Electronic Supplementary Material (ESI) for Sustainable Energy & Fuels.

Direct Laser Writing of Pure Lignin on Carbon Cloth for Highly Flexible Supercapacitors with Enhanced Areal Capacitance

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Supporting Information

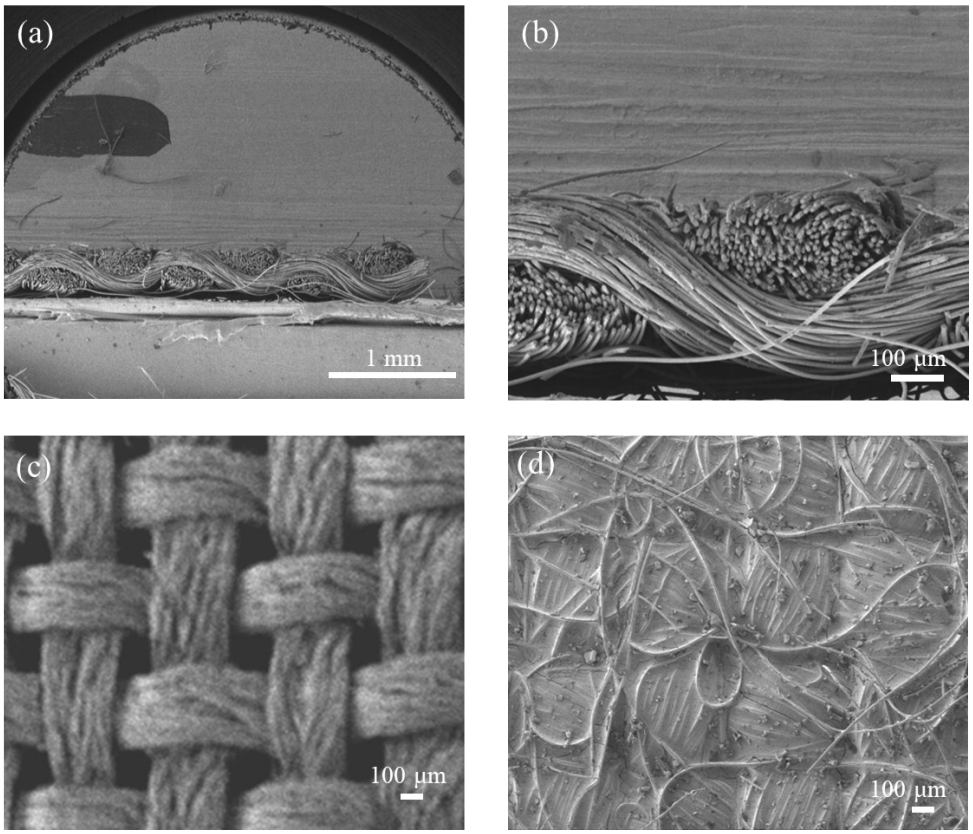

Figure S1. SEM images of (a, b) side view of original carbon cloth; (c) top view of original carbon cloth; (d) top view of carbon cloth after covering by molten lignin.

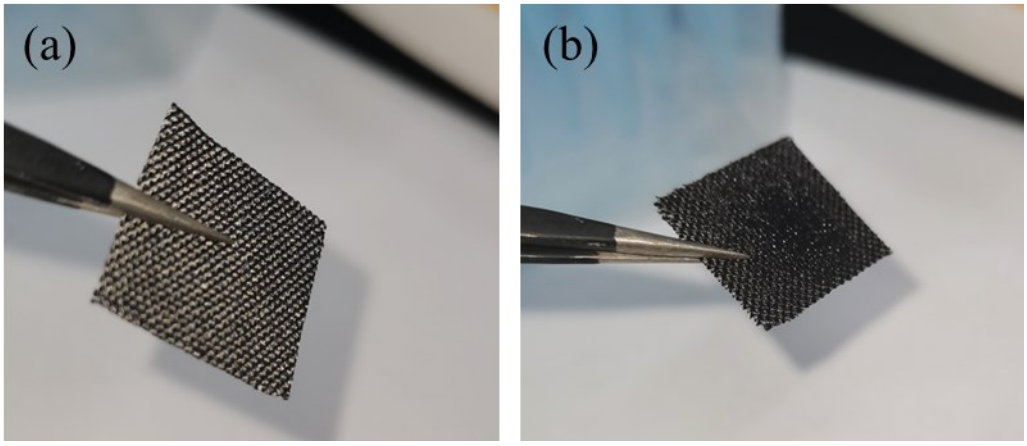

Figure S2. Photographs of (a) original carbon cloth; and (b) carbon cloth covering with melted lignin.

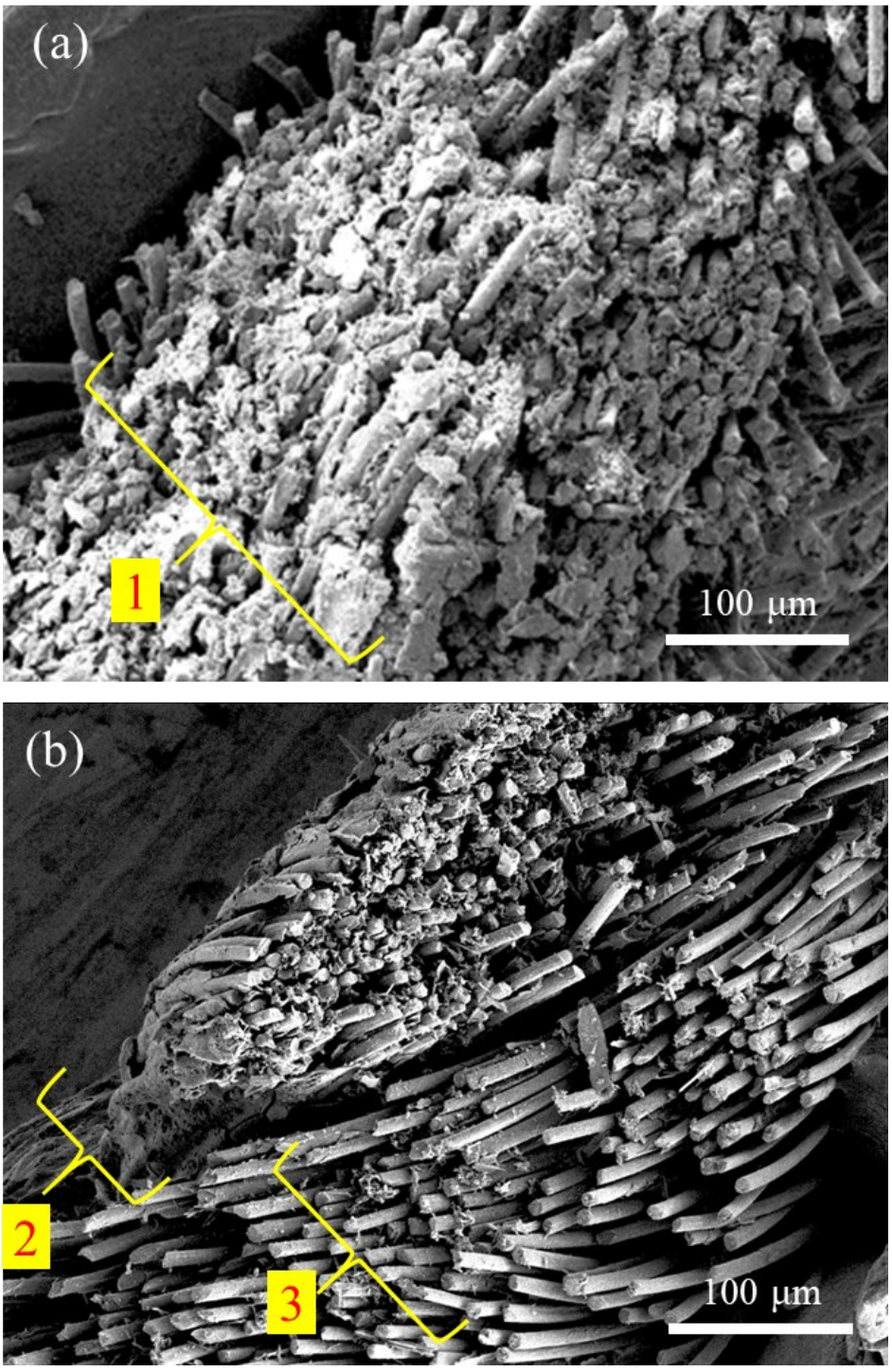

Fig.S3. Cross-section SEM images of (a) lignin melting on carbon cloth (it can be seen from region 1 that lignin melted and penetrated to the whole carbon cloth through the holes between carbon fibers); (b) LCE40 (it can be seen from region 2 that the lignin bonded on carbon cloth upon DLW and cannot be washed off, while region 3 stay untouched under DLW and the lignin was washed off).

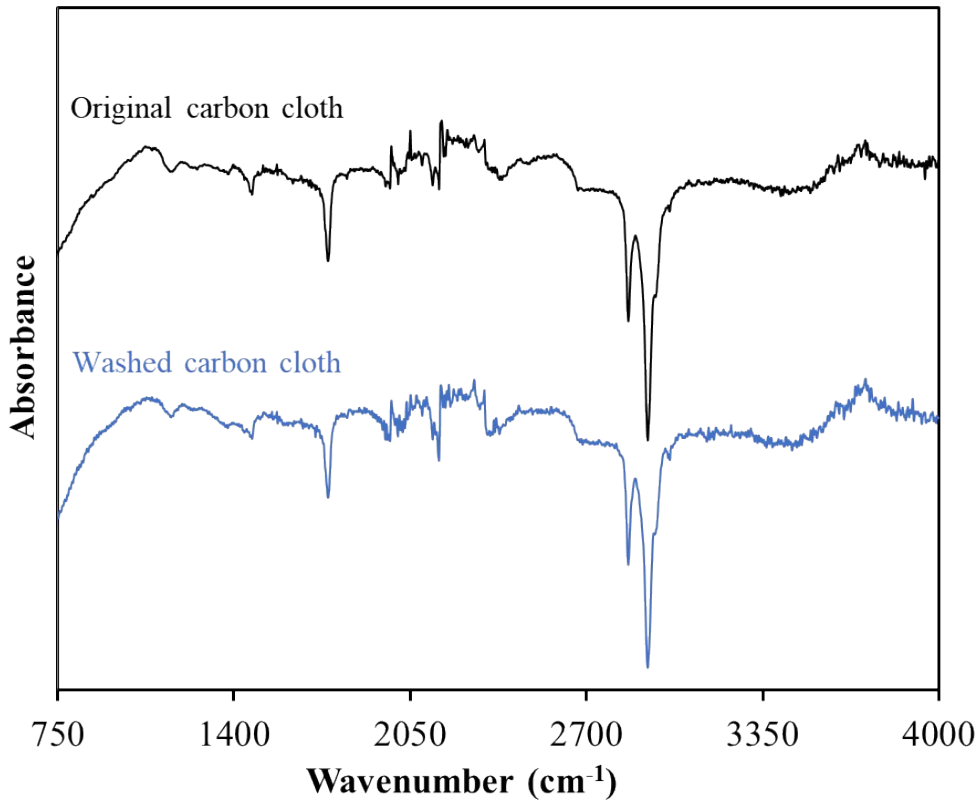

Figure S4. FTIR spectra of original carbon cloth and carbon cloth after melting of lignin and washing by 2M KOH solution.

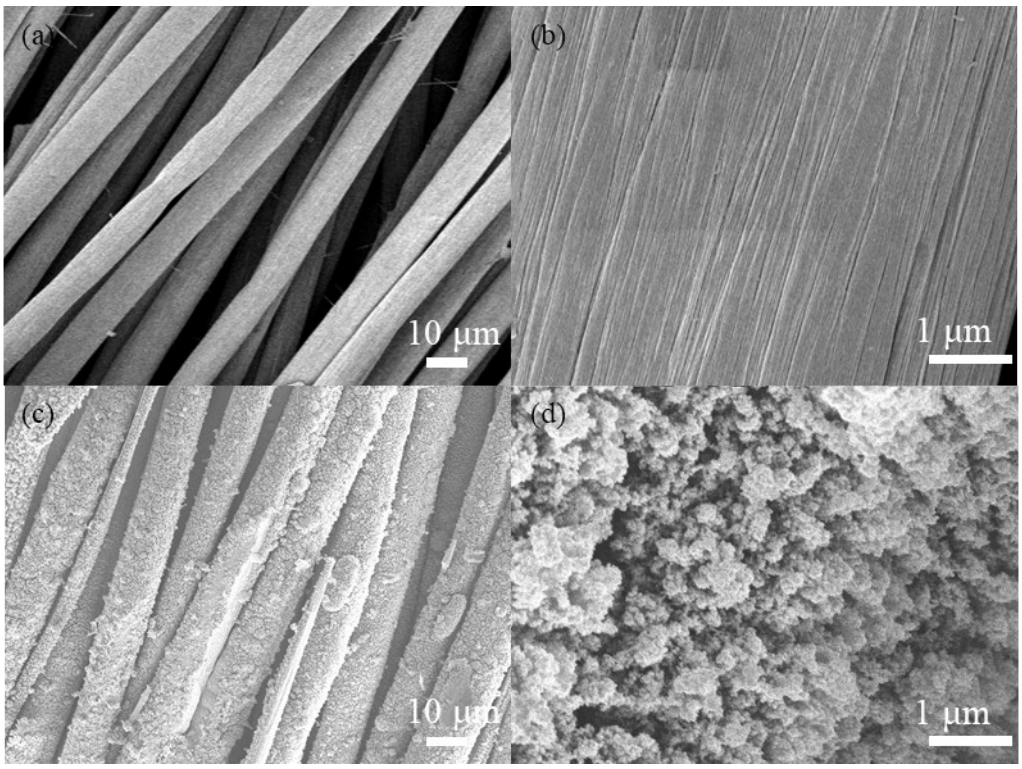

Figure S5. SEM images of carbon cloth before (a, b) and after (c, d) DLW under 20% laser power

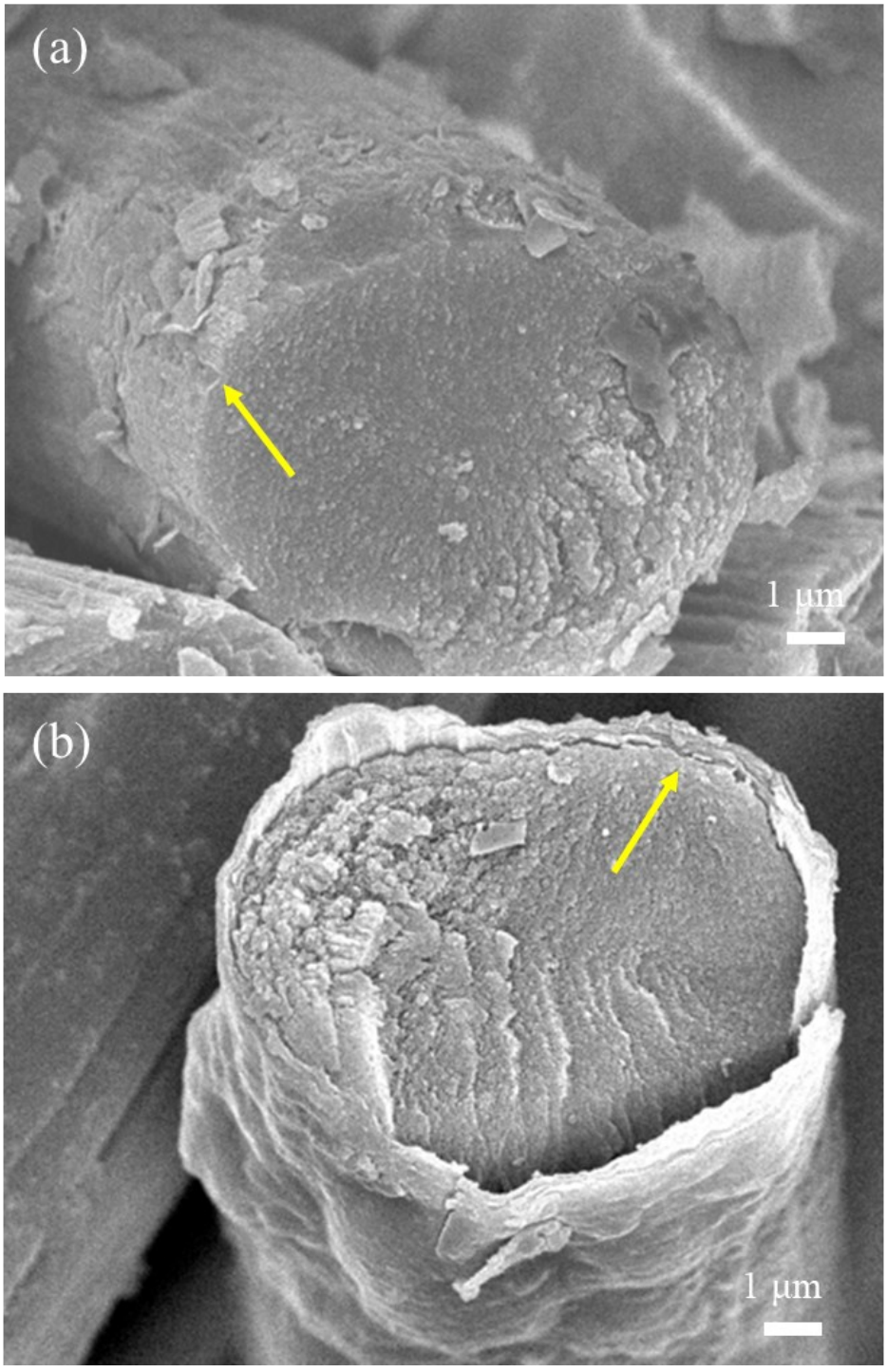

Fig.S6. The interfaces (LCE40) between carbon fiber and lignin-derived carbon (The carbon chips found on sample are caused by carbon fracture from scissors cutting).

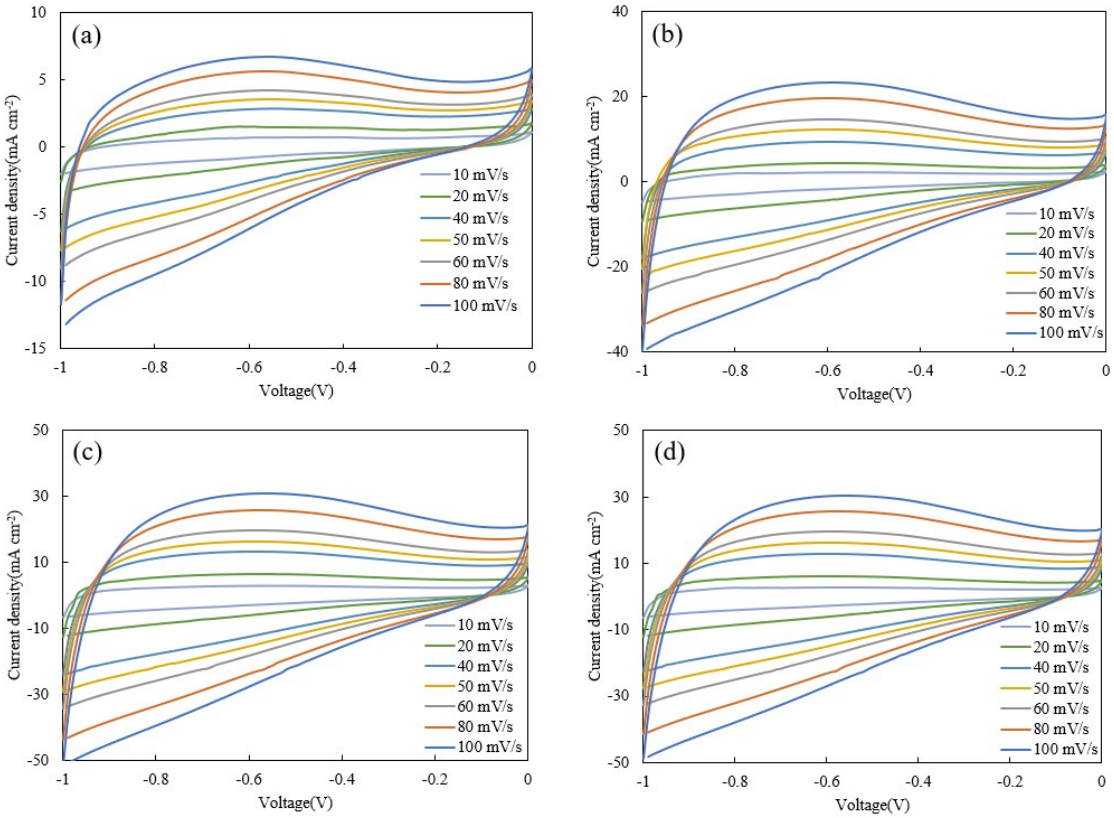

Figure S7. All plots are based on data from three-electrode system. CV curves at 10 - 100 mV s^{-1} for (a) LCE20, (b) LCE30, (c) LCE40, and (d) LCE50.

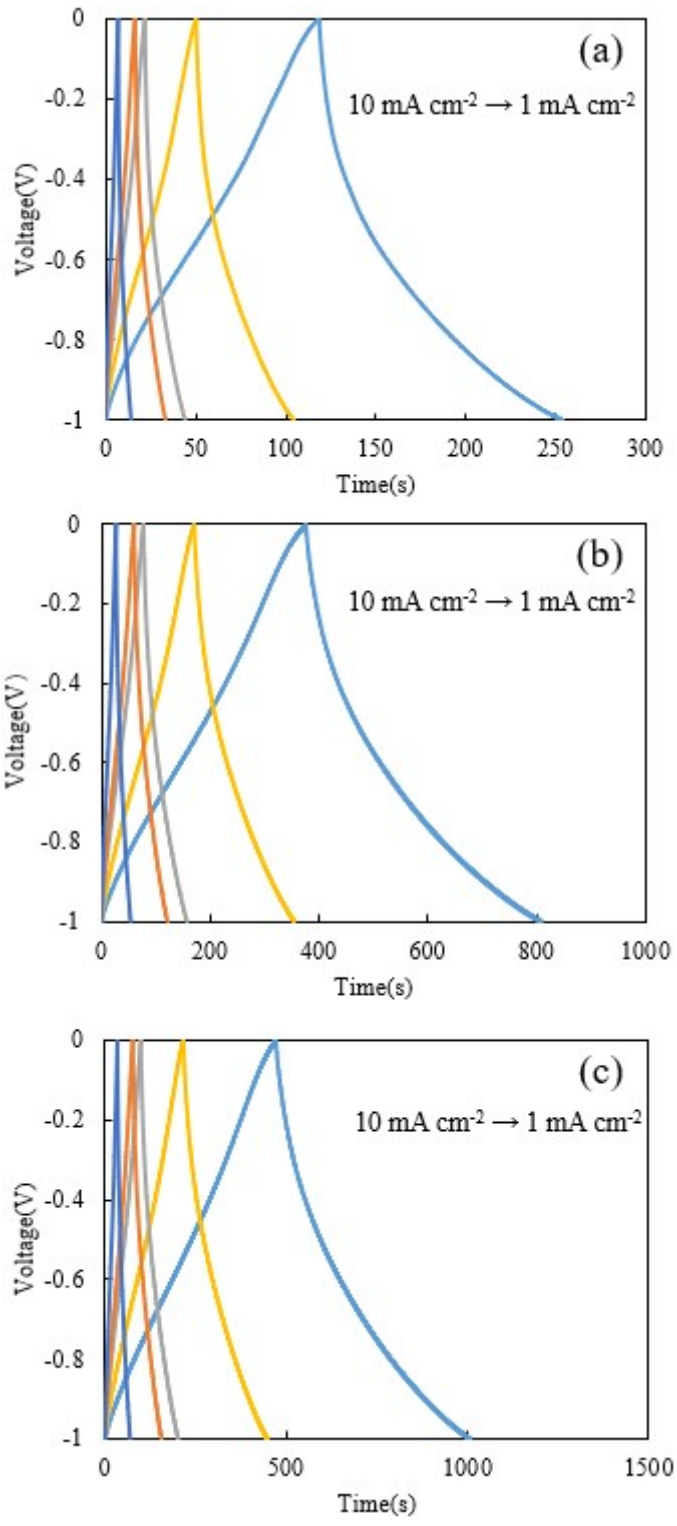

Figure S8. All plots are based on data from three-electrode system. GCD curves at 1, 2, 4, 5, 10 mA cm^{-1} for LCE20 (a), LCE30 (b), and LCE50 (c).

Table S1. Mass increase of carbon cloth upon DLW with lignin.

	LCE20	LCE30	LCE40	LCE50
Mass increase (mg)	0.64	1.75	2.74	2.61

Table S2. Comparison of the areal capacitances for LCE40-based device with other lignin-based DLW-derived carbons reported in the literature.

Carbon source	**Current Density (mA cm^{-2})**	**C_A (mF cm^{-2})**	**Fabrication method**	**Reference**
Lignin/PEO	0.1	25.44	a	[1]
Lignin/PEO	0.01	2.51	a	[2]
Lignin/PAN/MOS_2	0.1	16.2	a	[3]
Lignin/PVA	0.05	25.1	a	[4]
Polyimide (PI)	0.05	31.9	Purchased film (a)	[5]
Lignin	0.5	148.6	b	This work

a: fabricate lignin into a film with other polymers and apply laser beam to the film, where the film is etched to form carbon out of the film.
b: apply laser beam to lignin melting on carbon cloth and directly bond lignin-derived carbon on carbon cloth.

Reference

[1] F. Mahmood, C. Zhang, Y. Xie, D. Stalla, J. Lin, C. Wan, Transforming lignin into porous graphene via direct laser writing for solid-state supercapacitors , RSC Adv. 9 (2019) 22713–22720. https://doi.org/10.1039/c9ra04073k.

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