Supplementary Information

for

Dense and superhydrophobic biopolymer-coated large tablet produced with energy efficient UV-curing for controlled-release fertilizer

Mingchuan Yang,[a] Shan Li,[a] Shugang Zhang,[*a] Bin Gao,[b] Zhaohui Tong,[c] Dongdong Cheng,[a] Denglun Chen,[a] Ruya Huang[a] and Yuechao Yang[*ad]

[a]National Engineering Research Center for Efficient Utilization of Soil and Fertilizer Resources, College of Resources and Environment, Shandong Agricultural University, Tai'an, Shandong 271018, China.

[b]Agricultural and Biological Engineering, Institute of Food and Agricultural Sciences (IFAS), University of Florida, Gainesville, FL 32611, USA

[c]School of Chemical & Biomolecular Engineering, Renewable Bioproducts Institute, Georgia Institute of Technology, Atlanta, Ga 30332, USA.

[d]Department of Soil and Water Science, Tropical Research and Education Center, IFAS, University of Florida, Homestead, FL 33031, USA.

Co-corresponding authors:

[*]Yuechao Yang, Tel: +86-538-824 2215, E-mail: yangyuechao2010@163.com.

[*]Shugang Zhang, E-mail: shugangzhang2014@163.com.

Experimental Section

The UV-curable Biopolymer-Coated Large Tablet Fertilizers (BCFs) were fabricated as follows: Firstly, TPO-L (0.5% wt.) was added to BPUA and ultrasonically dispersed for 20 min. Then, the mixed system was sprayed on the LTFs surface through a spray gun, and cured with a UV LED lamp at room temperature. The BCFs were obtained by repeating the above process following the design (coating rates were 2%, 3% and 4%, respectively). The Hydrophobic BCFs (HBCFs) were fabricated as follows: Firstly, PDMS (5% wt.) was mixed with BPUA, then the mixture was heated to 50°C and stirred continuously for 15 min. After that, TPO-L (0.5% wt.) were added into the mixture and ultrasonically disperse it for 20 min. Then, the mixed system was sprayed on the LTFs surface through a spray gun, and cured with a UV LED lamp at room temperature. The HBCFs were obtained by repeating the above process following the design (coating rates were 2%, 3% and 4%, respectively).

Description

Fig. S1†. The flow chart of LTF preparation process and appearance of prilled urea and LTF;

Fig. S2†. The ideal grafting mode for TNS and the schematic diagram of thiol-ene click reaction between BPUA and TNS;

Fig. S3†. UV-DSC results of BPUA polymerization;

Fig. S4†. DTG analysis of three different coatings;

Fig. S5†. Surface energy of coating materials;

Fig. S6†. AFM roughness analysis of coatings;

Fig. S7†. Micro structural aspects and micro mechanical properties of coatings measured by AFM;

Table S1†. Physical properties of prilled urea and LTF;

Table S2†. Summary of the CRFs reported in literatures;

Table S3†. Comparison of raw material costs and electrical energy costs for different types of CRFs;

Video 1†. Demonstration of the preparation of fertilizers coated in the conventional heat-curing process.

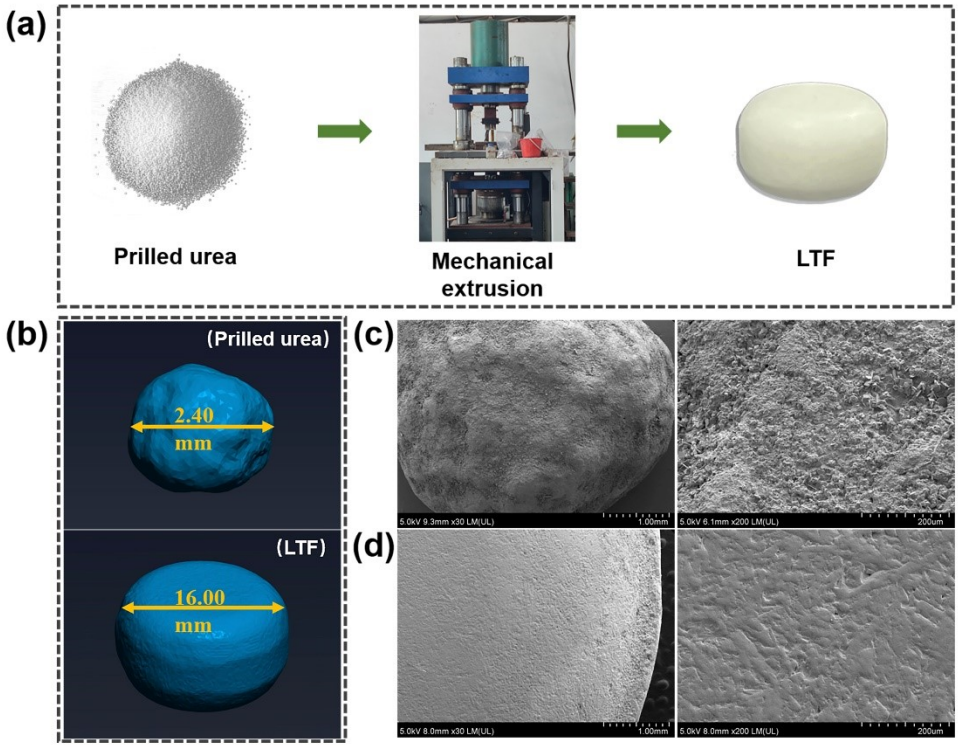

Fig. S1†. (a) The flow chart of LTF preparation process. Volume, surface areas and surface morphology from (b) three-dimensional scanning technology and SEM images of (c) prilled urea and (d) LTF.

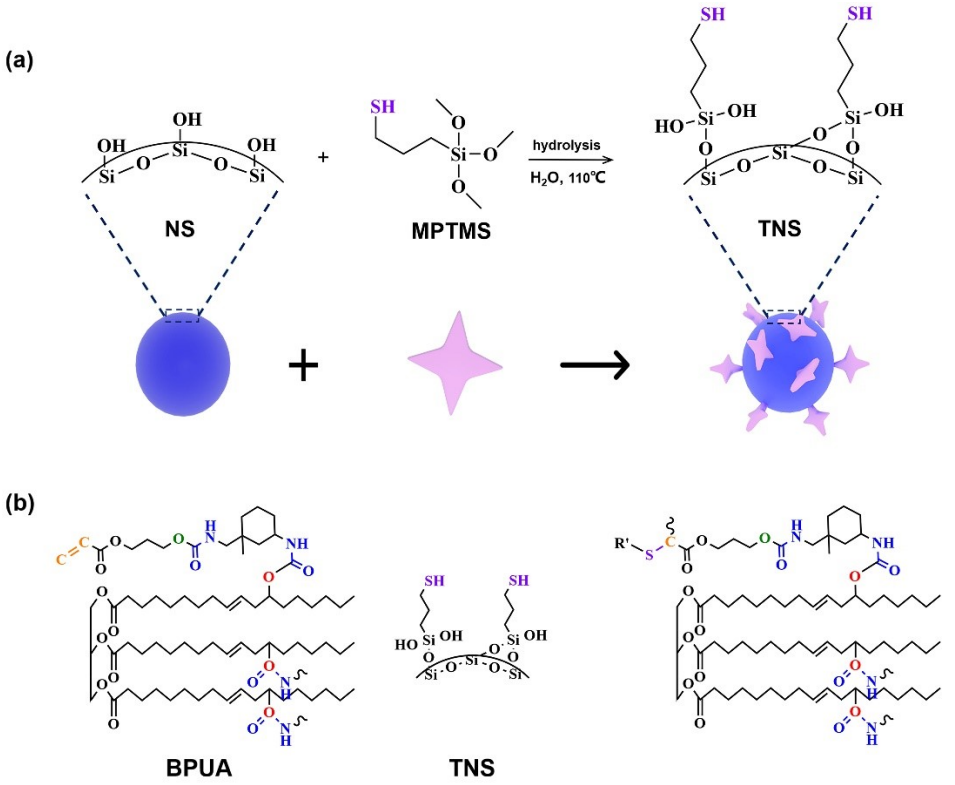

Fig. S2†. (a) the ideal grafting mode for TNS and (b) the schematic diagram of thiol-ene click reaction between BPUA and TNS.

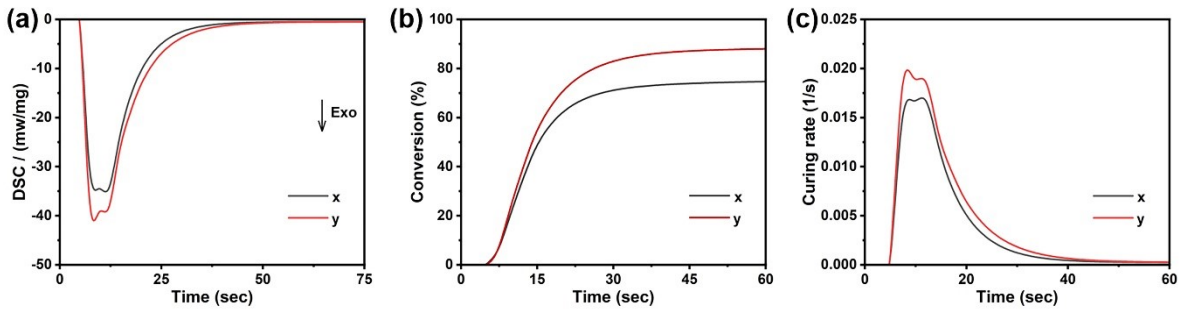

Fig. S3†. Effects of (*x*) no adding and (*y*) adding TNS on the (a) DSC, (b) conversion, and (c) curing rate of BPUA polymerization by UV-DSC.

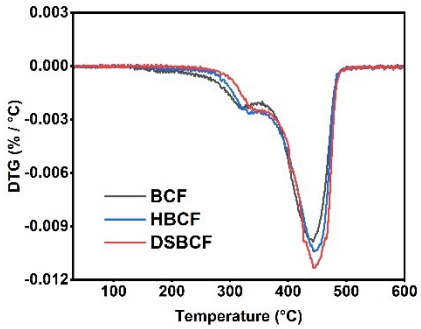

Fig. S4†. DTG analysis curves of BCF, HBCF and DSBCF coatings.

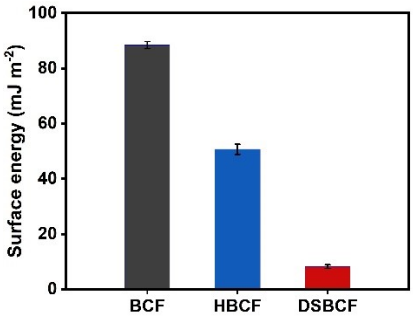

Fig. S5†. Surface energy of three different coating materials.

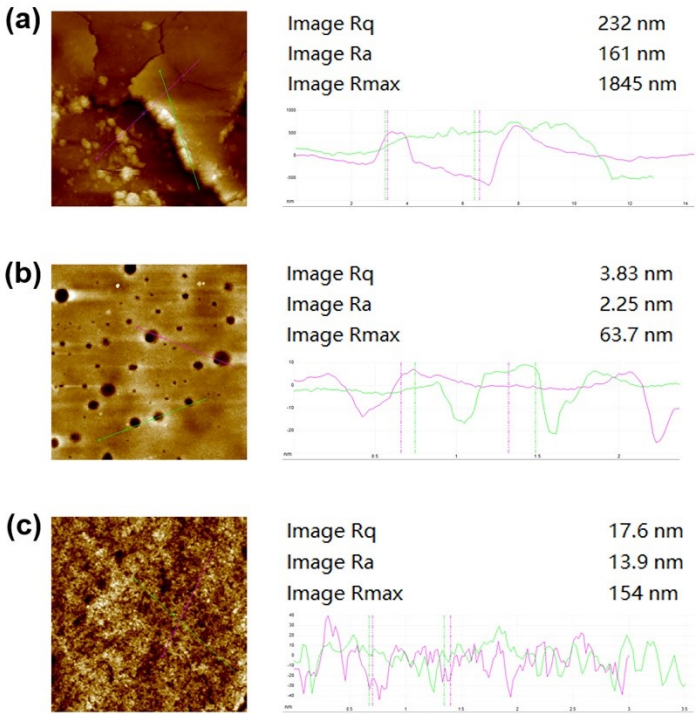

Fig. S6†. AFM roughness analysis of (a) BCF, (b) HBCF and (c) DSBCF coatings.

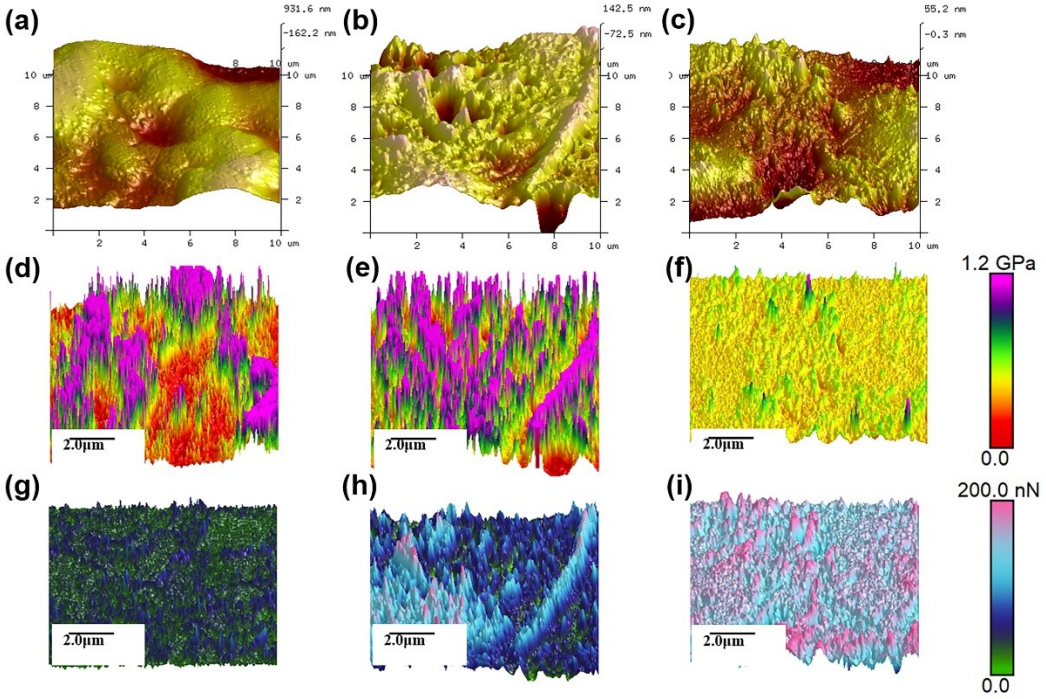

Fig. S7†. Micro structural aspects and micro mechanical properties measured by AFM. (a, b, c) height images, (d, e, f) elastic modulus images, (g. h. i) adhesion images of BCF, HBCF and DSBCF coating, respectively.

Table S1†. Physical Properties of prilled urea and LTF.

Fertilizer	Mass (g)	Surface area (mm^2)	Specific surface area ($mm^2\ g^{-1}$)	Average crushing strength (N)
Prilled urea	0.03 ± 0.01	49.33 ± 3.47	1644.33	40.6
LTF	2.00 ± 0.05	673.64 ± 9.02	336.82	396.7

Table S2†. Summary of the CRFs reported in literatures.

Sample	Coating contents [a] (%)	N release longevity (days)	Ref.
EPCU3	3.5 / 5.5 / 7.5	10 / 28 / 60	[1]
MLTCRU	6 / 8	43 / 136	[2]
DBPCF	3 / 5 / 7	13 / 28 / 38	[3]
SBPF	3 / 5 / 7	25 / 42 / 66	[4]
SBSF	3 / 5 / 7	28 / 69 / 104	[5]
SEWS-CRF	3	32	[6]
SBCU	3	28	[7]
DSBCF	2 / 3 / 4	42 / 77 / 119	Our work

Note: [a] Coating contents refers to the weight of coating materials as a percentage by weight of the fertilizer core.

Table S3†. Comparison of raw material costs and electrical energy costs for different types of CRFs.

Fertilizer types	Electrical energy cost [a]						Raw material cost [b]					
	PCRF		SBPCF20 [8]		DSBCF		PCRF		SBPCF20		DSBCF	
	Electric power /(kW h^{-1})	Power cost /($ ton^{-1})	Electric power /kW h^{-1}	Power cost /($ ton^{-1})	Electric power /kW h^{-1}	Power cost /($ ton^{-1})	Usage /(ton)	Price /($ ton^{-1})	Usage /(ton)	Price /($ ton^{-1})	Usage /(ton)	Price /($ ton^{-1})
Heat-curing	1.5	33.37	1.5	33.37	-	-	-	-	-	-	-	-
UV-curing	-	-	-	-	0.085	1.387	-	-	-	-	-	-
Urea	-	-	-	-	-	-	0.96	440	0.96	440	0.96	440
Polyol feedstock	-	-	-	-	-	-	0.035	1780	0.0075	74	0.009	1480
Liquefying agent	-	-	-	-	-	-	-	-	0.015	1185	-	-
Isocyanate	-	-	-	-	-	-	0.035	3700	0.046	3700	0.005	3700
Acrylate	-	-	-	-	-	-	-	-	-	-	0.0135	6665
PDMS	-	-	-	-	-	-	-	-	0.0014	5925	0.0015	5925
Nano-silica	-	-	-	-	-	-	-	-	0.00035	8890	0.0003	8890
Other additives	-	-	-	-	-	-	-	-	-	-	0.0012	5930
Total cost	-	-	-	-	-	-	647.57 $ ton^{-1}		622.3 $ ton^{-1}		562.87 $ ton^{-1}	

Notes: [a] The equipment used for heat-curing was the BY-600 granule surface treatment equipment from Changzhou Junnuo Drying Equipment Co., Ltd. The equipment used for UV-curing is the UV light (365 nm, 80 mw cm^{-2}, Zhonglian UV lamp). At the laboratory scale, the CRF per ton produced by heat-curing and UV-curing processes is 1.5 h and 1.11 h, respectively. Based on approximately $0.1483 per kW h^{-1} of electricity; [b] Compare three types of fertilizers with a controlled release period of 60 days, i.e. 7% coating content for petroleum-based polyurethane coated controlled-release fertilizers (PCRF) and previously reported superhydrophobic bio-based polyurethane coated controlled-release fertilizers (SBPCF) and 3% coating content for DSBCF.

Video 1†. This video showed the demonstration of the preparation of fertilizers coated in the conventional heat-curing process.

References

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