Upcycling Cotton-Polyester Textile Waste into High Surface Area Carbon for Energy Storage Applications

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Abstract:

The rapid increase in textile waste generation from fast fashion and population growth calls for innovative waste management and valorization technologies. This study converts textile waste into high-surface-area carbon materials through a simple pyrolysis process and investigates the synergistic behavior of thermally decomposing woven cotton-polyester materials. Three waste types—pure cotton, a 1:1 cotton-polyester blend, and pure polyester—were carbonized at 400, 500, and 600°C with a slow heating rate (4°C/min) under nitrogen. The cotton-polyester blend carbonized at 500°C yielded the highest surface area (576 m^2/g), outperforming cotton (197 m^2/g) and polyester (287 m^2/g). A favorable morphological interaction between cotton and polyester promotes the formation of mesoporous carbon of high surface area at relatively low temperatures. Typically, such high surface areas require chemical activation at temperatures above 700°C, highlighting the efficiency of this method. KOH activation further enhanced porosity of the textile waste biochar, and the resulting activated carbons were tested in symmetric supercapacitors. Activated carbon from cotton and the cotton-polyester blend achieved specific capacitances of 127 F/g and 70 F/g, respectively. This work demonstrates a scalable and sustainable approach to upcycle textile waste into high-performance carbon materials, advancing circular economy initiatives and renewable energy storage technologies.