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Microbattery Materials and Future Directions

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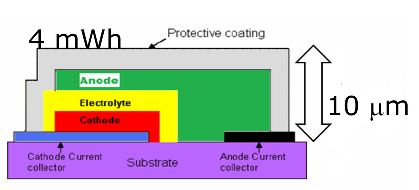
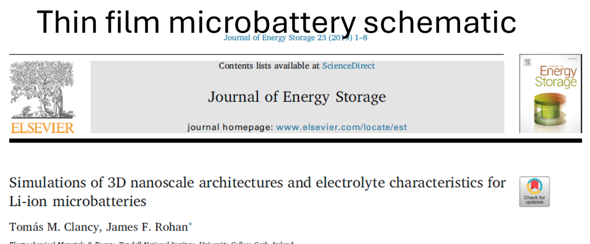
ABSTRACT: Microbatteries have been used to power a wide range of Internet of Things devices. As energy harvesting technology improves, the possibility of incorporating rechargeable batteries becomes a reality. Developing and testing novel battery materials is typically a time-consuming task. Microelectrodes have been used in sensor applications for rapid testing. Here we have developed a nickel microelectrode disc array (MDA) which is compatible with lithium chemistries.

Microbatteries for IoT applications



Thin film microbattery schematic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Simulations of 3D nanoscale architectures and electrolyte characteristics for Li-ion microbatteries
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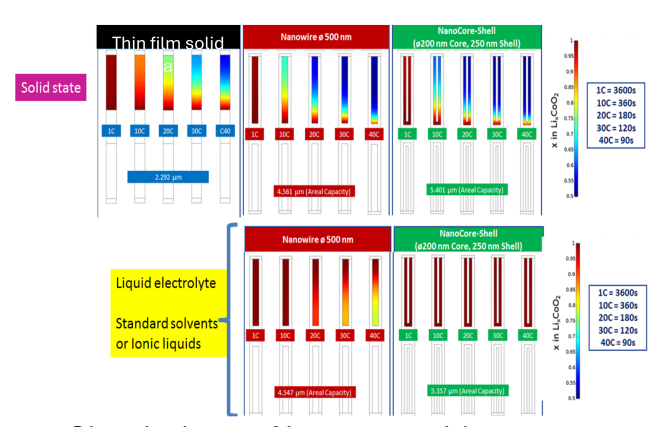


Simulations of battery architectures

Company		Ilika			iTen	Cymbet		TDK
Battery model		Stereax M50	Stereax M250	Stereax M300 (stacked)	ITX121010B or customisable	CBC005	CBC050	CeraCharge 1812
Solid state		Y	Y	Y	Y	Y	Y	Y
Packaged		-	-	-	Surface Mount	Bare Die	Bare Die	Y
Dimensions	Thickness (μm)	50	< 750	900	800	200	200	1100
	Length (mm)	5.5	12	5.5	3.2	2.25	6.1	4.4
	Width (mm)	3.5	12	3.5	2.5	1.7	5.7	3
	Area (mm^2)	19.25	144	19.25	8	3.825	34.77	13.2
Rated capacity	μAh	50	250	300	100	5	50	100
Voltage range	V	3 to 4	3.5	3 to 4	2.5	3.8	3.8	1.5
Internal resistance(25°C)	Ω	900	120	150	low - not specified	7000	500	low - not specified
Discharge current	μA	50	250	300	Customisable	5	100	100
Peak current	mA	1	5	6	100	0.1	1	5
Max. current continuous	mA	0.5	-	3	Customisable	0.02	0.2	0.02
Cycle life (20 – 40°C)		> 400 (100% DoD to 80% capacity)	> 500 (100% DoD to 80% capacity)	> 400 (100% DoD to 80% capacity)	1000 (100% DoD to 80% capacity)	500 (50% DoD)	500 (50% DoD)	1000 (90% DoD)

Commercial microbattery specifications and outputs

Roadmap for new large-scale battery materials

by 2025 | by 2030

Generation	1	2		3		4			5
		2a	2b	3a	3b	4a	4b	4c	
Type	Current	Current	State-of-The-Art	Advanced Lion HC	Advanced Lion HC	Solid State			Beyond Li-ion
Expected Commercialisation	Commercialised	Commercialised		2020	2025	>2025			
Cathode	NMC/NCA LFP LMO	NMC111	NMC424 NMC523	NMC622 NMC811	HE NMC Li-rich NMC HVS	NMC	NMC	HE NMC	
Anode	Modifed Gaphite $Li_4Ti_5O_{12}$	Modified Graphite	Modified Graphite	NMC910 Carbon (Graphite)+Si	Silicon/Carbon (C/Si)	Silicon/Carbon (C/Si)	Li metal		Li metal
Electrolyte	Organic LiPF6salts			(5-10%)	Organic+ Additives	Solid electrolyte -Polymer (+Additives) -Inogranic -Hybrid			
Separator	Porous Polymer Membranes								

Source: Nationale Plattform Elektromobilität, Marcel Meeus, JRC.

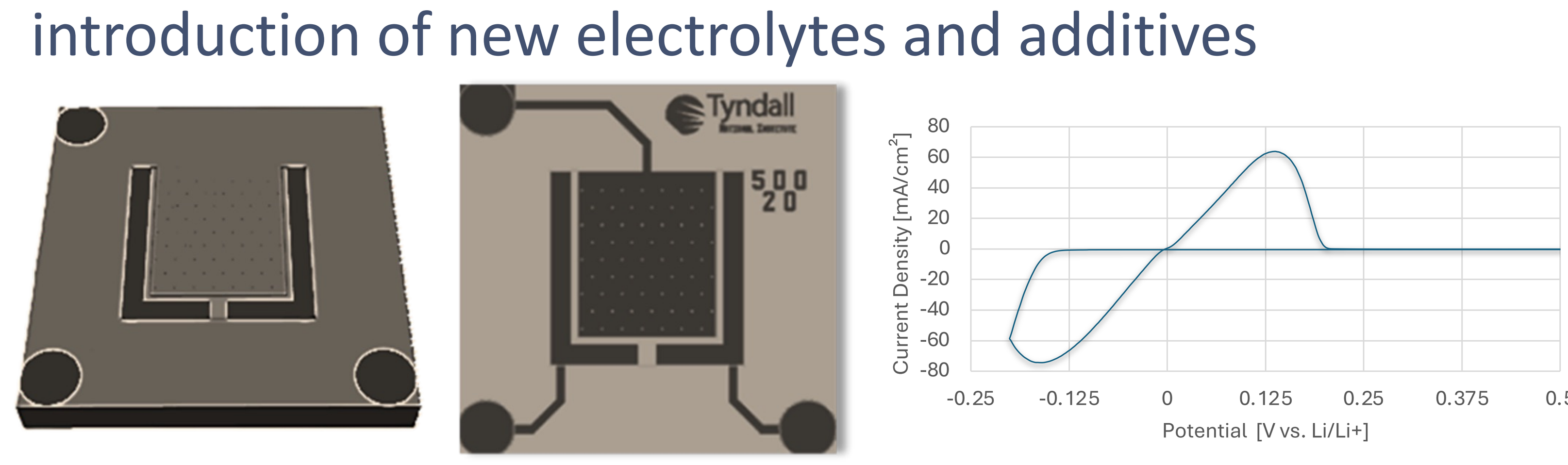
90 to 235 Wh/kg 200 to 630 Wh/l	350 Wh/kg 750 Wh/l	500 Wh/kg 1000 Wh/l

Microelectrodes for accelerated battery testing

Evaluating potential battery materials can be a time-consuming process, due to the low conductivity of the electrode and electrolyte materials. Many materials behave poorly at high charge rates when tested with typical large electrodes. Microelectrodes allow for more rapid analysis thanks to the improved diffusion and low current which minimises (iR) resistive losses or voltage distortions during rapid cycling.

Lithium metal cycling tests

The Ni MDA were first tested in a 1M $LiPF_6$:EC:DEC solvent electrolyte. Lithium plating tests were carried out and successfully cycled through over 50 plating/stripping cycles at 20 mV/s. Each cycle takes 1 minute. This MDA test chip will enable a range of lithium and post-lithium battery chemistries to be tested rapidly for the introduction of new electrolytes and additives



Microdisc array and cyclic voltammogram of Lithium metal plating on the Ni MDA at scan rate of 20 mV/s

Summary

- Microbatteries are generally ahead (solid-state) of larger scale batteries like EV cells. New materials, architectures and processing are still required to optimise energy per unit area/volume to match with the IoT applications.
- Testing new battery materials is a time-intensive process, hindering the use of novel, sustainable battery materials
- Microelectrodes provide a method for improved electrochemical testing.
- This microelectrode array is capable of testing lithium metal plating for next generation solid state batteries, introducing the possibility for rapid battery materials testing in the future.

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