

Solid carbon products from CO2 – theory, practice, products and markets

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Valuable use of GREEN CO₂

- Negative emissions needed [1]
- Green CO₂ BECCU for mitigation [1]
- There will be huge market for the technology
- 2.5 Billion € potential in CC alone in Finland
- Upgrading multiplies value
- Funding for business development and research from Green Deal



Figure: IEA Bioenergy 2018

[1] IPCC report 8/2018, 1.5 Deg

Market potential

- CCS market is expected to grow (Fig.)
- Industrial sources offer highly contentrated CO2 streams
- Carbon capture is approximately four time less power consuming compared to DAC
- End product can be different carbon products even Carbon Nano Tubes (CNT)
- CNT market grows approx. 17 % annually ¹⁾



Monetary market of CC and CCS globally 2018 and 2026 (Billion USS) Statista 2019

¹⁾ Marketandmarket 2019



BASIC IDEA



TJ(1 soodakattilat ja sulakarbonaattipolttokennot Tero Joronen (TAU); 14.2.2020

Molten salt electrolysis

- • $Li_2CO_3/CaCO_3$, K_2CO_3 , Na_2CO_3
- •High electrical eff. > 80 % [4]



[2] Hu, Liwen, et al. "Fabrication of graphite via electrochemical conversion of CO2 in a CaCl2 based molten salt at a relatively low temperature." *RSC advances* 9.15 (2019): 8585-8593.

[4] Yin, Huayi, et al. "Capture and electrochemical conversion of CO 2 to value-added carbon and oxygen by molten salt electrolysis." *Energy & Environmental Science* 6.5 (2013): 1538-1545.

[3] Ren, Jiawen, et al. "Transformation of the greenhouse gas CO2 by molten electrolysis into a wide controlled selection of carbon nanotubes." Journal of CO2 Utilization 18 (2017): 335-344.

Technical details

- Temperature is 750 °C
- Anode (Ni-alloy) ja kathode (Graphite) apply 1.5 V_{DC} [5]

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(1) M_2CO_3 \rightleftharpoons M_2O + CO_2 (M: Li/Ca, Na, K)
(2) 3M_2CO_3 = C + 3M_2O + 2CO_2 + O_2
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[5] Weng, Wei, Lizi Tang, and Wei Xiao. "Capture and electrosplitting of CO2 in molten salts." Journal of Energy Chemistry 28 (2019): 128-143.

[6] Licht, S. Co-production of cement and carbon nanotubes with a carbon negative footprint. Journal of CO2 Utilization 18 (2017): 378-389.



Experimental Procedure



Heating and cooling in the system with the middle position holder

Experimental Procedure

- The salt was melted in 2 steps
- Melting the salt completely took 1.5-2 h







The salt has been melted

Tampereen yliopisto

Electrolysis test 1 (3.2.2023)



Electrodes after electrolysis

Ni-cathode after electrolysis

- 26.16 g Li₂CO₃
- Voltage: 4 V
- Time: 30 min
- Starting current: 4.1 A
- Starting power: 16 W
- CO₂ flow rate 10 l/h



Market study – Carbon prices

Carbon structure	Estimated average value (€/kg _{prod})	Sensitivity (€/kg _{prod})
SWCNT	355,100	11,000 – 728,000
DWCNT	10,500	7,500 – 28,000
MWCNT	24,500	4,000 – 60,000
CNO	40,000	36,000 – 118,000
CNF	7,800	5,600 – 27,000
Graphene	36,700	4,000 – 84,000

Important to note:

-Scale-up is only max.100 times larger

-Optimistic view, large uncertainties

-Specific nanotubes hard to manufacture?

Conclusion/ Next steps

- Solid carbon products seem to have potential
- Material selection successful
- Homogenius Carbon Nano Onions produced
- Tubular products with Zn, tests continue
- Products are of high value
- Markets are estimated to increase
- Finalization of the market study
- Process modelling by Aspen Plus
- Control of the CNT and continuous process