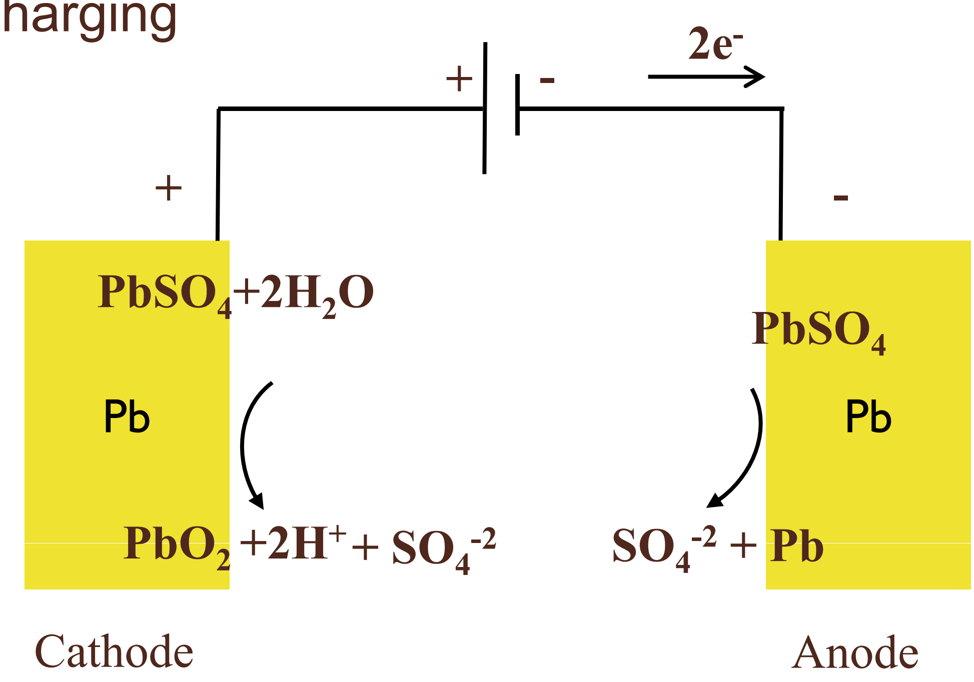
4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Batteries: Pb-S

Charging



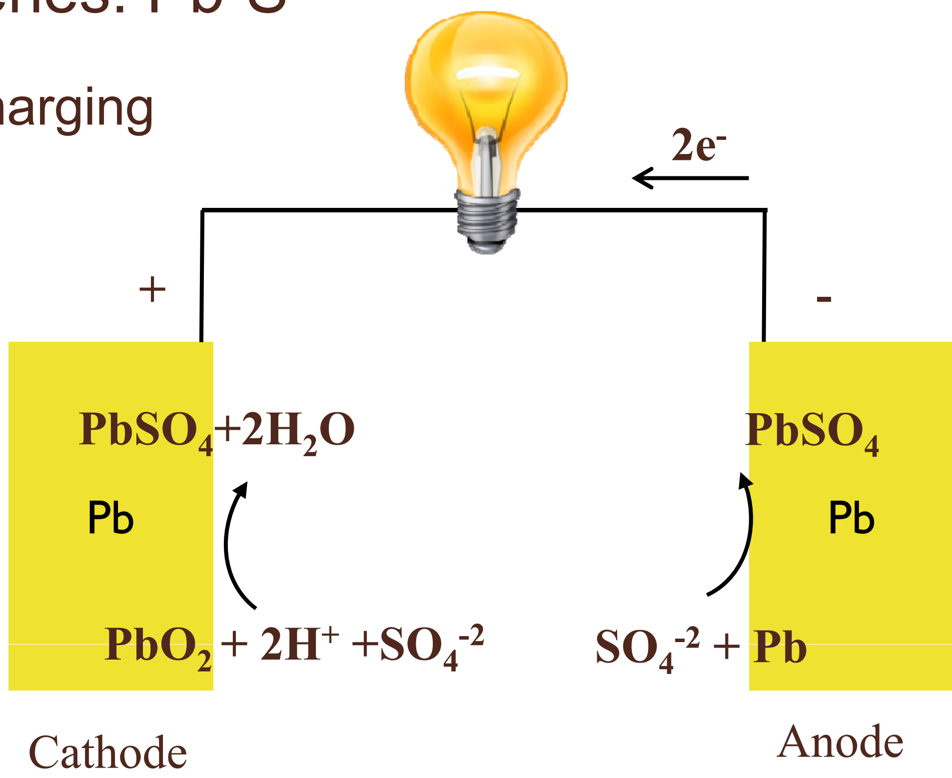
https://www.youtube.com/watch?v=1Bx5pOajdzg
https://www.youtube.com/watch?v=3zd-rCr8RgE
https://www.youtube.com/watch?v=HhxtfULIO7c

4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Batteries: Pb-S

discharging



https://www.youtube.com/watch?v=4IgHj2Uim_0

4. Applications with organic, inorganic and hybrid materials

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4.5 Batteries and Supercapacitors

Where the voltage comes from?

STANDARD REDUCTION POTENTIALS IN AQUEOUS SOLUTION AT 25°C

Half-reaction			$E°$(V)
$F_2(g) + 2\,e^-$	→	$2\,F^-$	2.87
$Co^{3+} + e^-$	→	Co^{2+}	1.82
$Au^{3+} + 3\,e^-$	→	$Au(s)$	1.50
$Cl_2(g) + 2\,e^-$	→	$2\,Cl^-$	1.36
$O_2(g) + 4\,H^+ + 4\,e^-$	→	$2\,H_2O(l)$	1.23
$Br_2(l) + 2\,e^-$	→	$2\,Br^-$	1.07
$2\,Hg^{2+} + 2\,e^-$	→	Hg_2^{2+}	0.92
$Hg^{2+} + 2\,e^-$	→	$Hg(l)$	0.85
$Ag^+ + e^-$	→	$Ag(s)$	0.80
$Hg_2^{2+} + 2\,e^-$	→	$2\,Hg(l)$	0.79
$Fe^{3+} + e^-$	→	Fe^{2+}	0.77
$I_2(s) + 2\,e^-$	→	$2\,I^-$	0.53
$Cu^+ + e^-$	→	$Cu(s)$	0.52
$Cu^{2+} + 2\,e^-$	→	$Cu(s)$	0.34
$Cu^{2+} + e^-$	→	Cu^+	0.15
$Sn^{4+} + 2\,e^-$	→	Sn^{2+}	0.15
$S(s) + 2\,H^+ + 2\,e^-$	→	$H_2S(g)$	0.14
$2\,H^+ + 2\,e^-$	→	$H_2(g)$	0.00

Half-reaction			$E°$(V)
$2\,H^+ + 2\,e^-$	→	$H_2(g)$	0.00
$Pb^{2+} + 2\,e^-$	→	$Pb(s)$	−0.13
$Sn^{2+} + 2\,e^-$	→	$Sn(s)$	−0.14
$Ni^{2+} + 2\,e^-$	→	$Ni(s)$	−0.25
$Co^{2+} + 2\,e^-$	→	$Co(s)$	−0.28
$Tl^+ + e^-$	→	$Tl(s)$	−0.34
$Cd^{2+} + 2\,e^-$	→	$Cd(s)$	−0.40
$Cr^{3+} + e^-$	→	Cr^{2+}	−0.41
$Fe^{2+} + 2\,e^-$	→	$Fe(s)$	−0.44
$Cr^{3+} + 3\,e^-$	→	$Cr(s)$	−0.74
$Zn^{2+} + 2\,e^-$	→	$Zn(s)$	−0.76
$Mn^{2+} + 2\,e^-$	→	$Mn(s)$	−1.18
$Al^{3+} + 3\,e^-$	→	$Al(s)$	−1.66
$Be^{2+} + 2\,e^-$	→	$Be(s)$	−1.70
$Mg^{2+} + 2\,e^-$	→	$Mg(s)$	−2.37
$Na^+ + e^-$	→	$Na(s)$	−2.71
$Ca^{2+} + 2\,e^-$	→	$Ca(s)$	−2.87
$Sr^{2+} + 2\,e^-$	→	$Sr(s)$	−2.89
$Ba^{2+} + 2\,e^-$	→	$Ba(s)$	−2.90
$Rb^+ + e^-$	→	$Rb(s)$	−2.92
$K^+ + e^-$	→	$K(s)$	−2.92
$Cs^+ + e^-$	→	$Cs(s)$	−2.92
$Li^+ + e^-$	→	$Li(s)$	−3.05

http://www.sparknotes.com/testprep/books/sat2/chemistry/chapter6section7.rhtml

4. Applications with organic, inorganic and hybrid materials

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4.5 Batteries and Supercapacitors

Batteries: the voltage

Anode	$PbO_2 + 2\ H_2SO_4 + 2\ e^- \xrightarrow{discharge}$	$2\ H_2O + PbSO_4 + SO_4^{2-}$	+ 1.69 V
Cathode	$Pb + SO_4^{2-} \xleftarrow[charge]{}$	$PbSO_4 + 2\ e^-$	- 0.36 V
		$V_{max}=$	+ 2.05 V

Stored energy: 40 Wh/kg

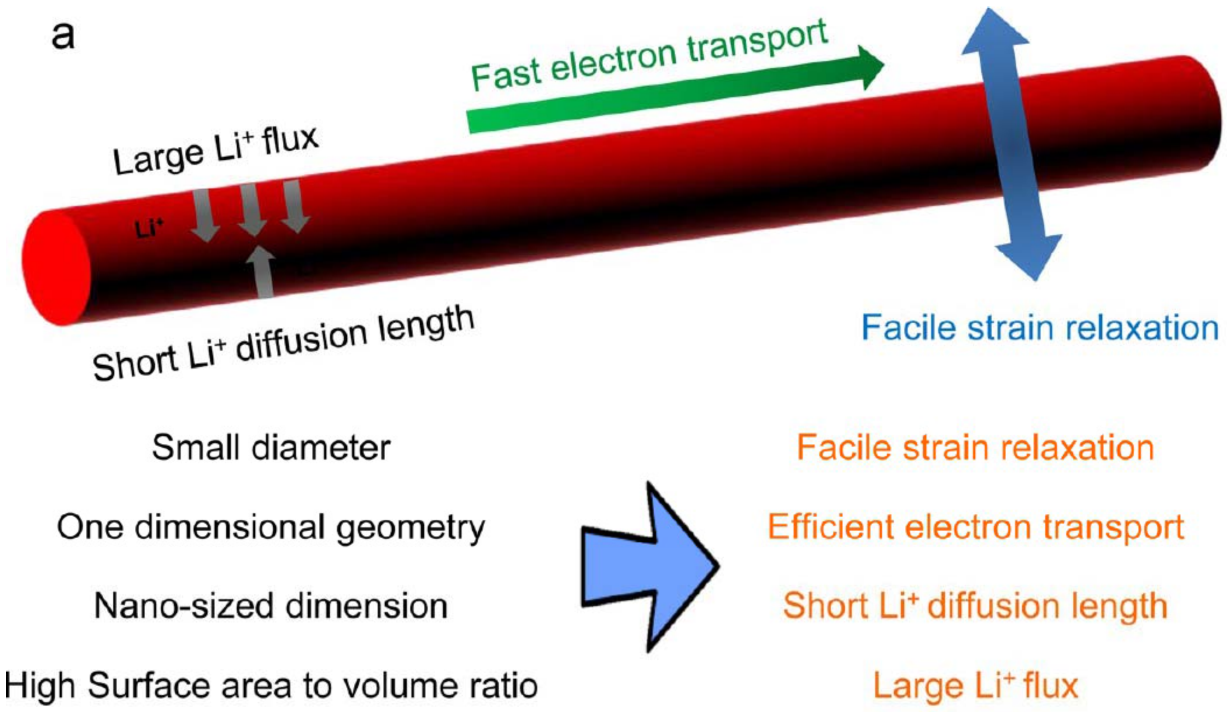
Anode:	$LiCoO_2 \xrightarrow{discharge}$	$Li_{1-x}CoO_2 + xLi^+ + xe^-$	+ 0.7 to +1.3 V
Cathode:	$C_6 + xLi^+ + xe^- \xleftarrow[charge]{}$	Li_xC_6	- 2.8 to -2.9 V
		$V_{max}=$	+ 3.5 to +4.2 V

Stored energy: 110 Wh/kg

4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Batteries: Li-Si

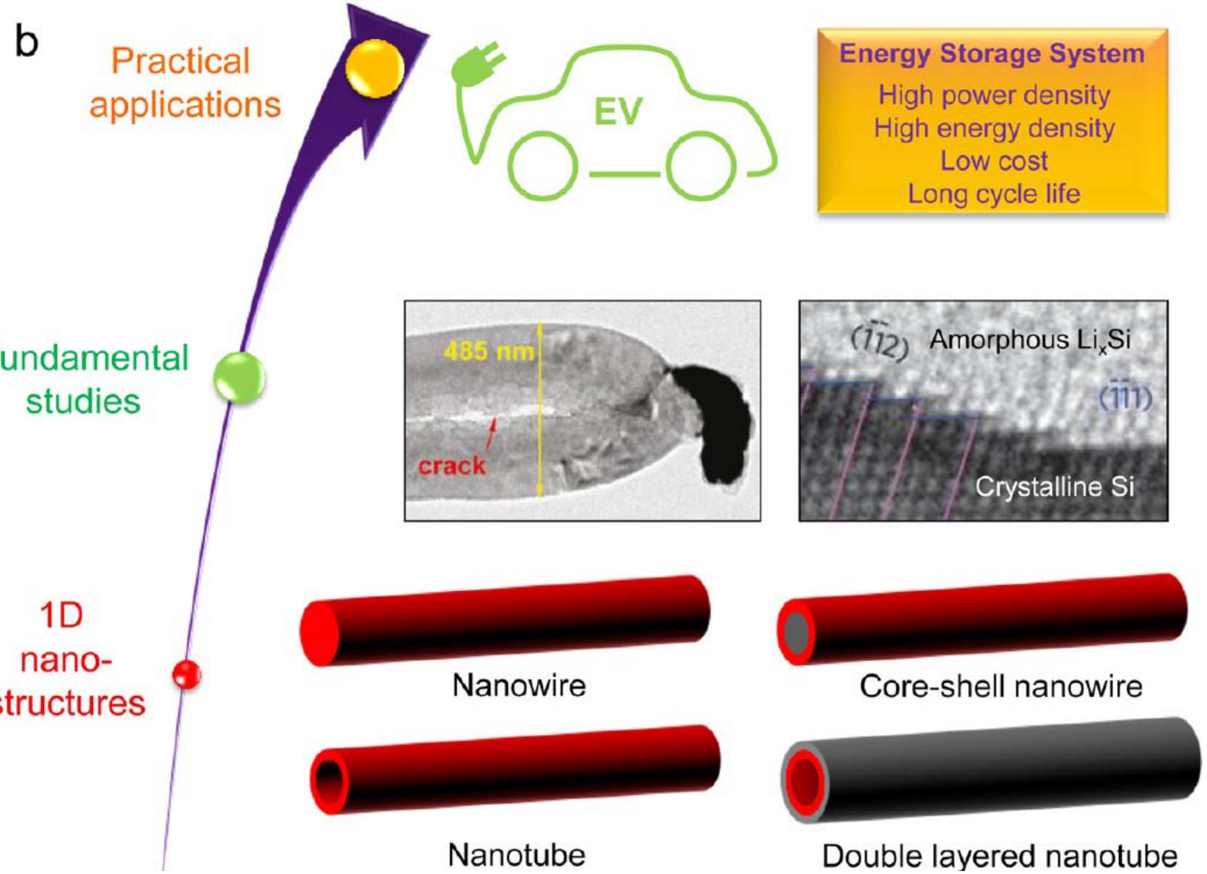


Song et al. J. Phys. Chem. Lett. 2014, 5, 720−731

4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Batteries: Li-Si

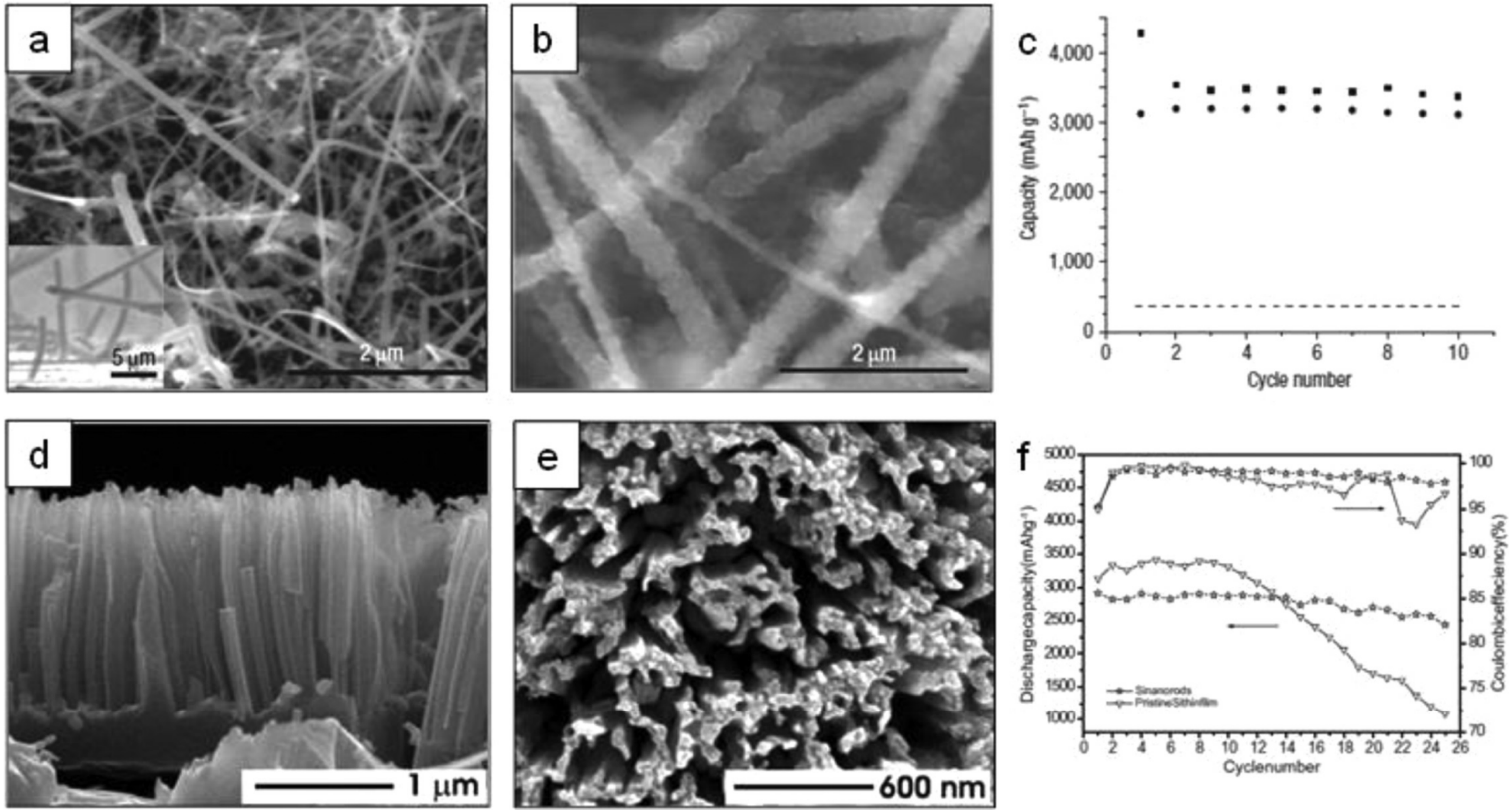


Song et al. J. Phys. Chem. Lett. 2014, 5, 720−731

4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Batteries: Li-Si



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4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

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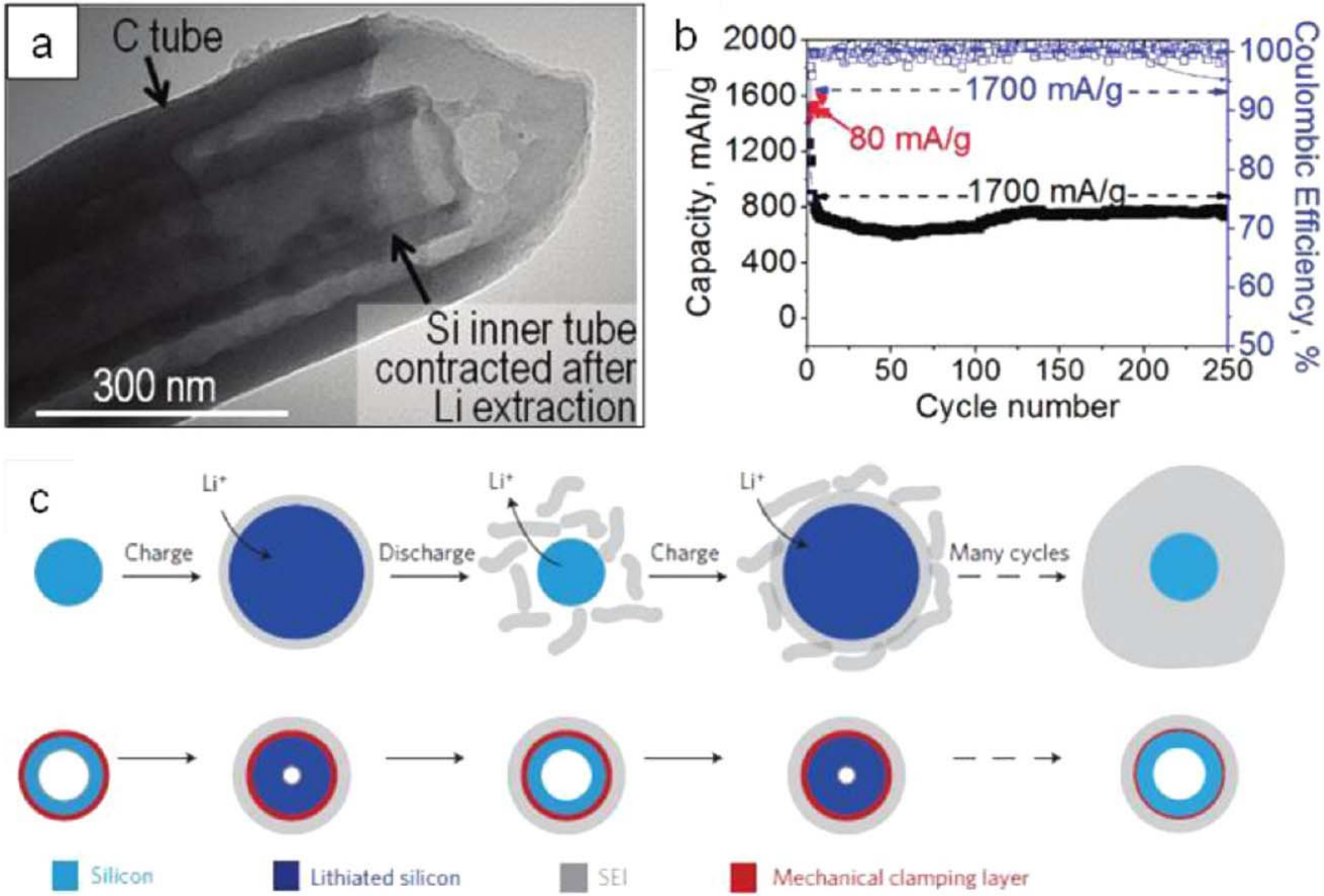
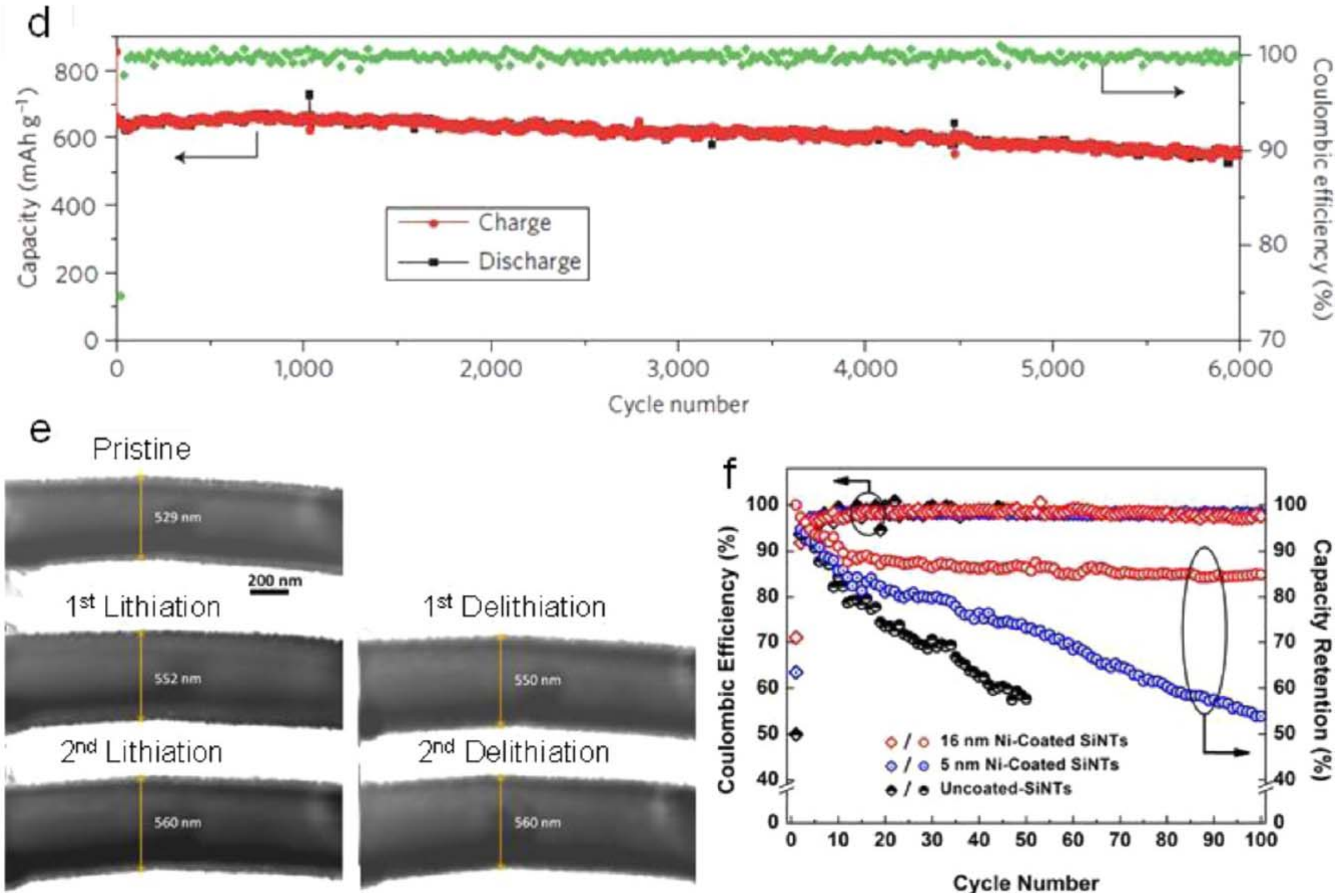


4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Batteries: Li-Si



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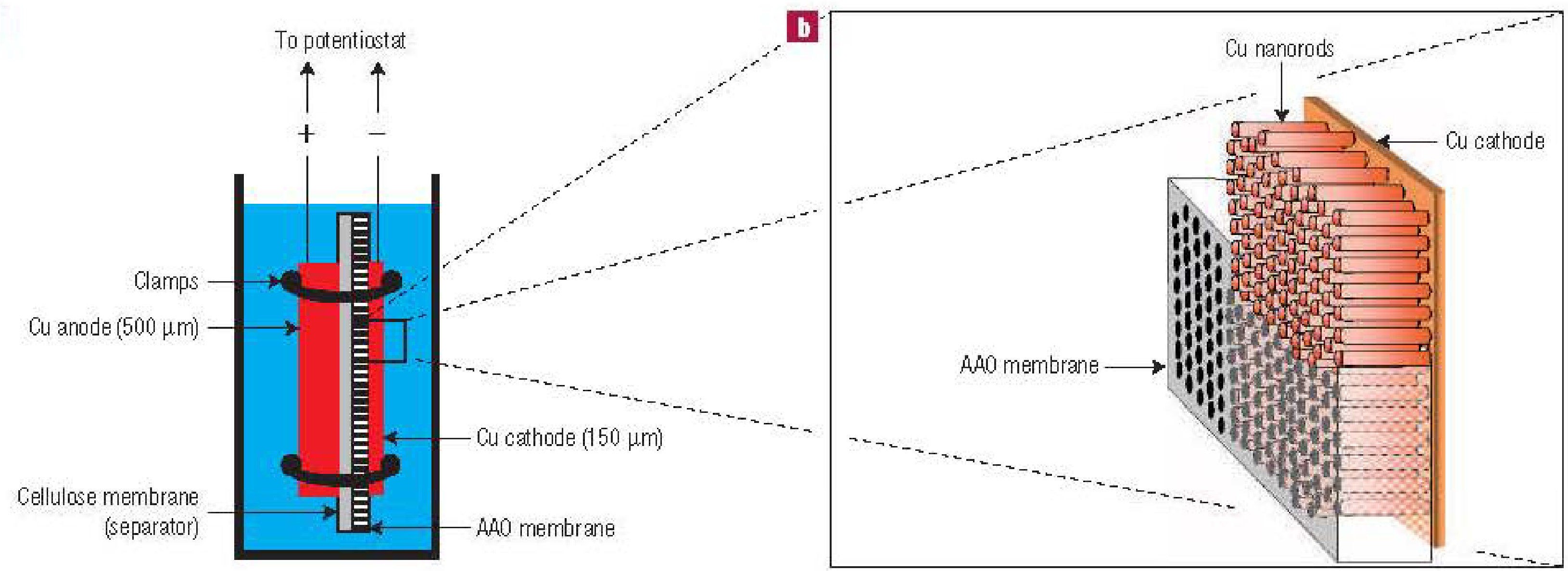
4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Batteries

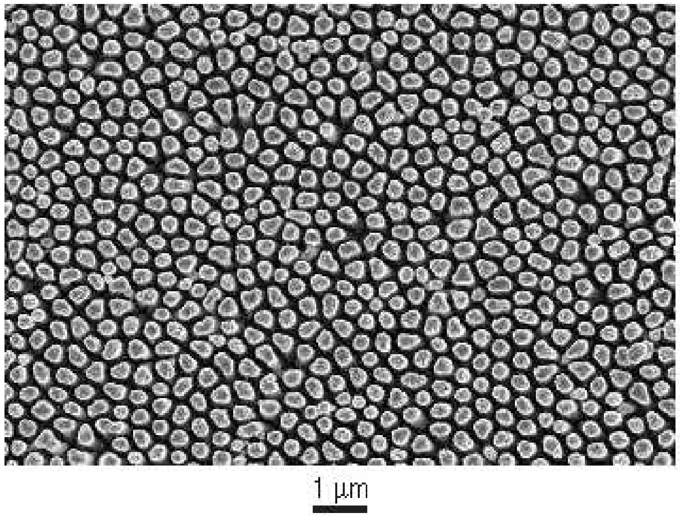


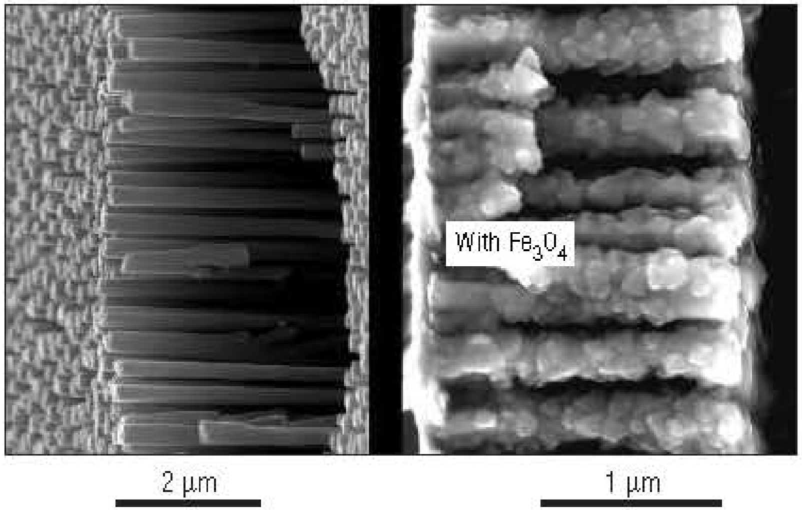
http://dx.doi.org/10.1038/nmat1672

4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Batteries: nano- Li-Cu/Fe_3O_4



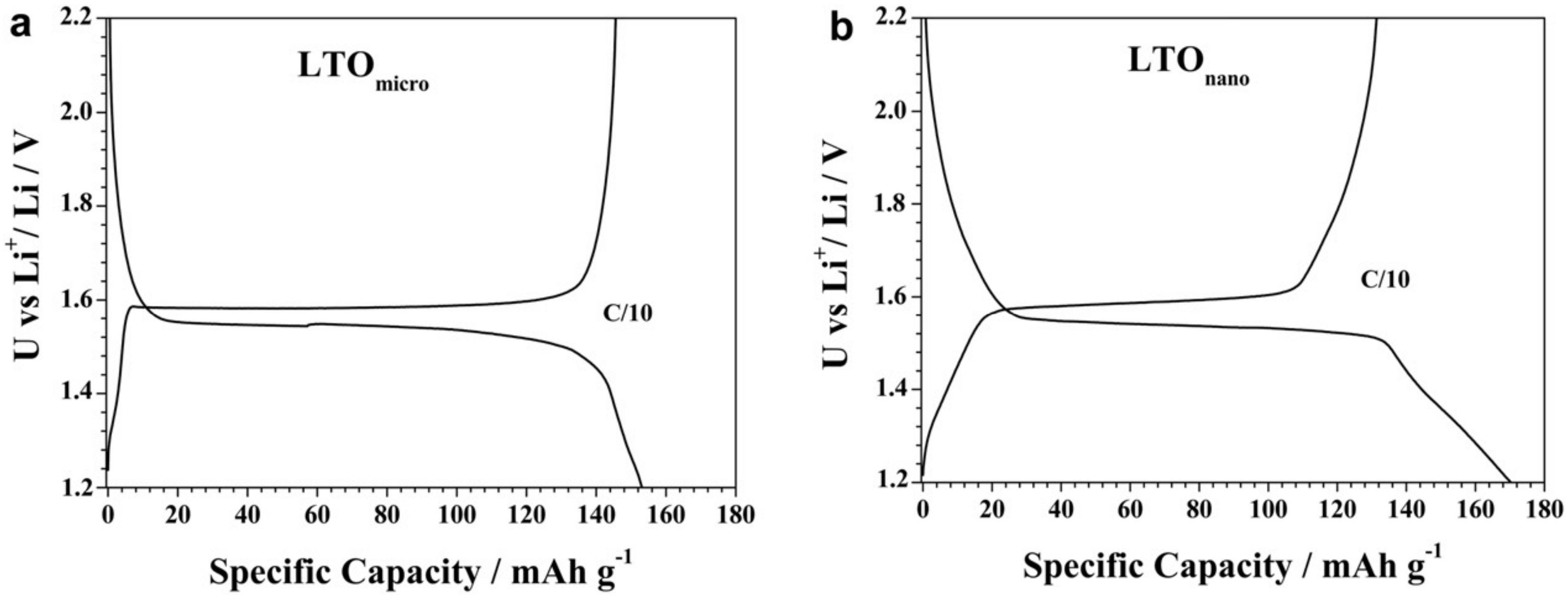


http://dx.doi.org/10.1038/nmat1672

4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Batteries: nano structured $Li_4Ti_5O_{12}$ (LTO)

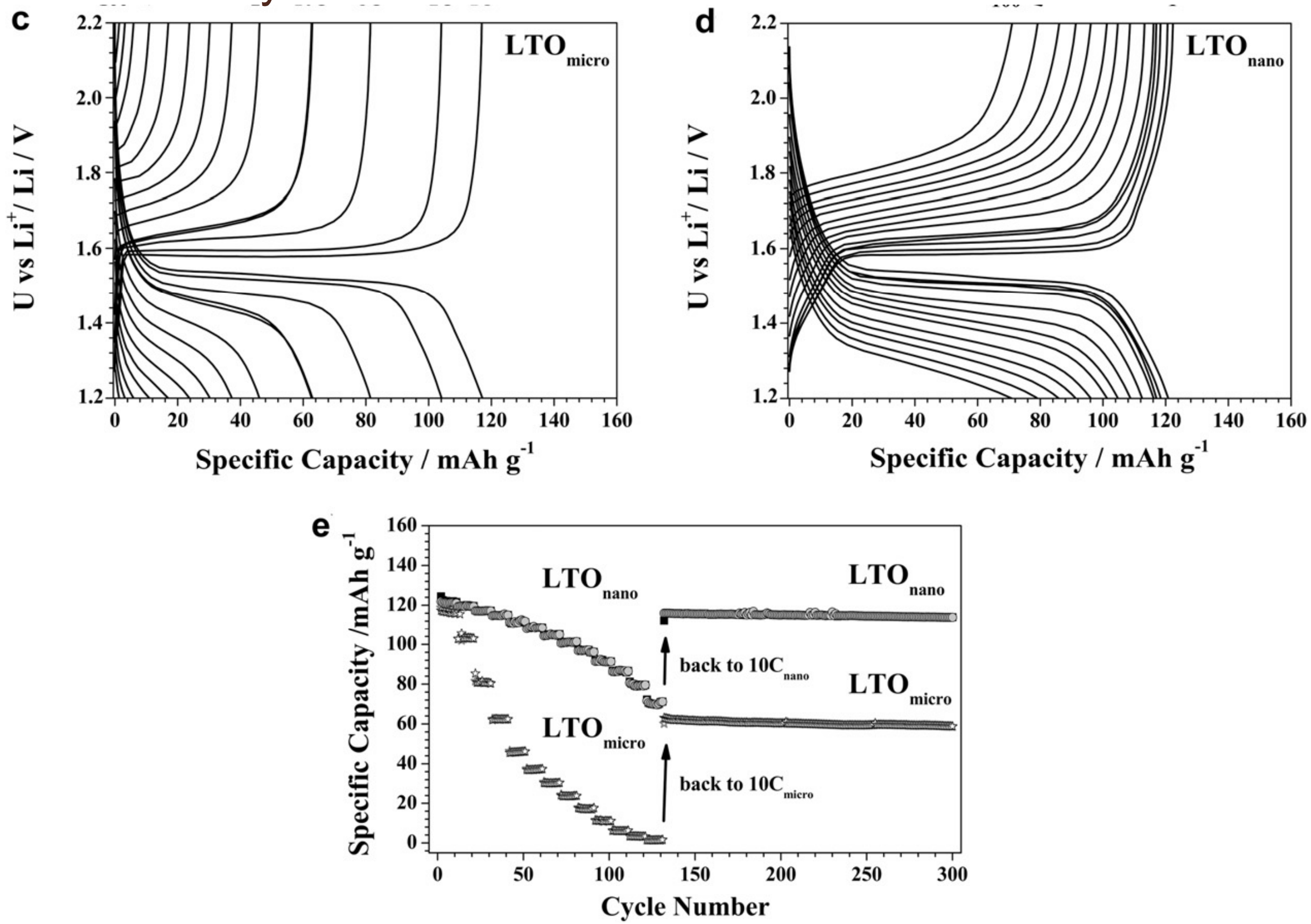


D. Bresser et al. / Journal of Power Sources 219 (2012) 217e222

4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Charge rates and ciclability

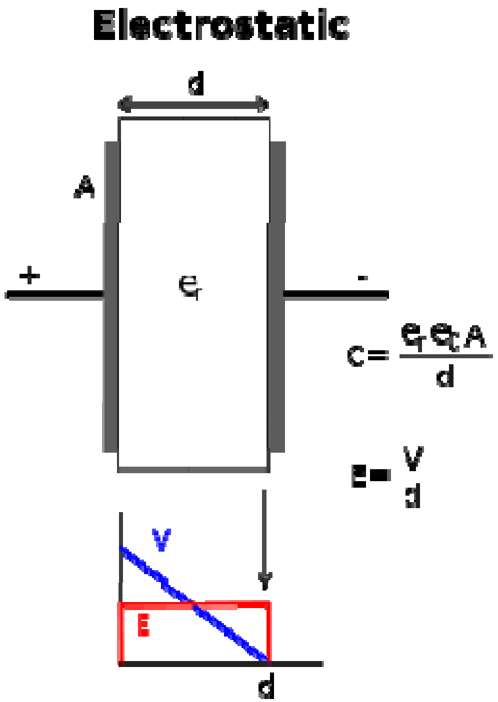


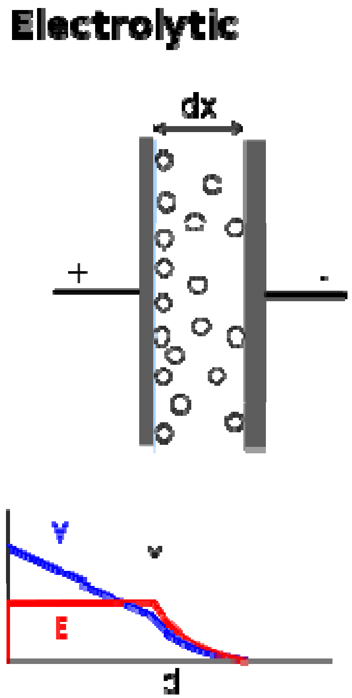
D. Bresser et al. / Journal of Power Sources 219 (2012) 217e222

4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Supercapacitors

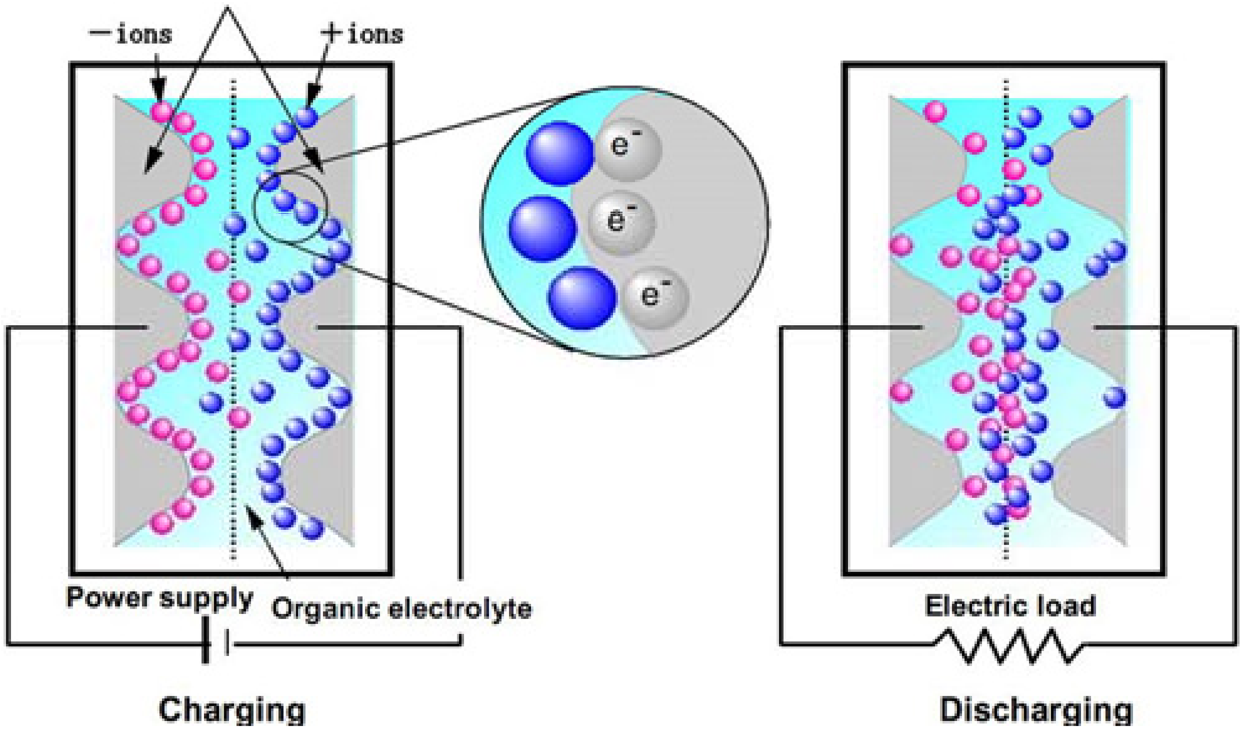




4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Supercapacitors

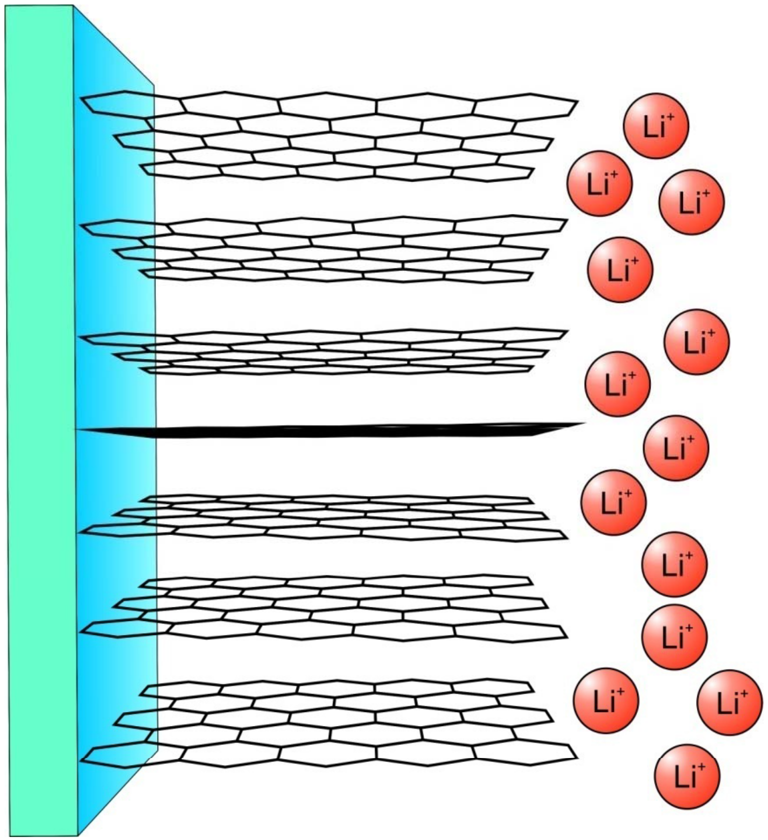


4. Applications with organic, inorganic and hybrid materials

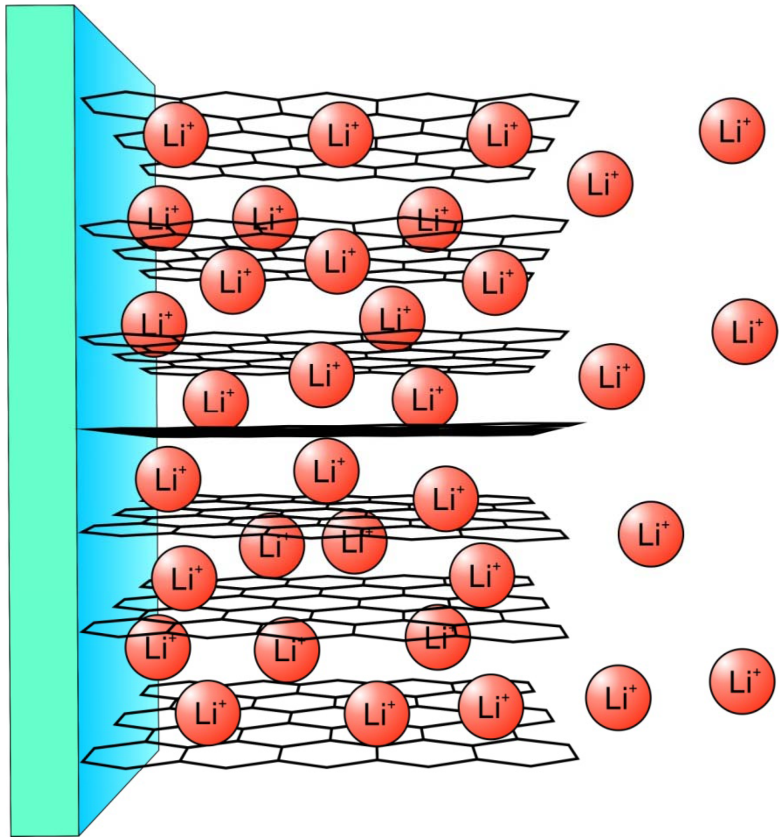
4.5 Batteries and Supercapacitors

Supercapacitors

Graphite electrodes inmmersed in solution



Discharged

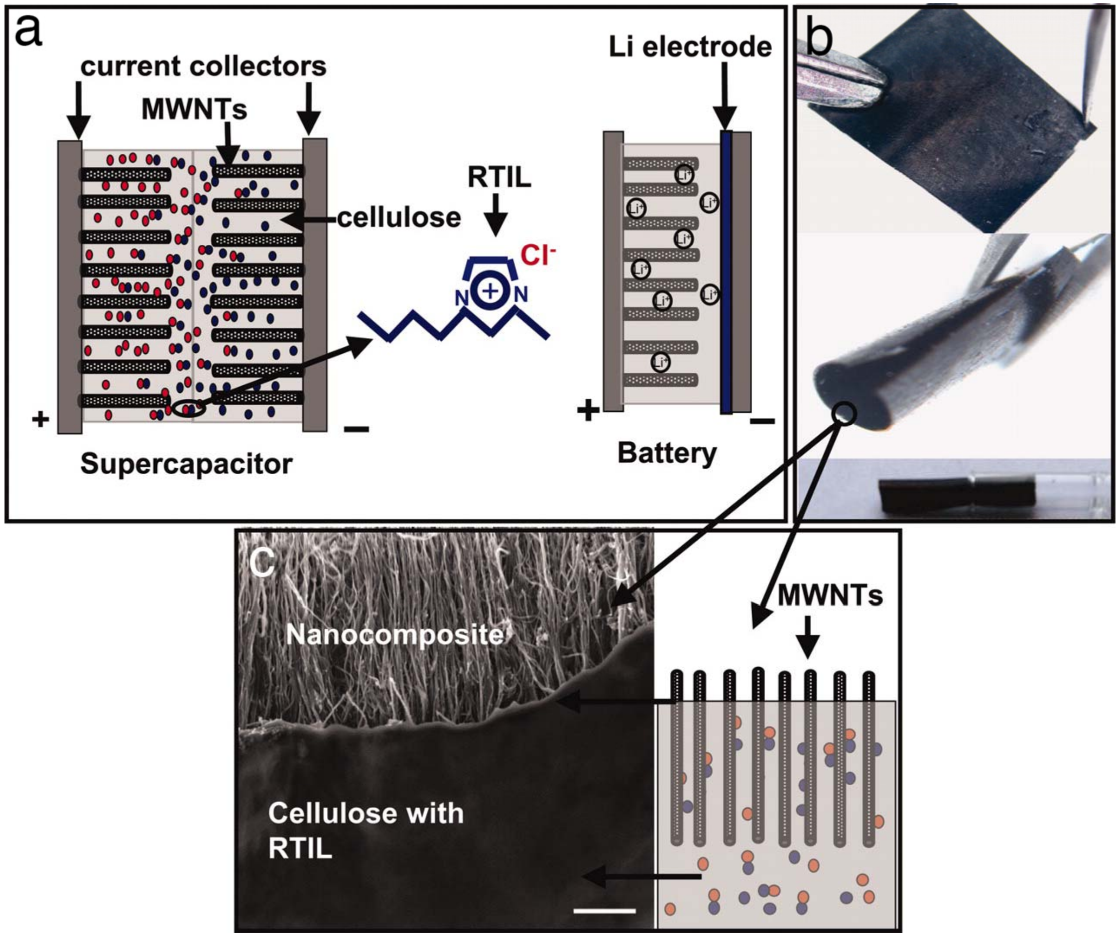


Charged

4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

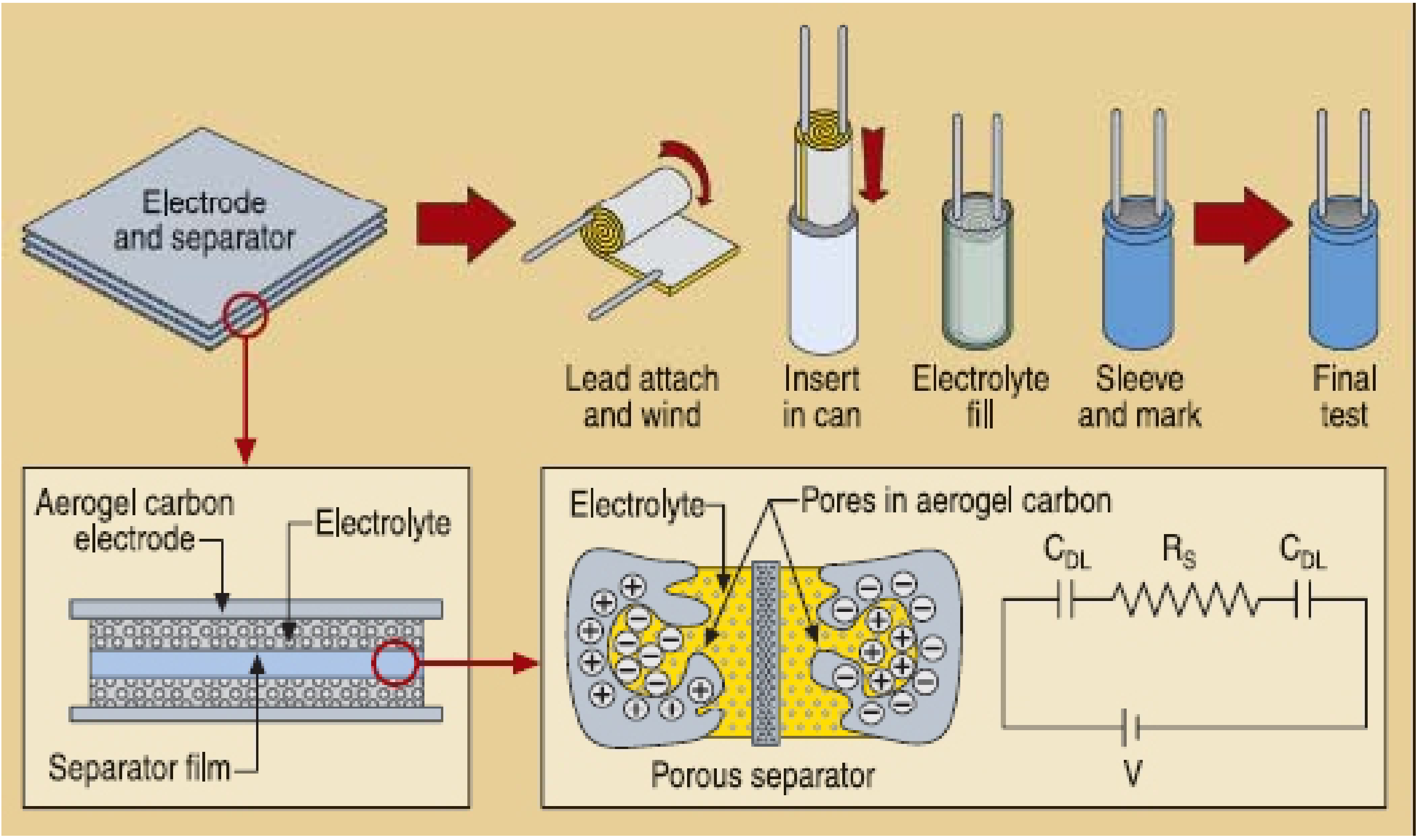
Supercapacitors



4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

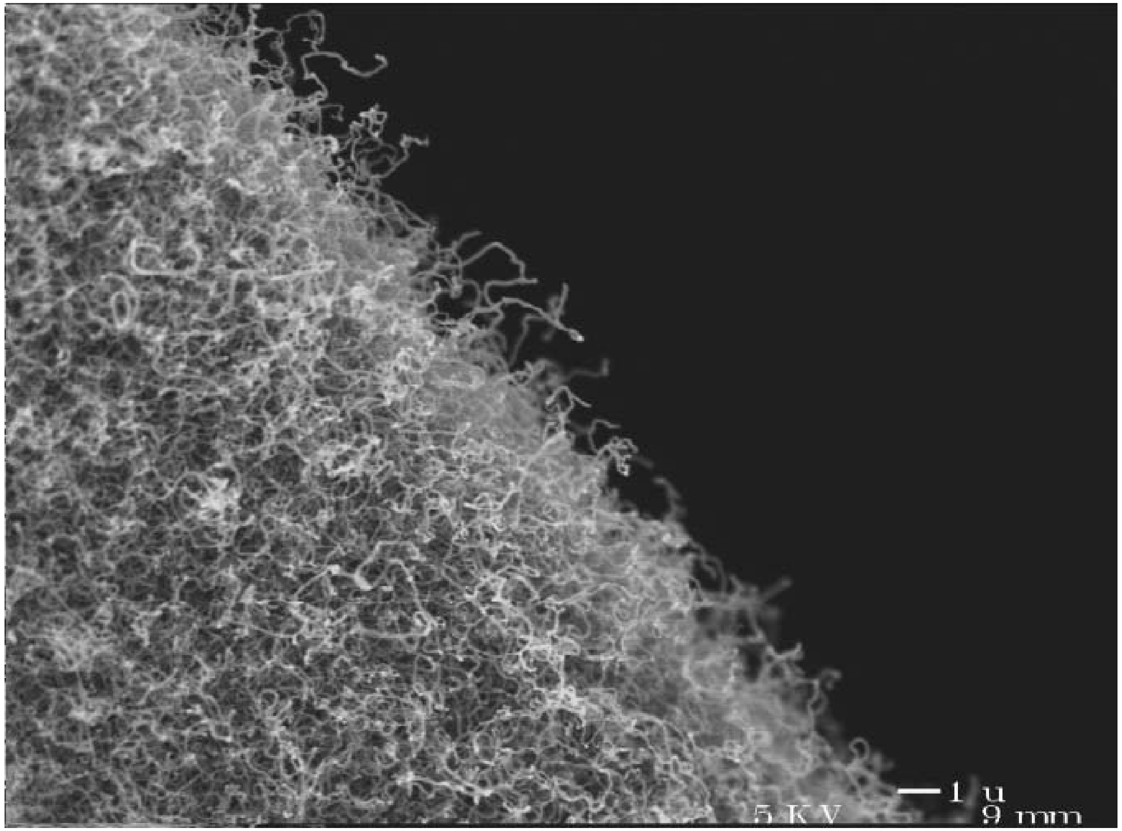
Supercapacitors



4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Supercapacitors



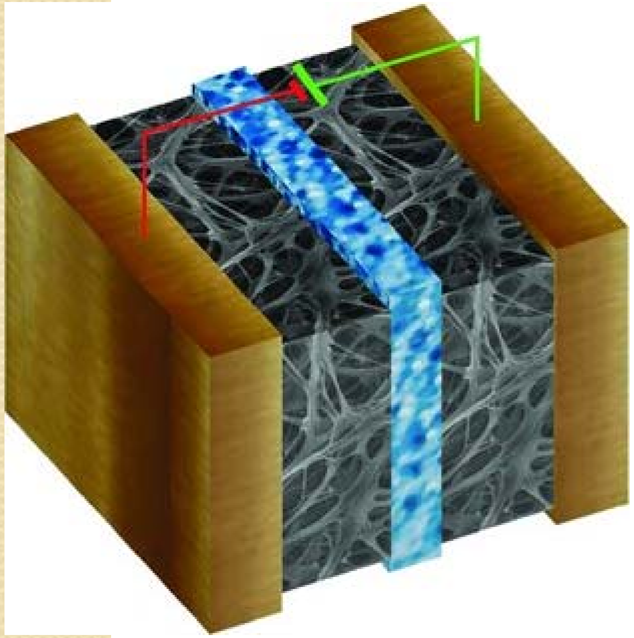
Carbon Nanotubes Grown Directly on an Fe-Doped Carbon Aerogel

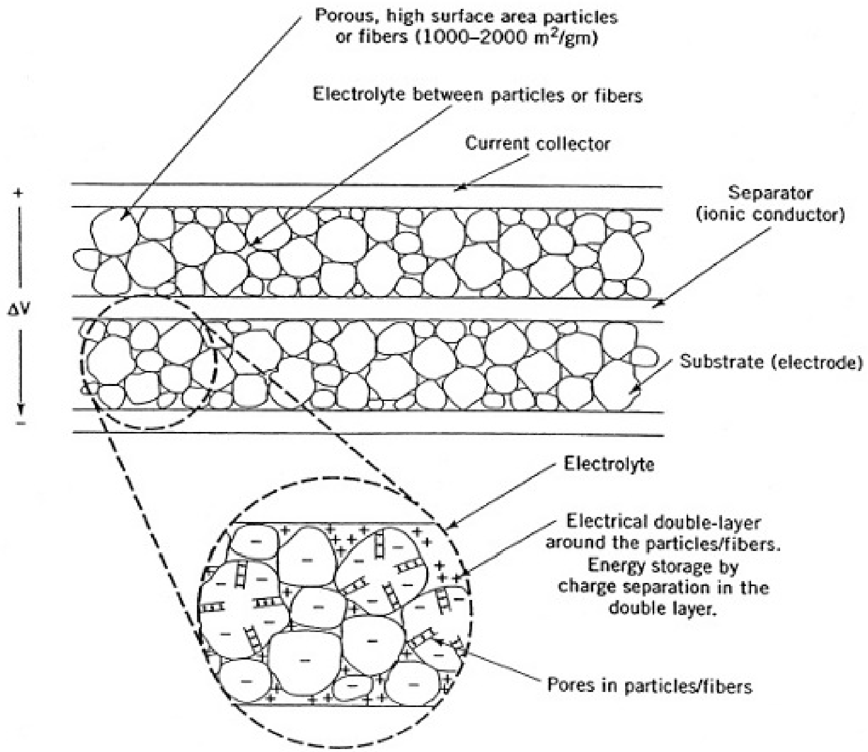
http://www.aerogel.org/?p=71

4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Supercapacitors



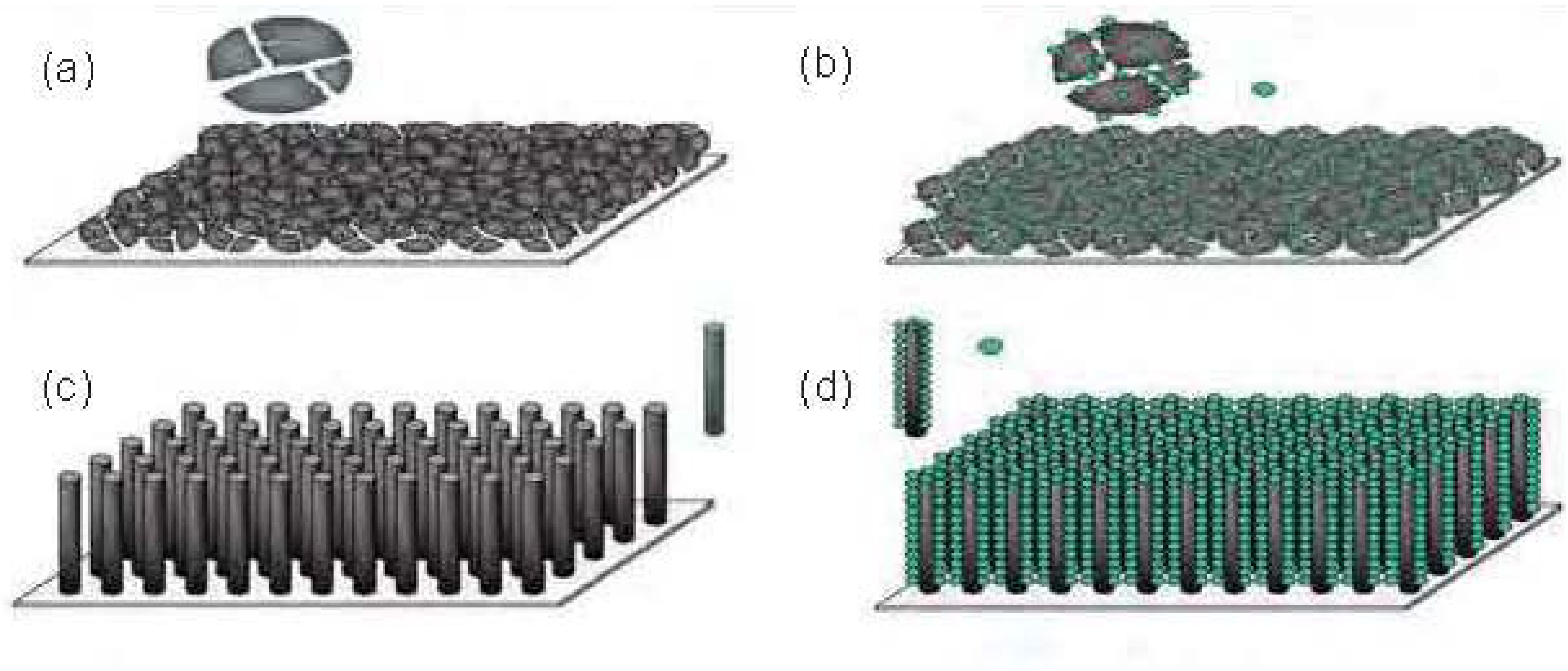


http://www.intechopen.com/books/carbon-nanotubes/carbon-nanotube-supercapacitors

4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Supercapacitors



4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Supercapacitors:

Energy storage

$$E = \frac{1}{2} C V_{dc}^{2} \rightarrow E = \frac{1}{2} C (V_{\max}^{2} - V_{\min}^{2})$$

E(y2014) = 15-30 Wh/kg

Power

$$P_{eff} = \frac{1}{8} \frac{V^{2}}{R_{i}} \approx 15 \text{ kW/kg}$$

https://www.youtube.com/watch?v=EoWMF3VkI6U
https://www.youtube.com/watch?v=RzGpfi4OkPY
https://www.youtube.com/watch?v=jpy8G3yBeJ4

4. Applications with organic, inorganic and hybrid materials

4.5 Batteries and Supercapacitors

Comparison