754.
9. L. Yin, X. Zhou, J. Yu, H. Wang and C. Ran, Compos. Part A Appl. Sci. Manuf., 2016, 90, 626–632.
10. Z. Tian, J. Sun, S. Wang, X. Zeng, S. Zhou, S. Bai, N. Zhao and C.-P. Wong, J. Mater. Chem. A, 2018, 6, 17540–17547.
11. X. Zeng, Y. Yao, Z. Gong, F. Wang, R. Sun, J. Xu and C.-P. Wong, Small, 2015, 11, 6205–6213.
12. J. Hu, Y. Huang, Y. Yao, G. Pan, J. Sun, X. Zeng, R. Sun, J.-B. Xu, B. Song and C.-P. Wong, ACS Appl. Mater. Interfaces, 2017, 9, 13544–13553.
13. J. Chen, X. Huang, Y. Zhu and P. Jiang, Adv. Funct. Mater., 2016, 27, 1604754.
14. K. M. F. Shahil and A. A. Balandin, Nano Lett., 2012, 12, 861–867.
15. A. Yu, P. Ramesh, M. E. Itkis, E. Bekyarova and R. C. Haddon, J. Phys. Chem. C, 2007, 111, 7565–7569.
16. W. Zhou and D. Yu, J. Appl. Polym. Sci., 2010, 118, 3156–3166.
17. Y. Feng, X. Li, X. Zhao, Y. Ye, X. Zhou, H. Liu, C. Liu and X. Xie, ACS Appl. Mater. Interfaces, 2018, 10, 21628–21641.