Sustainable carbon electrodes for energy storage

Kristiina Oksman

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Outline

- Human-made carbon materials from renewable resources
- Electrospinning of lignin-PVA to a fibermat and its carbonization to carbon fiber network
- Ice-templating of lignin-cellulose aerogels and their carbonization to carbon aerogels
- Their use as electrode materials in supercapacitors
- Plan for the WISE project

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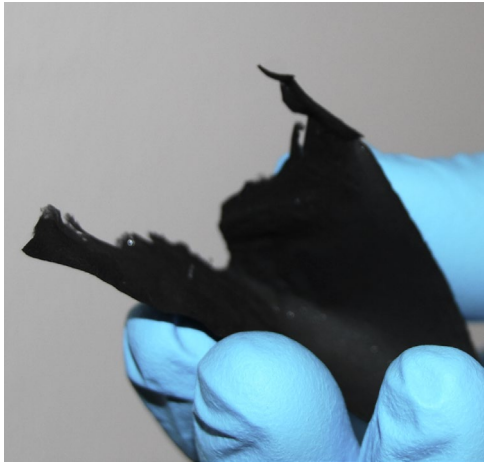
Human-made carbon materials: Carbon aerogels and carbon fibers

- Lightweight
- Hierarchically porous structure
- High surface area
- Free standing



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Article

Green Carbon Nanofiber Networks for Advanced Energy Storage

Jiayuan Wei, Shiyu Geng, Olli Pitkänen, Topias Järvinen, Krisztian Kordas,* and Kristiina Oksman*

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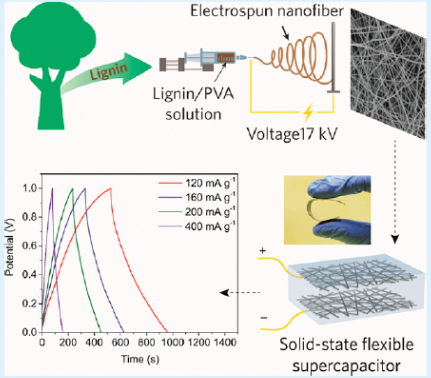
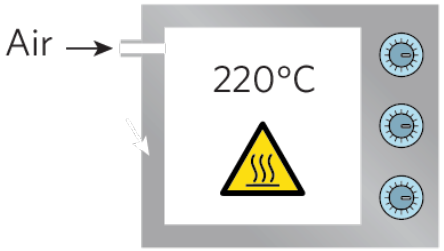
ABSTRACT: Energy storage devices such as supercapacitors of high performance are in great need due to the continuous expansion of digitalization and related devices for mobile electronics, autonomous sensors, and vehicles of different kinds. However, the nonrenewable resources and often complex preparation processes associated with electrode materials and structures pose limited scale-up in production and difficulties in versatile utilization of the devices. Here, free-standing and flexible carbon nanofiber networks derived from renewable and abundant bioresources are demonstrated. By a simple optimization of carbonization, the carbon nanofiber networks reach a large surface area of 1670 m^2 g^{-1} and excellent specific gravimetric capacitance of ~240 F g^{-1}, outperforming many other nanostructured carbon, activated carbon, and even those decorated with metal oxides. The remarkable electrochemical performance and flexibility of the green carbon networks enable an all-solid-state supercapacitor device, which displays a device capacitance of 60.4 F g^{-1} with a corresponding gravimetric energy density of 8.4 Wh kg^{-1} while maintaining good mechanical properties.

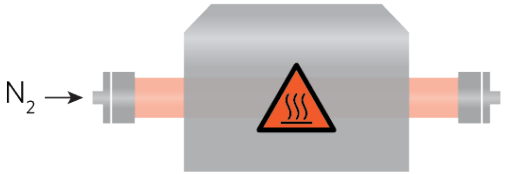
KEYWORDS: *green carbon, electronics, energy storage, lignin, electrospinning*



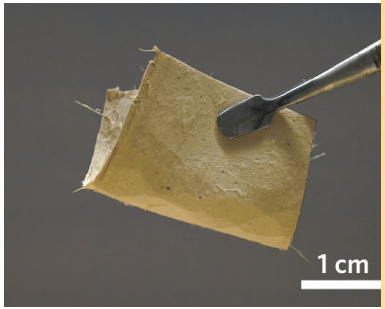
Carbonization



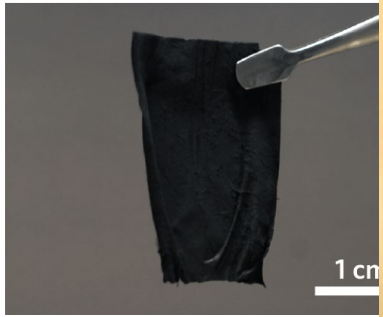
Stabilization



Carbonization
800 – 1400°C



stabilized sample



carbonized sample

SEM image of fibers carbonized at 1400 °C

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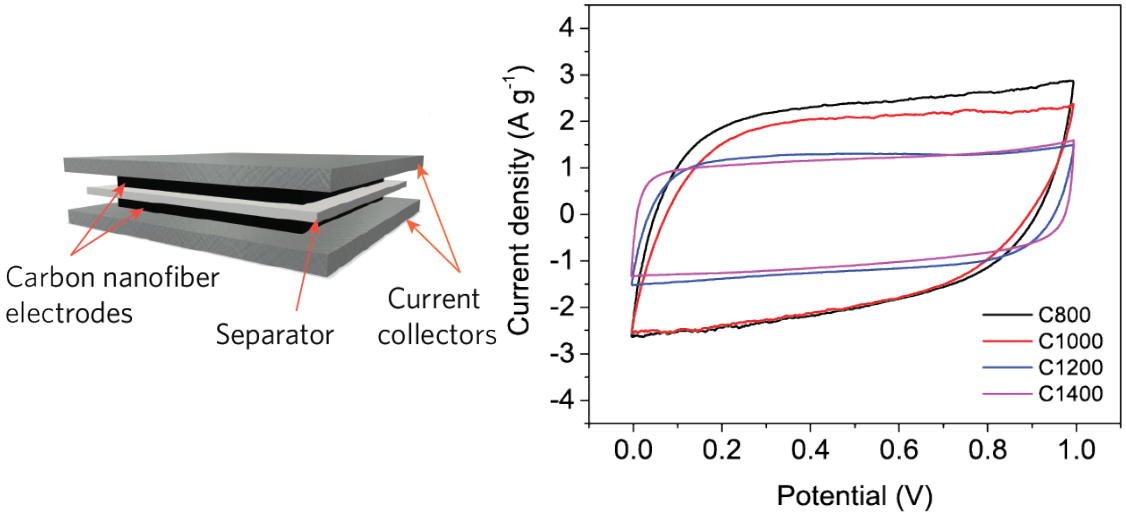
Electrochemical performance



- CVs of 800 1000 ºC had larger area under the curve and higher specific capacitance
- Higher carbonization temperature resulted to lower performance

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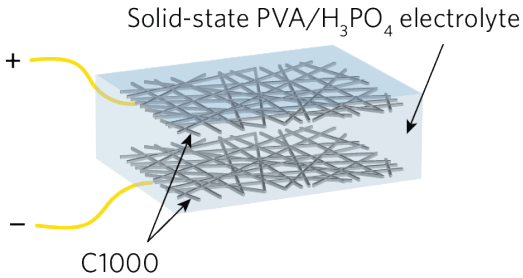
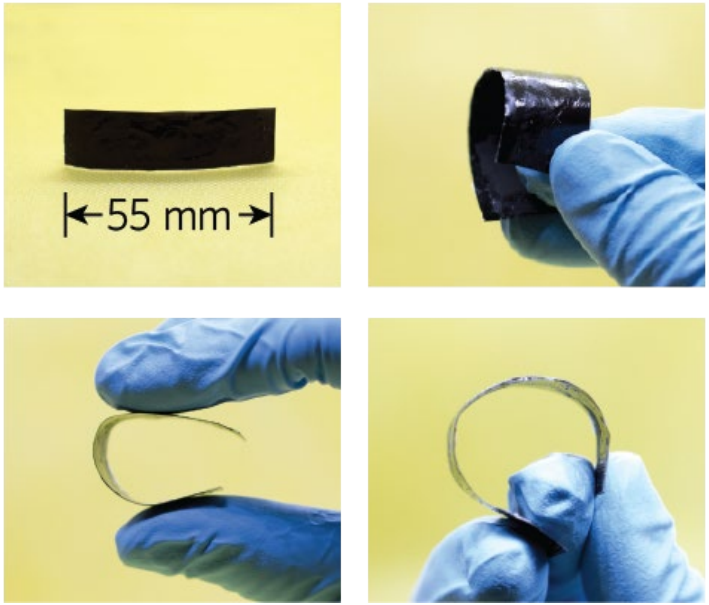
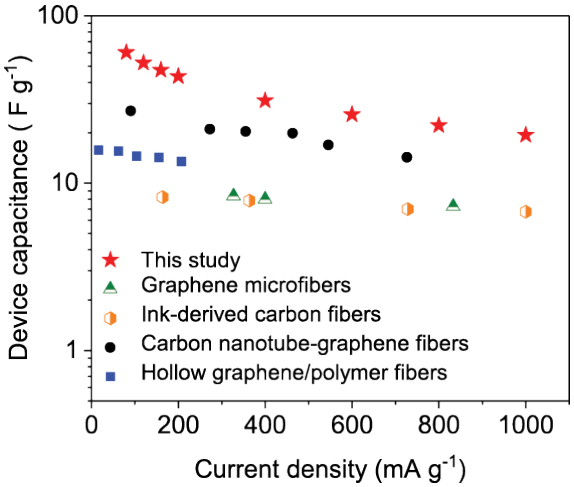
All solid-state supercapacitors







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Ice-Templating of Lignin and Cellulose Nanofiber-Based Carbon Aerogels: Implications for Energy Storage Applications

Bony Thomas, Shiyu Geng, Jiayuan Wei, Henrik Lycksam, Mohini Sain, and Kristiina Oksman*

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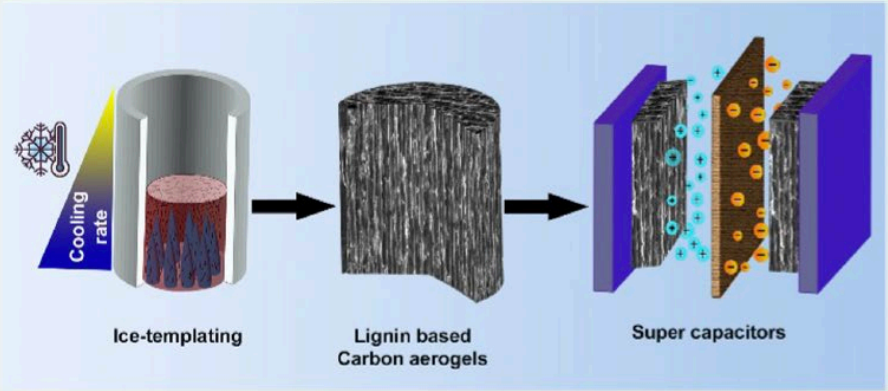
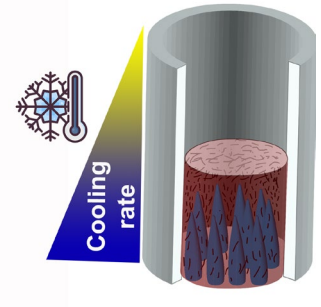
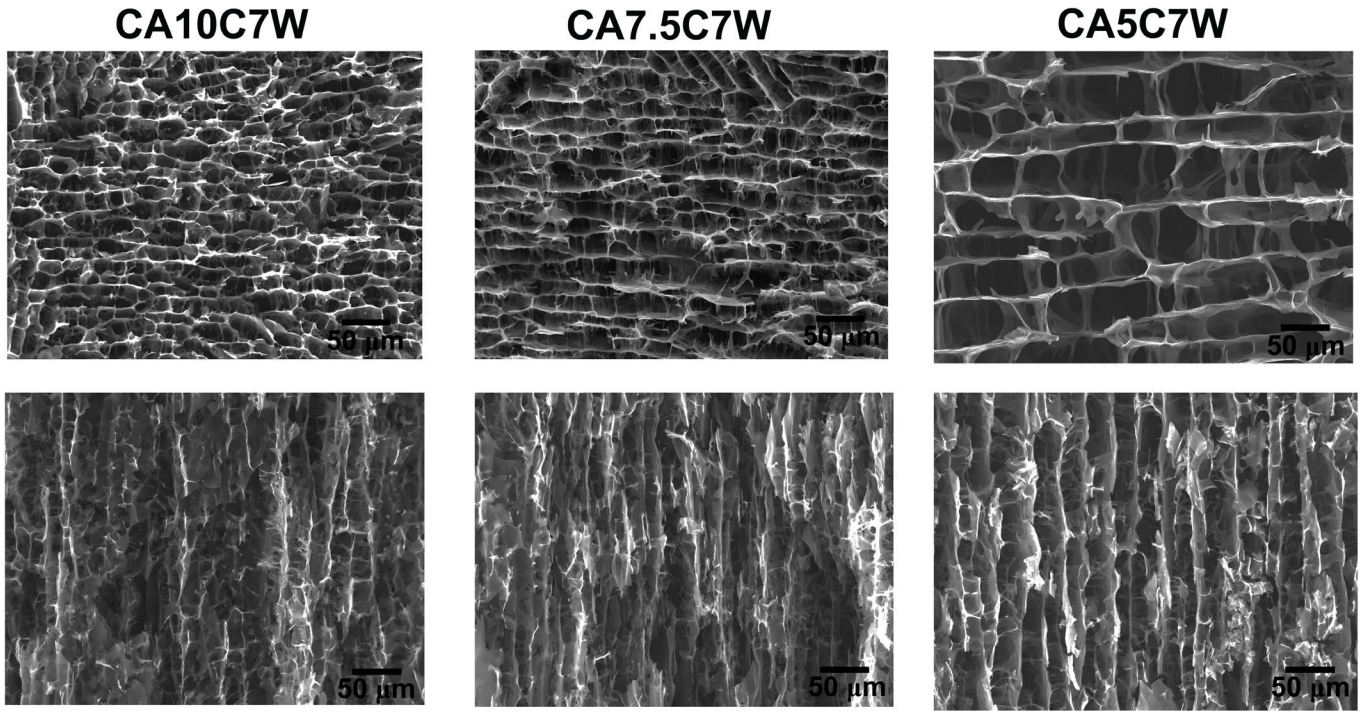


Effect of ice-templating parameters on the structure





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https://doi.org/10.1021/acsanm.2c01033

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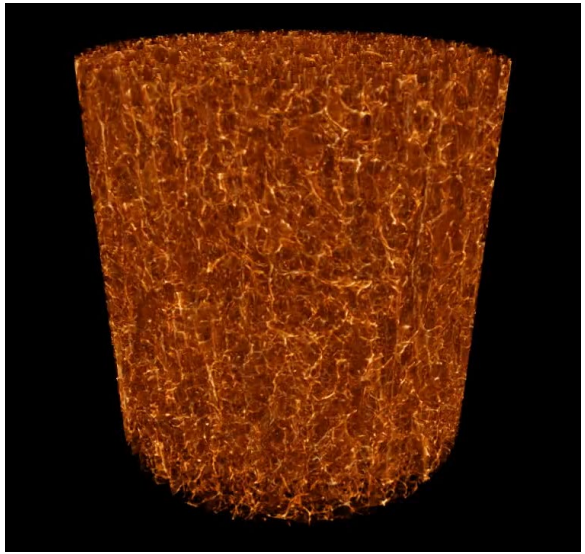
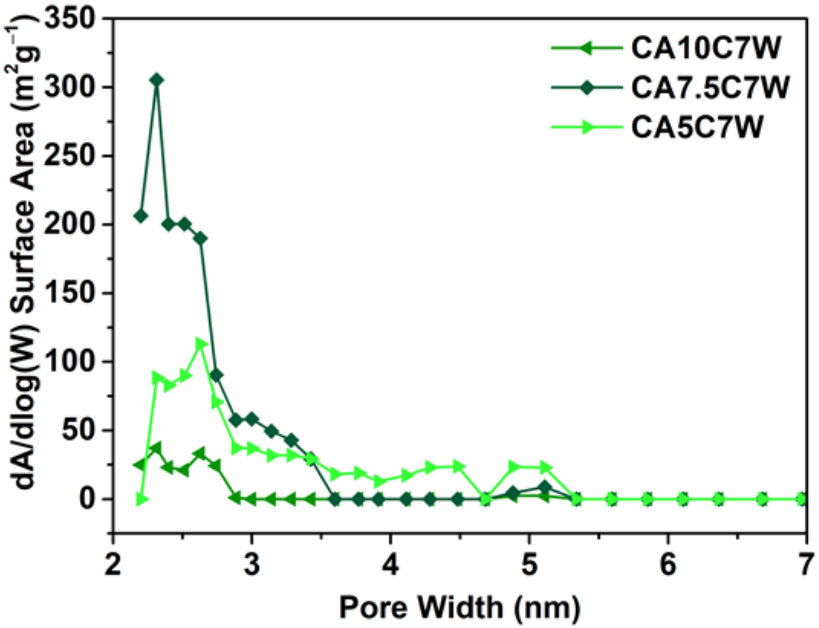
Effect of ice-templating parameters on the aerogel structure

3D µ-CT





CA with the highest SSA show largest number of microporosity (2-5 nm)

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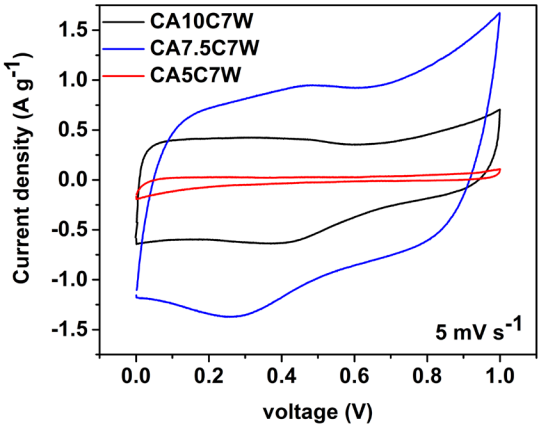
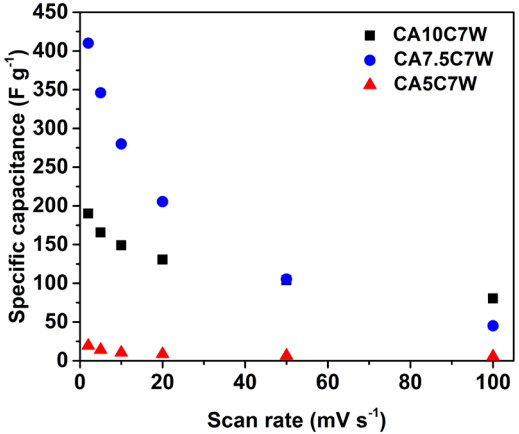
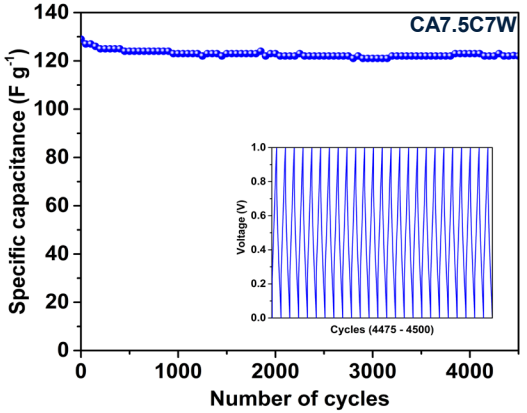
Electrochemical performance of carbon aerogels







- Near rectangular shaped CVs and CA7.5C7W having highest area under the curve.
- Highest specific capacitance 410 F g^{-1} at 2 mV s^{-1}
- Charge discharge cycling stability 94% (4500 cycles)

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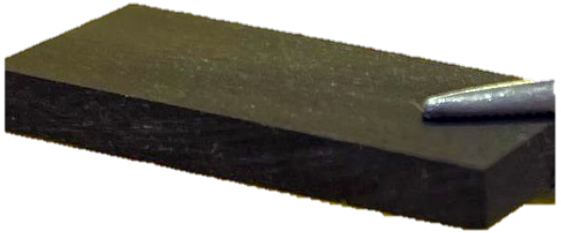
Solid carbon composite electrodes

Lignin aerogel

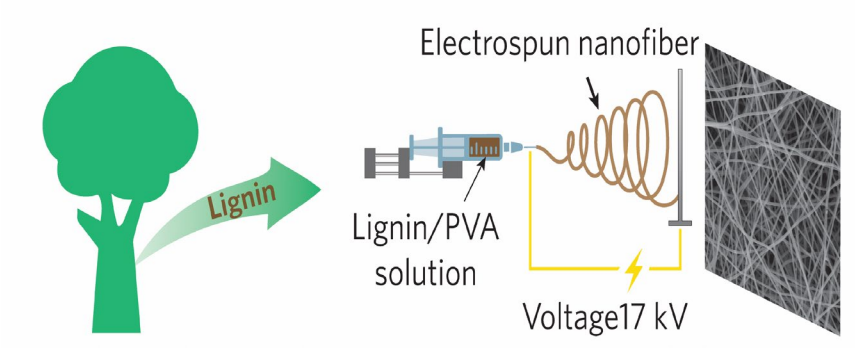
Carbon aerogel

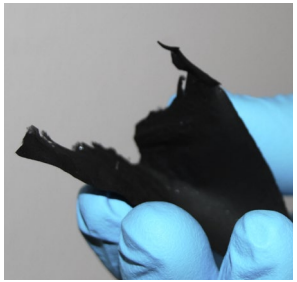
Composite

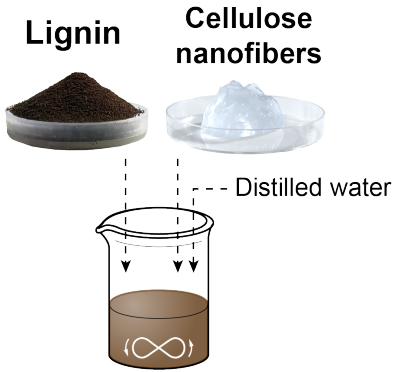


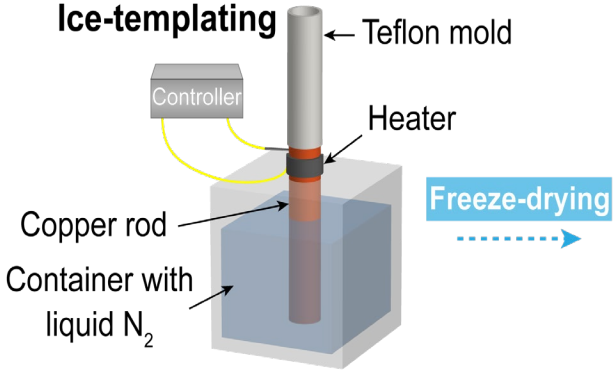
- Develop porous carbon structures, ice-templating and electrospinning, impregnated with solid polymer electrolyte
- Model the flow behavior of the electrolyte and interaction with carbon
- Evaluate sustainability

Summary









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Thank you

Vetenskapsrådet

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