Uued elektrienergia salvestamise tehnoloogiad

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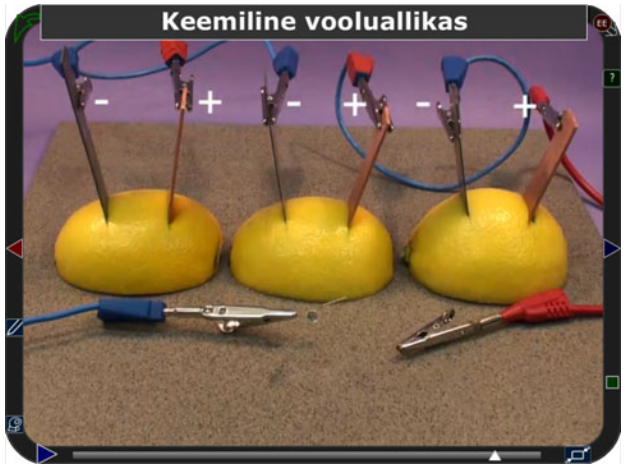
Kuidas saab elektrienergiat salvestada?

- Füüsikaline protsess -> superkondensaator

- Mehhaaniline -> hooratas, veereservuaar

- Keemiline energia salvestamine -> patarei, aku, kütuseelement



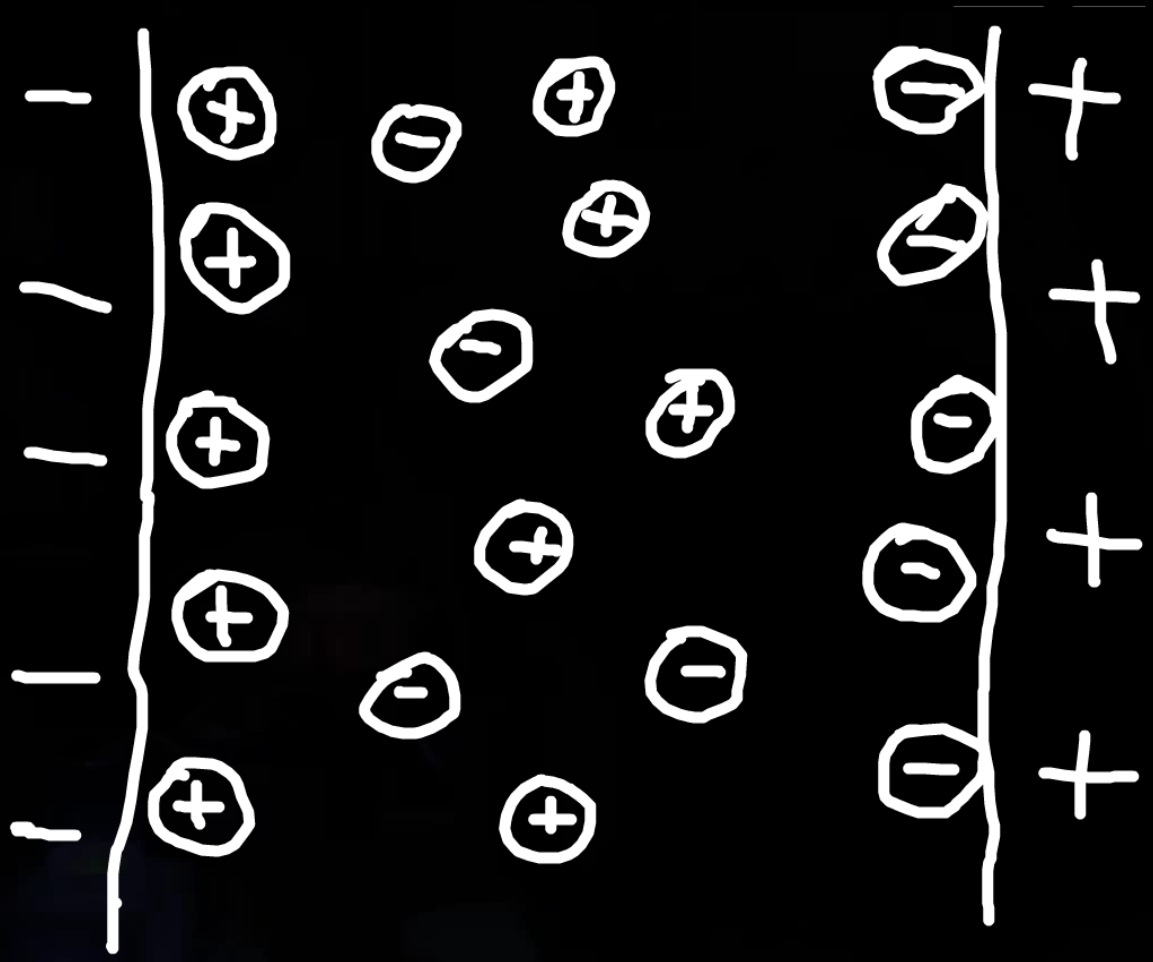
Olemasolevad süsteemid

- Al-õhk patarei -> 1300 Wh kg^{-1}
- Li patarei -> 360 Wh kg^{-1}
- Li-ioon aku -> 200 Wh kg^{-1}
- NiMH aku -> 120 Wh kg^{-1}
- Pliiaku -> 40 Wh kg^{-1}
- Superkondensaator -> 5-10 Wh kg^{-1}

[1] http://en.wikipedia.org/wiki/Energy_Density

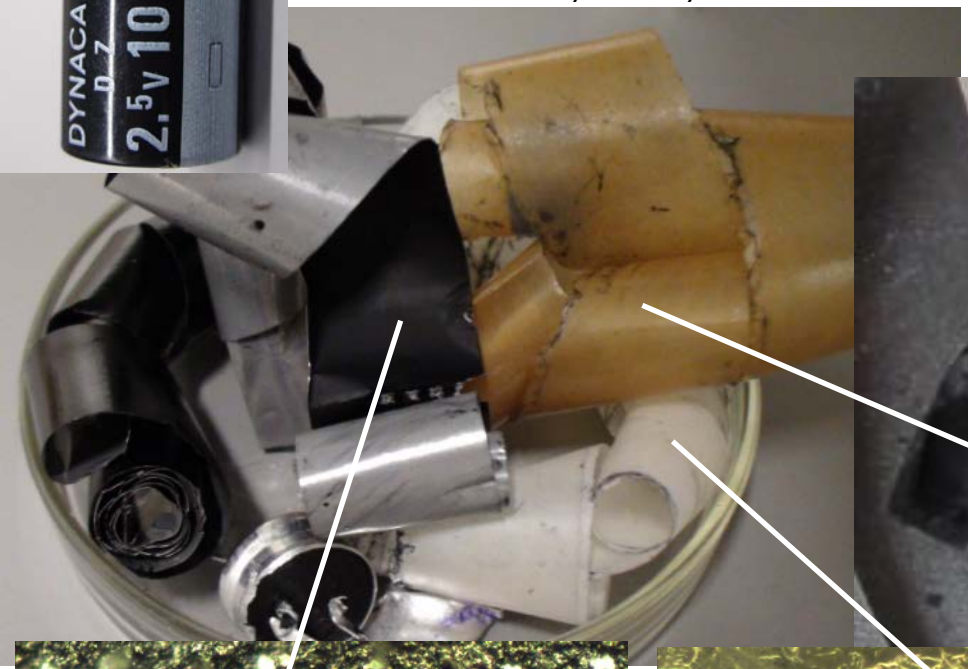
Superkondensaatori tööpõhimõte

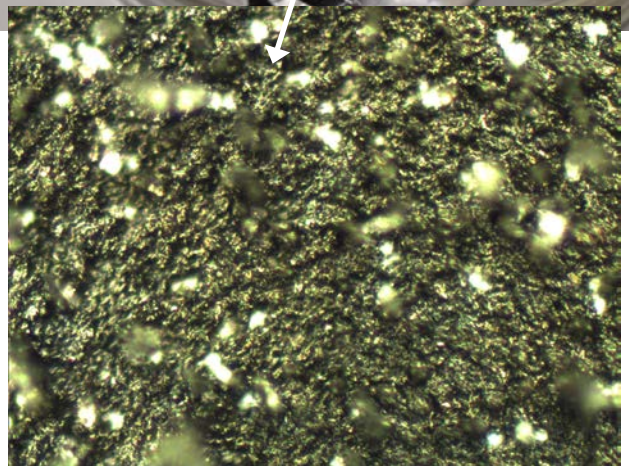
- Laetud superkondensaatoris on elektroodidel laeng, mida stabiliseerivad adsorbeerunud ioonid.
- Poorne süsinik on väga suure eripinnaga

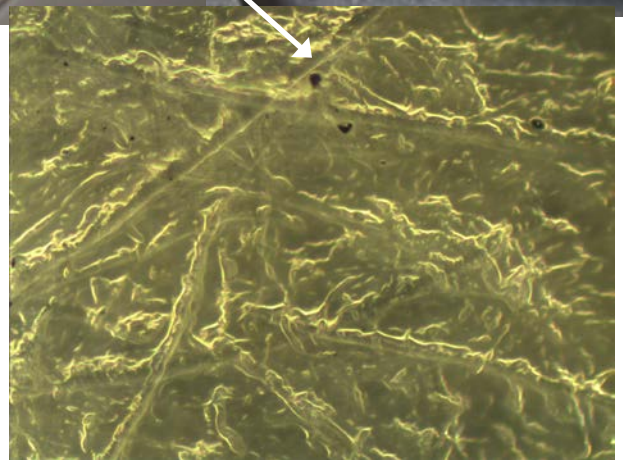


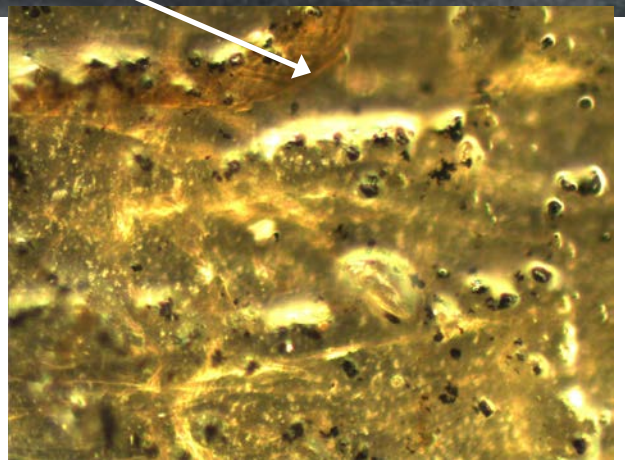
Lammutame superkondensaatori laiali

Leia pildilt voolukollektor, membraan, aktiivsüsi, kest, elektrolüüt?







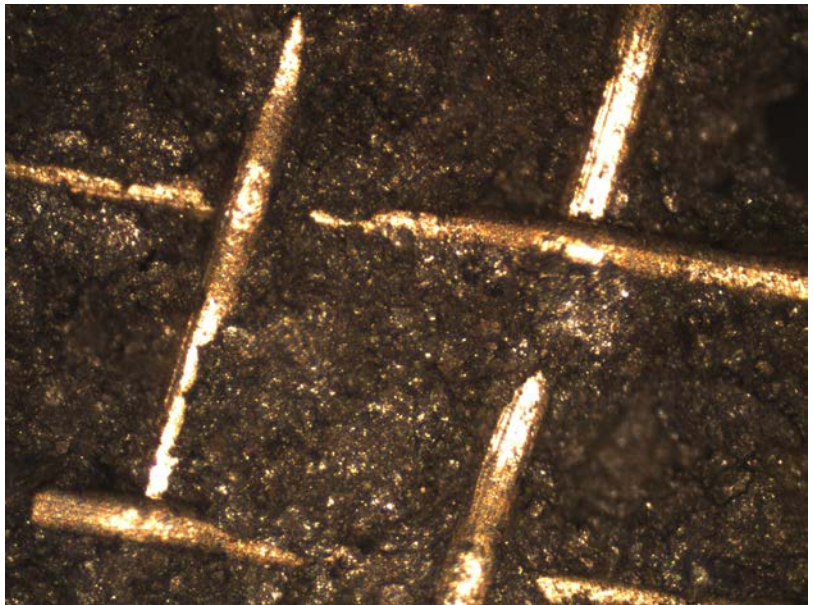


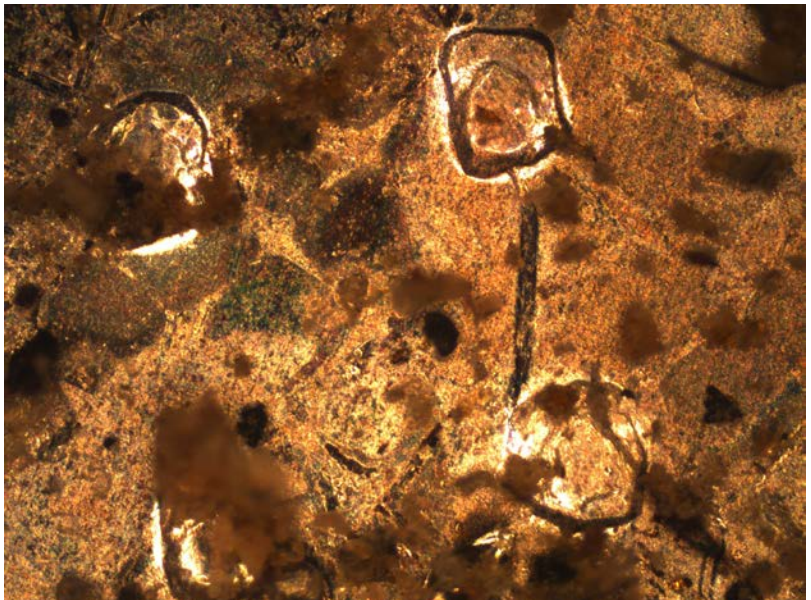
Lammutame liitiumpatarei

Anoodil(-): $Li \rightarrow Li^+ + e^-$

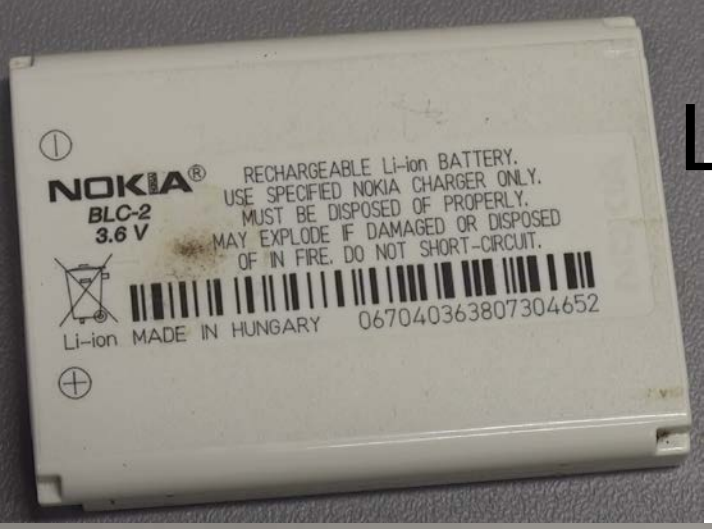
Katoodil(+): $MnO_2 + Li^+ + e^- \rightarrow LiMnO_2$

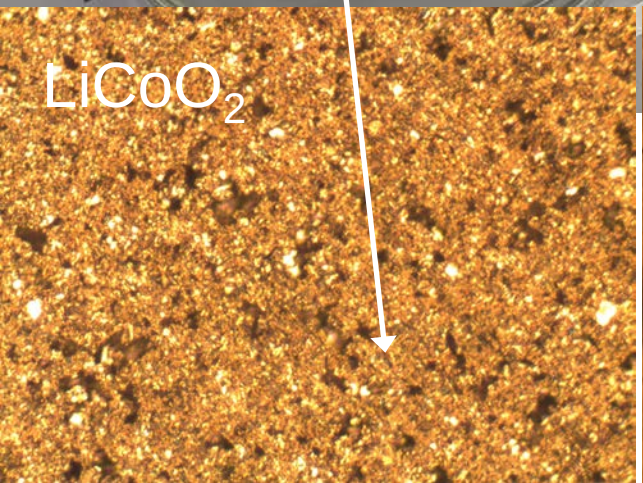
Kokku: $Li + MnO_2 = LiMnO_2$

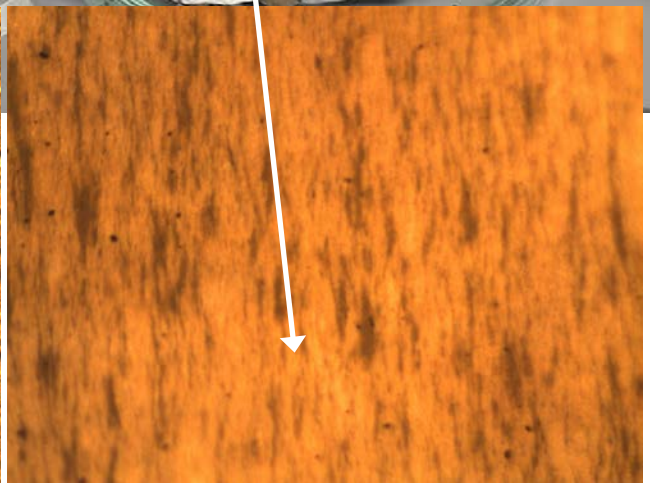


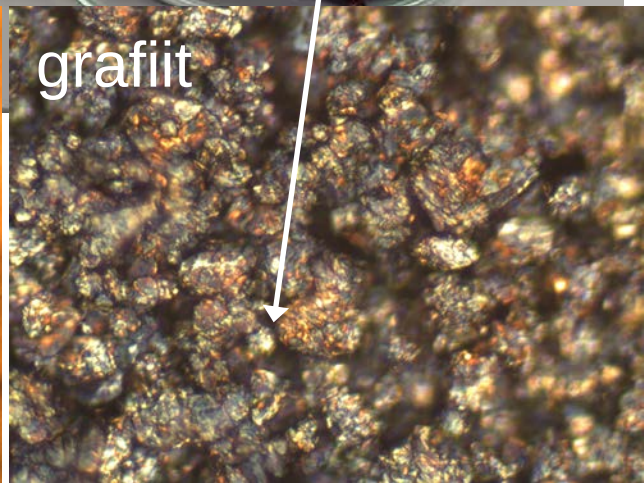


Lammutame Li-ioon aku laiali









Li-ioon aku tööpõhimõte

Cu - Li-grafiit	$Li^+PF_6^-$ org. elektrolüüt	$LiCoO_2$ - Al

- TÜHJENEMISEL:
- (+)elektroodil: $Li_{1-x}CoO_2 + xLi^+ + xe^- <-> LiCoO_2$

Co^{4+} redutseerub Co^{3+}, Li+ ioonid tasakaalustavad laengu

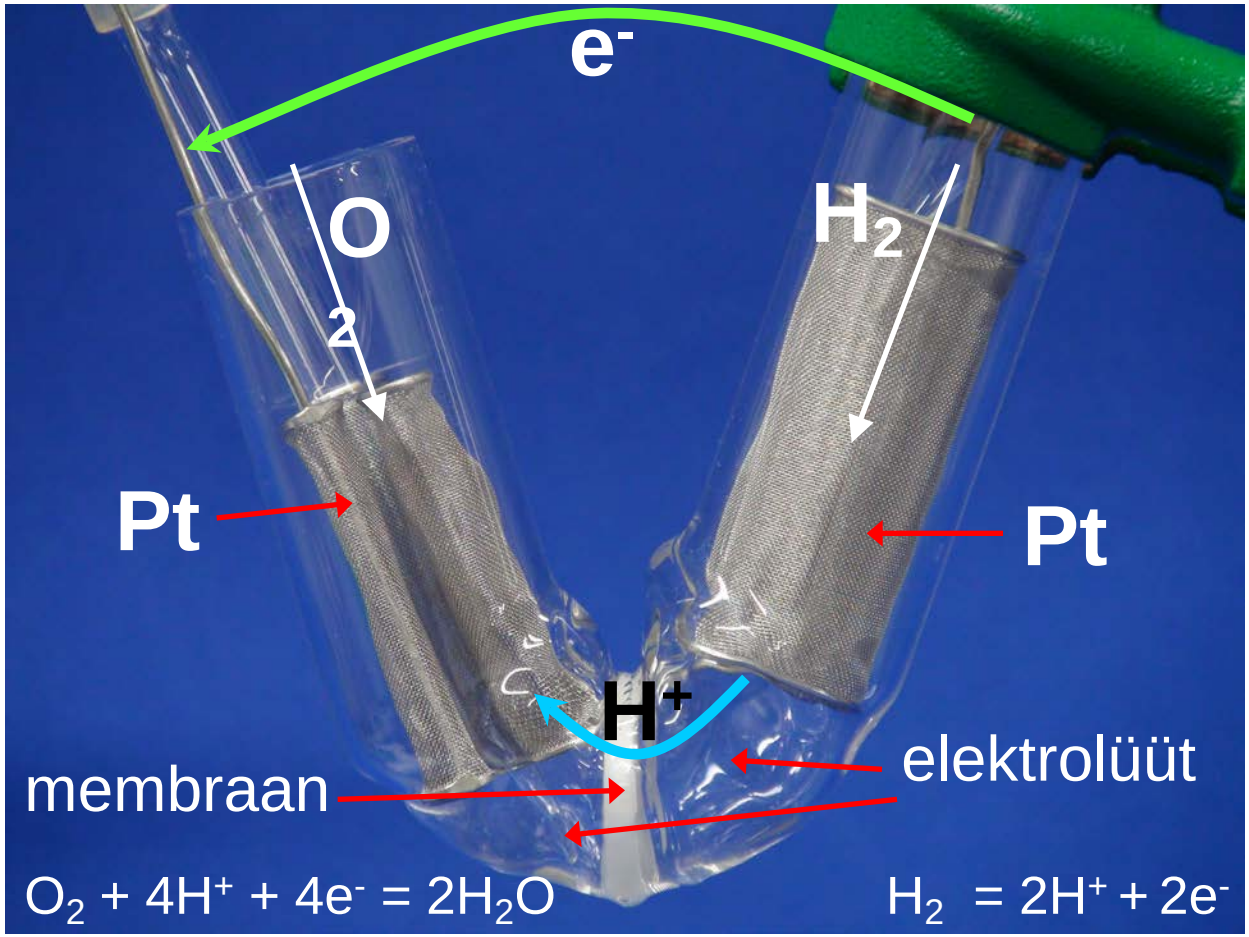
- (-)elektroodil: $Li_xC_6 <-> xLi^+ + xe^- + 6C$

Li-grafiit oksüdeerub Li+ ioonideks, mis liiguvad (+)elektroodile

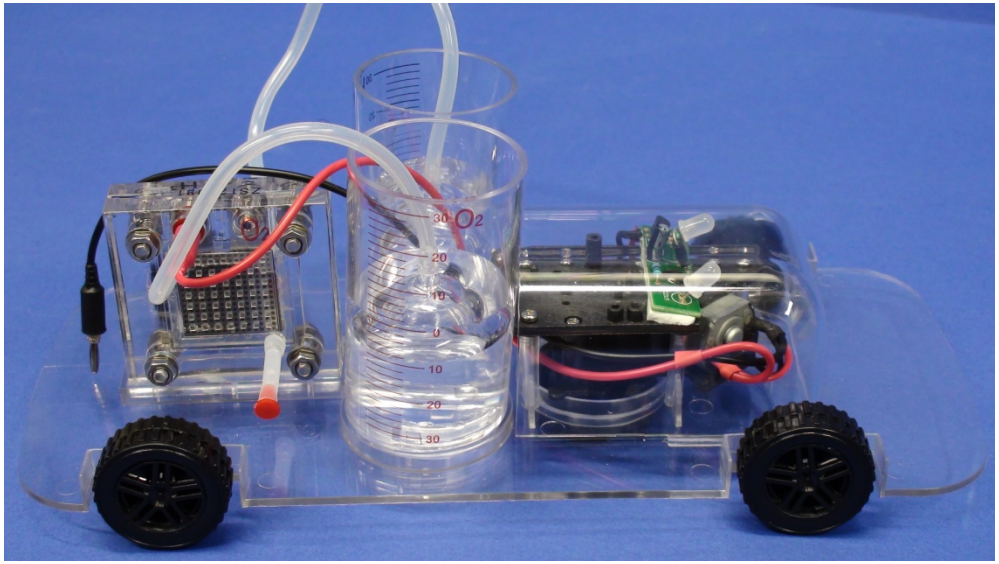
- Elektrolüüt on näiteks $LiPF_6$ lahus etüleenkarbonaadi ja dietüülkarbonaadi segus.

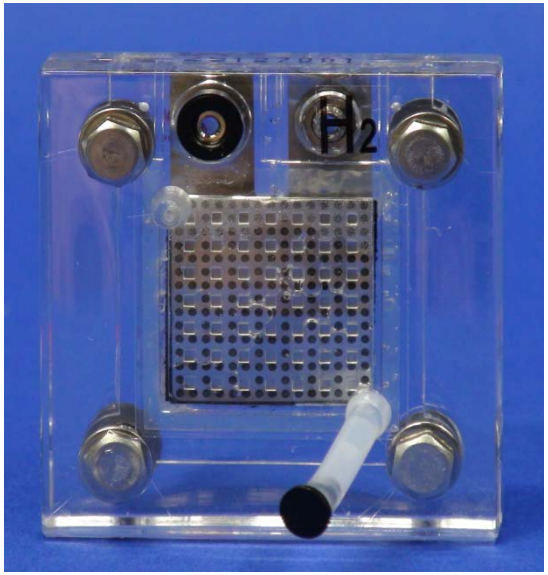
Kütuseelemendi tööpõhimõte

- PEM - polümeerelektrolüüt-membraaniga kütuseelement: plaatina-süsi, nafion, toatemperatuur
- SOFC - tahkeoksiid kütuseelement: keraamika, 600-1000 ^{0}C

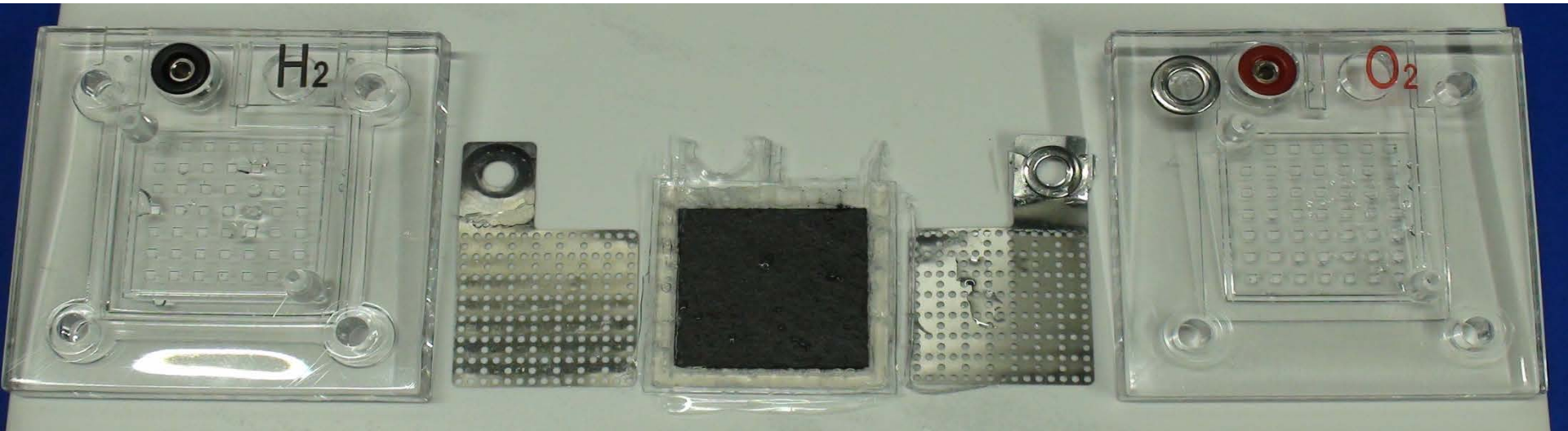


Lammutame PEMi laiali

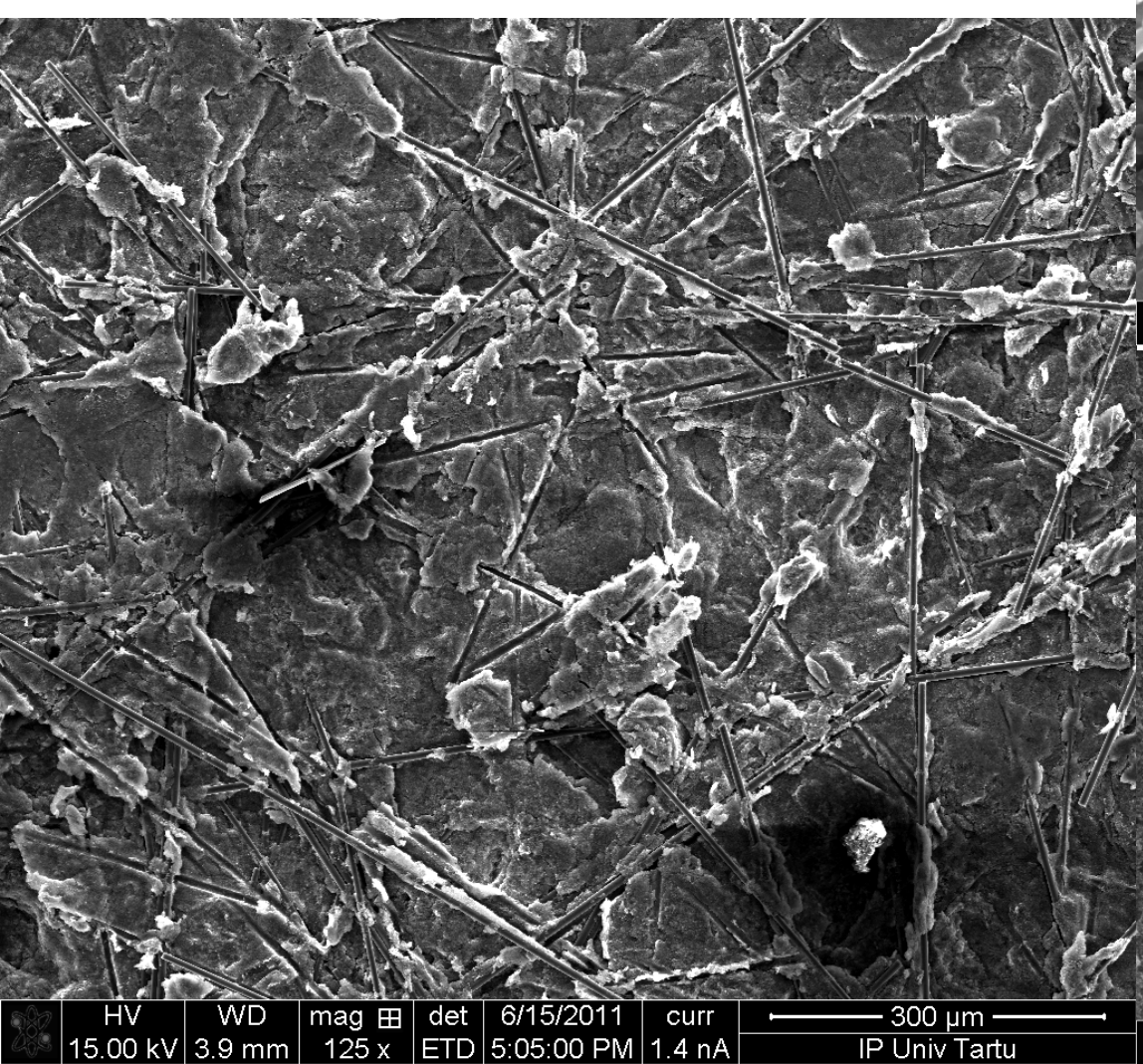


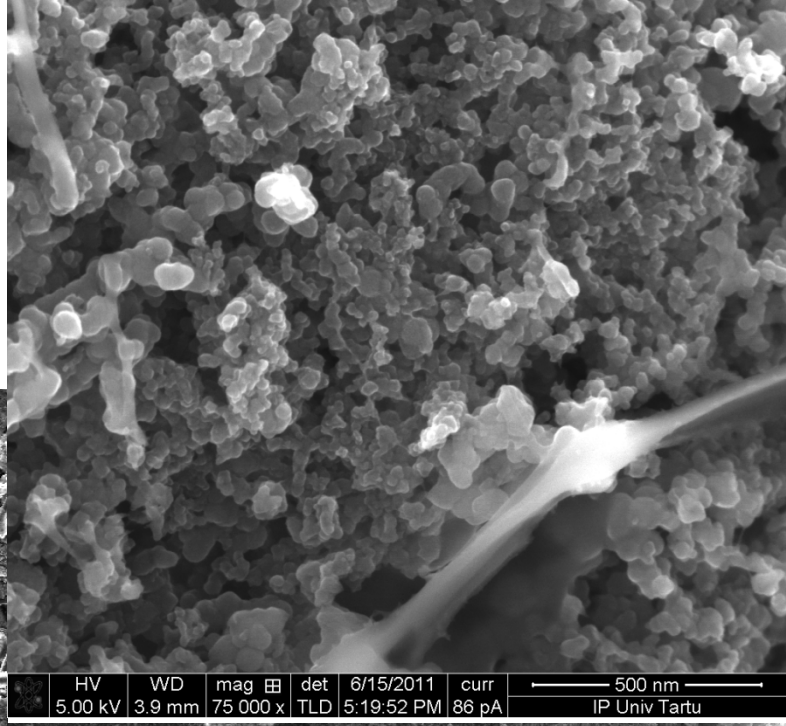


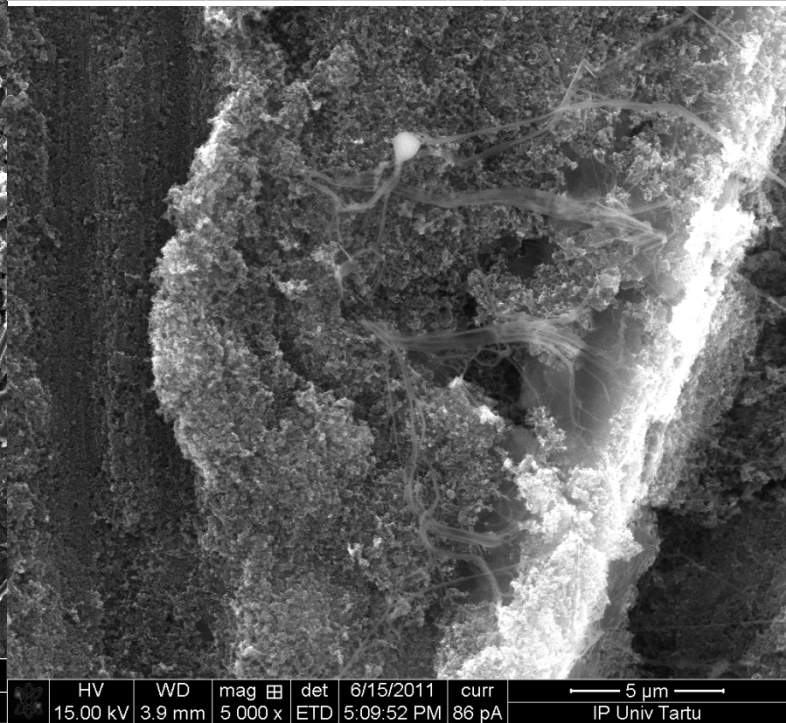
Leia pildilt kest, voolukollektorid, elektroodid ja membraan.



PEM elektrood mikroskoobi all





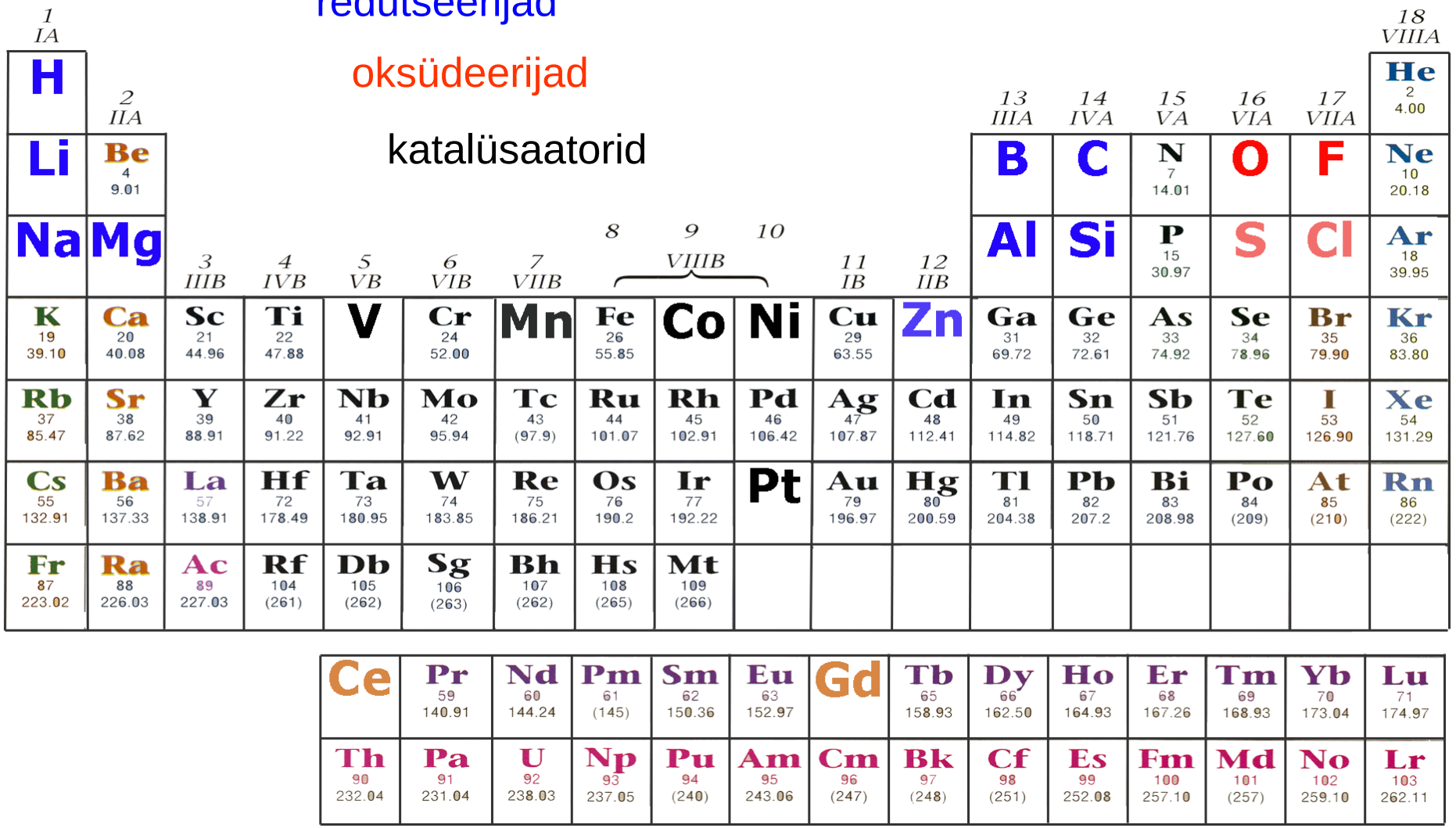


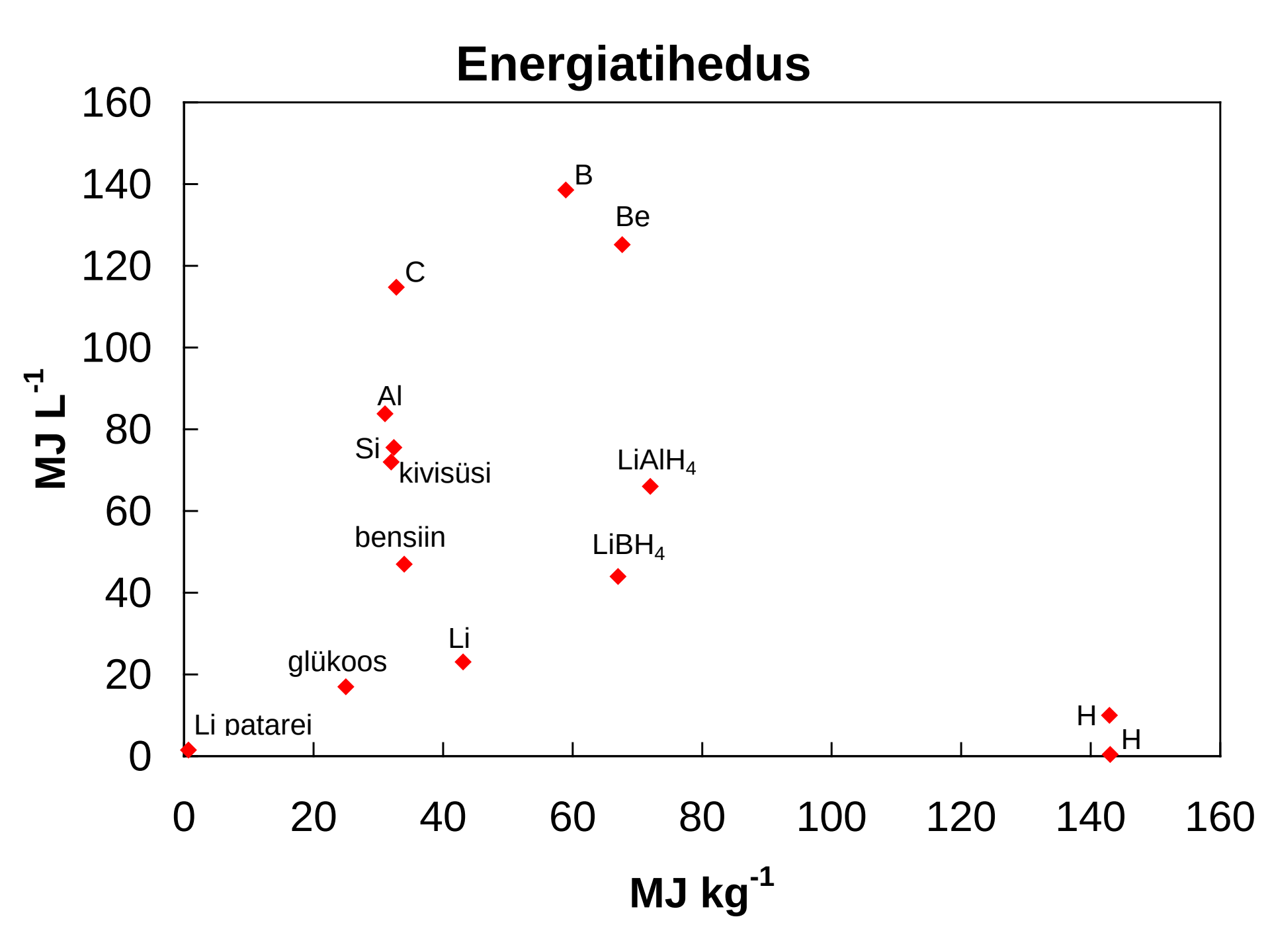
Huvipakkuvad elemendid tuleviku energiasalvestites

redutseerijad

oksüdeerijad

katalüsaatorid




Energiatihedus
MJ L-1
MJ kg-1
0
20
40
60
80
100
120
140
160
B
Be
C
Al
Si
kivisüsi
LiAlH4
bensiin
LiBH4
Li
glükoos
Li patarei
H
H

Teoreetilised patareid

(hapniku massi arvestamata, 50% redutseerijat)

- B-õhk -> 8000 Wh kg^{-1} (19000 Wh L^{-1})*
- Li-õhk -> 6000 Wh kg^{-1} (3200 Wh L^{-1})
- Si-õhk -> 4500 Wh kg^{-1} (10500 Wh L^{-1})
- Al-õhk -> 4300 Wh kg^{-1} (11600 Wh L^{-1})
- Mg-õhk -> 3200 Wh kg^{-1} (5500 Wh L^{-1})

- Müügilolev Li aku -> 170 Wh kg^{-1}

[1] http://en.wikipedia.org/wiki/Energy_Density

Hind (99%) / SIAL (tööstuslik)

- B 2000-4000 EUR/kg
- Li 1600 EUR/kg (110 $/kg)
- Mg 86 EUR/kg
- Si 52 EUR/kg (2 $/kg)
- Al 44 EUR/kg (2 $/kg)

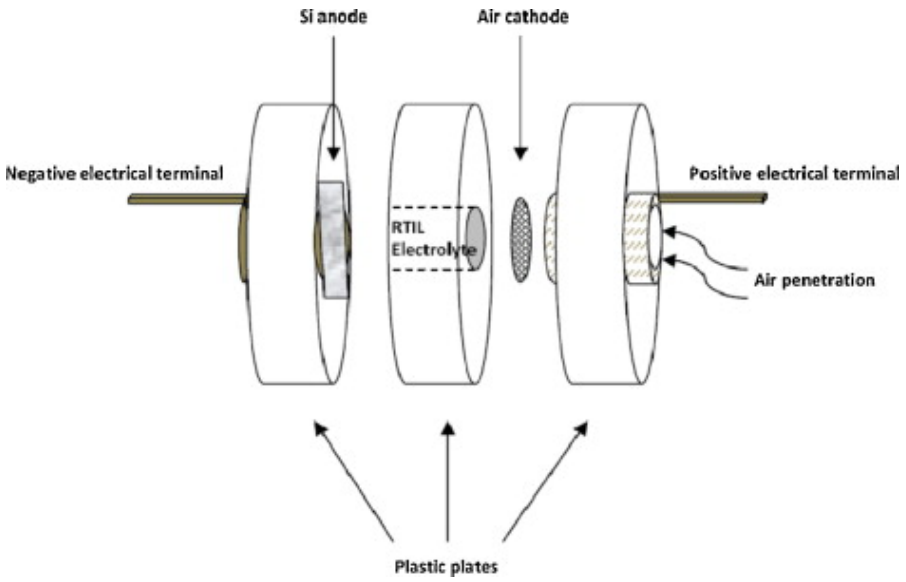
- Maakoores: Si – 25,7 %; Al – 8,1 %; Li – 0,002%.

Al-õhk patarei

- anoodil: $Al + 3OH^- \rightarrow Al(OH)_3 + 3e^-$
- katoodil: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
- kokku: $4Al + 3O_2 + 6H_2O \rightarrow 4Al(OH)_3$
- Selline patarei (mehhaaniliselt taaslaetav) võimsustihedusega 1300 Wh kg^{-1} on kasutatav USA sõjaväes.

Si-õhk patarei

- p-Si| EMI·2.3HF·F |O_2 (C)

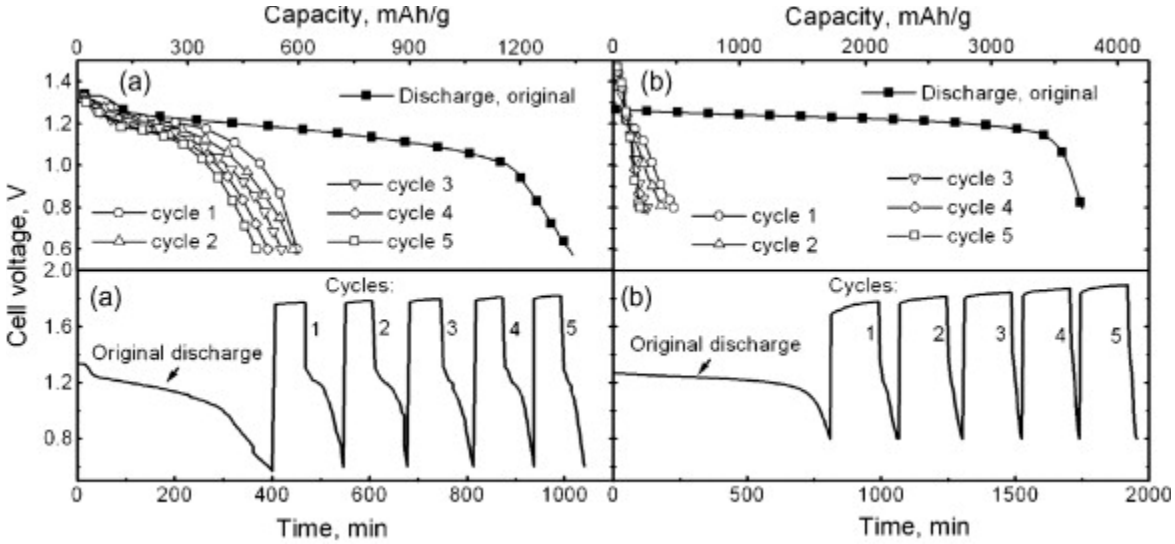


[G. Cohn, D. Starosvetsky, R. Hagiwara, D.D. Macdonald, Y. Ein-Eli, Silicon-air batteries, Electrochem. Comm. 11 (2009) 1916.]

Boriidpatarei

K_2FeO_4–VB_2 > 310 mAh g^{-1} -> 370 Wh kg^{-1}

TiB_2 võt VB_2 anood. Katood on 76.5% K_2FeO_4, 8.5% AgO, 5% KOH ja 10% 1 µm grafiiti.



Charge/discharge of alkaline TiB_2 anode–NiOOH secondary button cell

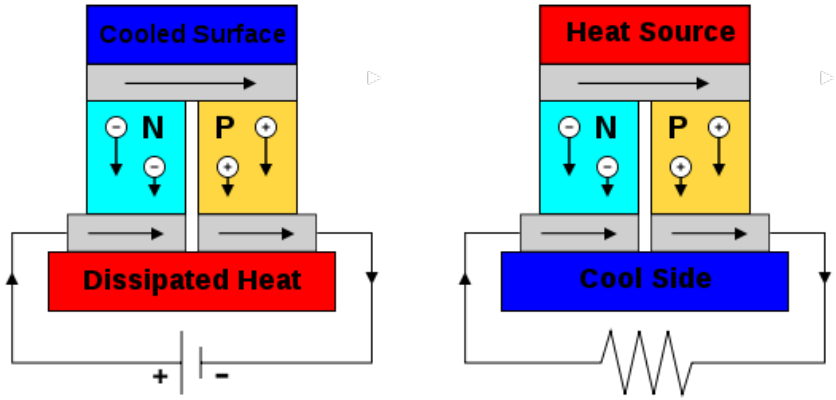
[X. Yu, S. Licht, High capacity super-iron boride battery, Electrochim. Acta 52 (2007) 8138.]

Li-õhk ja Li-räni aku

- ei vähenda liitiumi hinna probleemi, kuid energiatihedust on võimalik suurendada ja sellega tegelevad paljud teadlased üle maailma
- Li-ioon nanotraatidega patarei -> 700 Wh kg^{-1}. Kui grafiidi (LiC_6) asemel kasutada räni (Li_4Si) saame olulise massi kokkuhoiu. Tsükleeritavus on viletsam, kuid esimesi kommertsiaalseid tooteid on varsti turule oodata.
- Kasutades MnO_2 või CoO_2 asemel hoopis õhku võidaksime selle massi arvelt – Li-õhk aku peaks andma üle 1000 Wh kg^{-1}

Soojus otse elektriks

- Bi_2Te_3 on levinuim termoelektriline materjal (ZT = 0.9)
- Hiljuti on 2 teadlastegruppi leidnud, et individuaalsed räni nanotraadid võivad käituda kui efektiivsed termoelektrilised materjalid (ZT = 1.0)



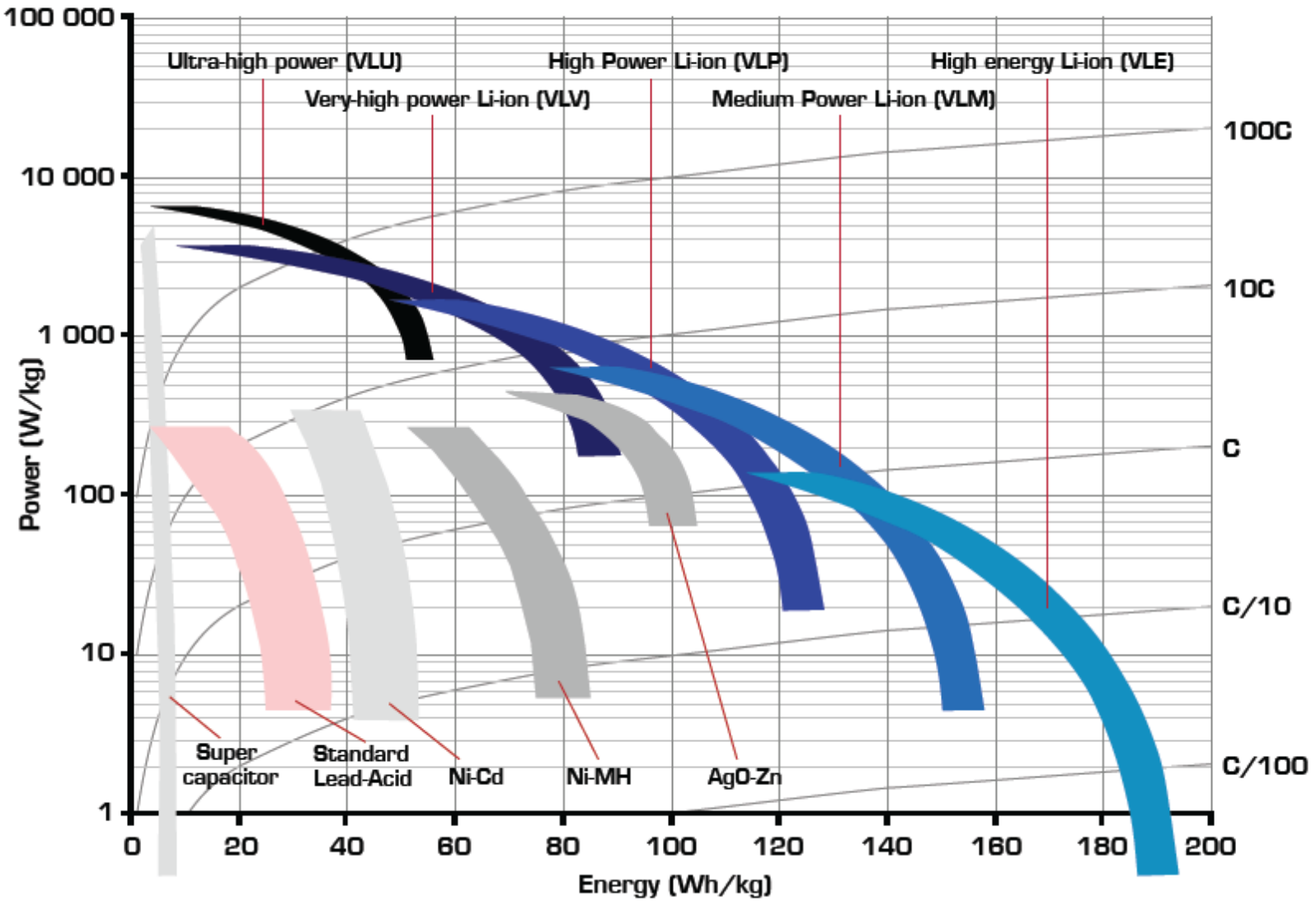
http://en.wikipedia.org/wiki/Thermoelectric_effect

Vormel 1 KERS

- F1 Võistkonnad võivad kiirendamiseks kasutada 60 kW võimsusega KERSi, mis salvestab kokku 400 kJ (111 Wh) energiat. “Boost” nupule vajutades saab seda lisanduvat 60 kW (82 hobujõudu) kasutada 6,6 sekundi jooksul ringi kohta. F1 autod on enamjaolt valinud elektrilise salvestussüsteemi, vaid Williams katsetab hoorattaga.
- Pooled tiimid, sealhulgas Ferrari ja Renault, kasutavad elektrilist KERS süsteemi, mille on välja töötanud itaalia firma Magnetti Marelli. See süsteem kasutab ühte 60 kW vedelikujahutusega harjadeta alalisvoolumootorit ja Li-ioon akusid prantsuse firmalt Saft.

AUTOMOTIVE, *01:33 March 26, 2009*

Li-ion: full coverage of every storage requirement



http://www.saftbatteries.com/Technologies_Lithium_Liion_301/Language/en-US/Default.aspx

Chemistry: Potent potato power

Nature **465** , 848 (17 June 2010) | doi:10.1038/465848d
Published online 16 June 2010

Cited research: *J. Renew. Sustain. Energy* **2**, 033103 (2010)

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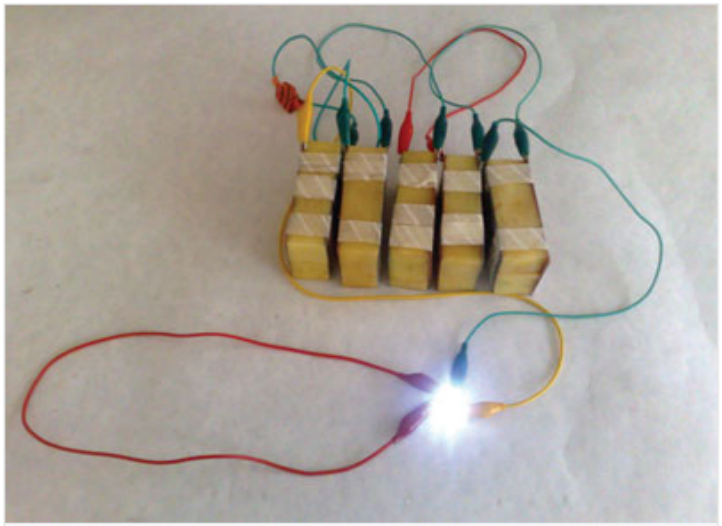
Schoolchildren are routinely shown how to convert potatoes into makeshift batteries using copper and zinc electrodes. Haim Rabinowitch at the Hebrew University of Jerusalem in Israel and his colleagues now report a way to rev up the power output: by boiling the potatoes first.

Boiled or electroporated *Solanum tuberosum* produced a voltage up to ten times higher than raw potatoes. The authors calculate that energy production from these potatoes is five- to fiftyfold cheaper than commonly used batteries and can produce light, through LEDs (light-emitting diodes, pictured), more cheaply than kerosene lamps. Potatoes could thus provide an inexpensive way to power low-energy appliances.

The authors suggest that rupturing tissue membranes by boiling or electroporation alters the properties of the tissue sandwiched between the electrodes such that it enhances the energy-generating capabilities of the biological power cell. **D.C.**



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4. **The inheritance of anthocyanin pigmentation in potato (Solanum tuberosum L.) and mapping of tuber skin colour loci using RFLPs**

Selgitav videomaterjal

- Keemiline vooluallikas
  http://www.chemicum.com/?video=95&lan=EE
- Vesinik-hapnik kütuseelement
  http://www.chemicum.com/?video=96&lan=EE
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  http://www.chemicum.com/?v=Superkondensaatori_teadus.flv&lan=EE

Demonstratsioonkatse või praktikum

Teeme ise:

- Sidruni(kartuli)patarei: sidrun, vaskplaat, tsinkplaat
- Vesinik-hapnik kütuseelement: Väävelhappe lahus, plaatinaelektroodid, klaasist V-toru klaasmembraaniga, hapniku- ja vesinikuballoon, voolikud ja klaastorud.
- Alumiinum-õhk patarei: süsielektroodid, alumiiniumfoolium, Toru-Siil, keedusool, anum, Tic-Tac tops
- Superkondensaator: süsielektroodid (veefilter, sõel, EPO, kruustangid), kätepaber, Toru-Siil, Tic-Tac, kiirEPO. Täielik valmistamine nõuab 2 päeva liimide kuivamise tõttu. Esimene laadimine kestab ka ööpäev.

-> krokodillidega juhtmed ja tester

Ja käivitame lambi, mootori või heligeneraatori

Millega tegeldakse Chemicumis

- Kütuseelemendid – prof. Enn Lust
- Superkondensaatorid – van. teadur Alar Jänes
- Kõigega – teadur Tavo Romann