Perspectives of cheap carbons in supercapacitor applications

Meelis Härmas, **Thomas Thomberg, Tavo Romann, Alar Jänes, Enn Lust**
Institute of Chemistry, University of Tartu,
Ravila 14A, 50411 Tartu, Estonia
meelisharmas@gmail.com

Activated carbon has been widely studied and used in applications such as energy storage, environmental remediation and resource recovery. In the fields of energy storage, the electrode materials are known as a key factor determining the performance of an electrical double layer capacitor (EDLC) [1]. This study focuses on the energetic capabilities of different material made form organic precursors in EDLC.
Activated microporous carbon materials used for the preparation of electrodes have been synthesized from the hydrochars prepared via hydrothermal carbonization process (HTC). Since precursor materials produced less than desirable porosity, an activation with $ZnCl_2$, KOH or its mixture was carried out. Resulting activated carbons were physically characterized by using scanning electron microscopy, Raman spectroscopy, X-ray diffraction and nitrogen and carbon dioxide sorption methods. 1M triethylmethylammonium tetrafluoroborate solution in acetonitrile and activated carbon-based electrodes were combined into test cells which electrochemical characteristics were established by cyclic voltammetry, constant current charge/discharge, electrochemical impedance spectroscopy and constant power discharge methods.
Activation of HTC only with $ZnCl_2$ or KOH substantially increases the number of micropores as well as creates some mesopores, thus, produces the carbon material with mixed micro- and mesoporous structure which enhances energy and power density of EDLC. Highest porosity and Brunauer-Emmett-Teller specific surface area (S_{BET} = 2150 m^2 g^{-1}), micropore surface area (S_{micro} = 2140 m^2 g^{-1}) and total pore volume (V_{tot} = 1.01 cm^3 g^{-1}) have been achieved for HTC activated using KOH with a mass ratio of 1:4 at 700 ˚C.

The S_{BET}, S_{micro}, V_{tot} and electrochemical characteristics were heavily influenced by the synthesis conditions of carbon materials. Wide region of ideal polarizability ($\Delta V \leq 3.0$ V), very short characteristic relaxation time (0.66 s), and high specific series capacitance (134 F g^{-1}) have been calculated for the aforementioned activated carbon material, demonstrating that this system can be used for completing the EDLC with high energy- and power densities [2,3]. The results reveal that HTC is an effective way for converting sugars or even natural biomass into high-valued functional solids. However, it still needs more effect to fully investigate the hydrochars characteristics and explore and develop their potential applications.

Acknowledgements
This research was supported by the EU through the European Regional Development Fund (Centers of Excellence, 2014-2020.4.01.15-0011 and 3.2.0101–0030, TeRa project SLOKT12026T. Higher education specialization stipends in smart specialization growth areas 2014-2020.4.02.16-0026) and Institutional Research Grant IUT20–13. This work was partially supported by Estonian Research Council grants PUT1033 and PUT55.

References
[1] R. Kötz, M. Carlen, Principles and applications of electrochemical capacitors, Electrochimica Acta. 45 (2000) 2483–2498. doi:10.1016/S0013-4686(00)00354-6.
[2] M. Härmas, T. Thomberg, H. Kurig, T. Romann, A. Jänes, E. Lust, Microporous–mesoporous carbons for energy storage synthesized by activation of carbonaceous material by zinc chloride, potassium hydroxide or mixture of them, Journal of Power Sources. 326 (2016) 624–634. doi:10.1016/j.jpowsour.2016.04.038.
[3] M. Härmas, T. Thomberg, T. Romann, A. Jänes, E. Lust, Carbon for Energy Storage Derived from Granulated White Sugar by Hydrothermal Carbonization and Subsequent Zinc Chloride Activation,

J. Electrochem. Soc. 164 (2017) A1866–A1872. doi:10.1149/2.0681709jes.

Euroopa Liit
Euroopa
Regionaalarengu Fond

Eesti
tuleviku heaks