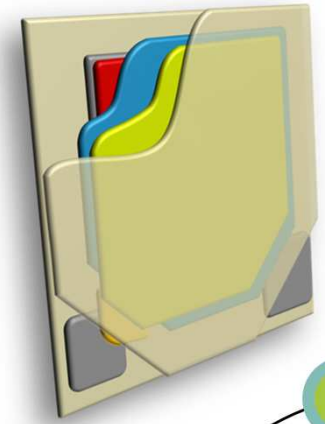
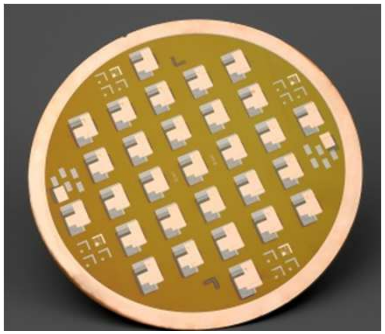
Overview of lithium microbatteries: components, manufacturing and applications

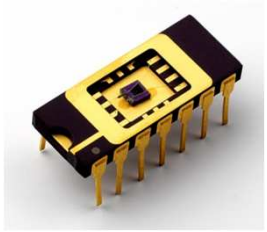
Dr Raphaël Salot, CEA-LETI

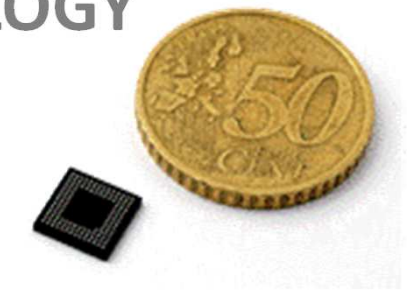
SiNERGY Workshop in LET'S 2014 conference





THIN FILM BATTERY TECHNOLOGY





R&D ON THIN FILM BATTERY

APPLICATIONS

MANUFACTURING CAPABILITIES

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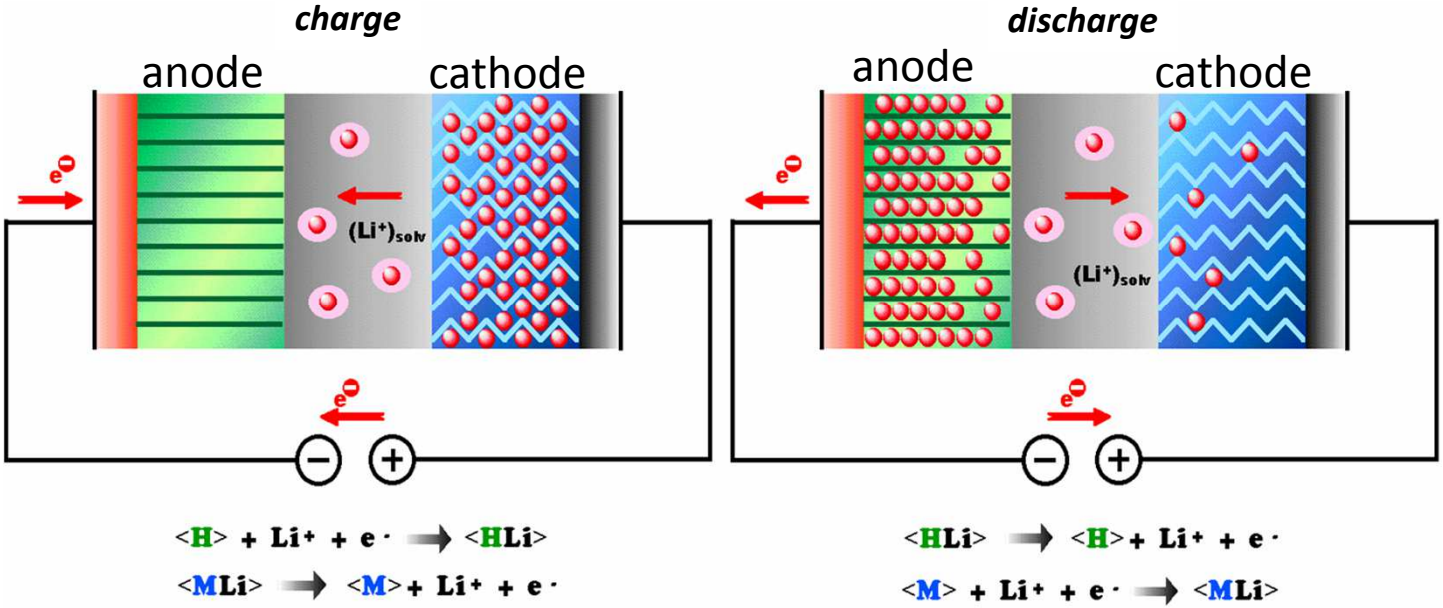
Lithium – Ion rechargeable battery concept

Operating principle



1. The anode and cathode materials have reversible Li ions insertion / extraction capability.
2. At each charge / discharge cycle, the Li ions flow from one electrode to the other through the electrolyte.
3. The electrolyte has a low electronic conductivity and a high ionic conductivity. Electrons cannot go through the electrolyte.
4. An electronic current is generated in the external circuit to balance the internal ionic current.

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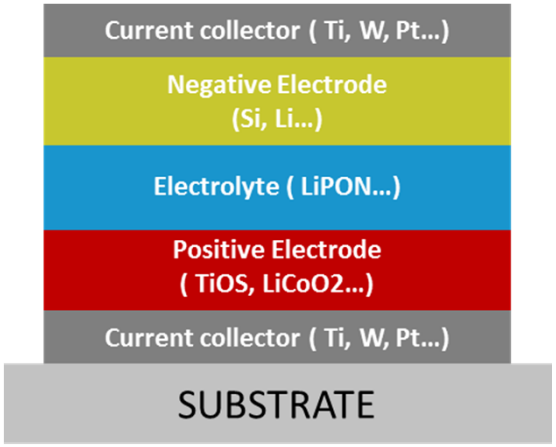
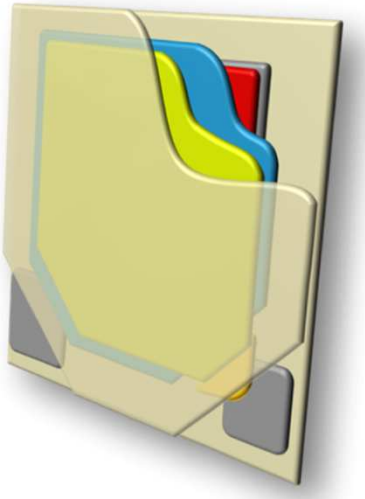
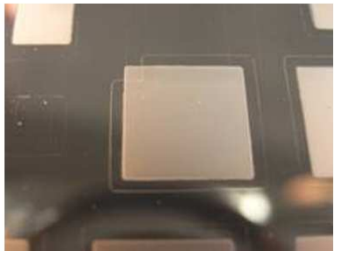
Li – ion thin film microbattery technology

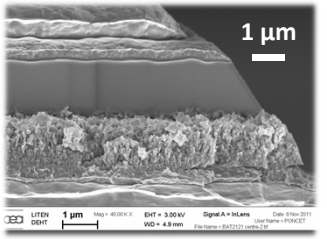
Typical layer stack crossview





- Lithium battery
  - Physics similar to classical lithium battery
- **Solid state battery**
  - No liquid: glassy lithiated electrolyte
- Thin film micro battery
  - Overall thickness : 5-20 µm
  - Manufacturing with industrial thin film deposition equipment





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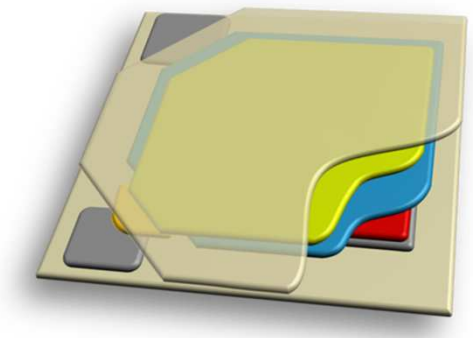
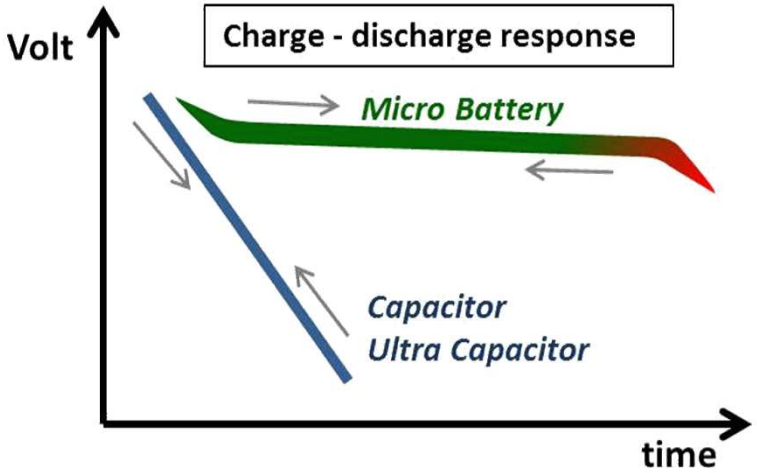
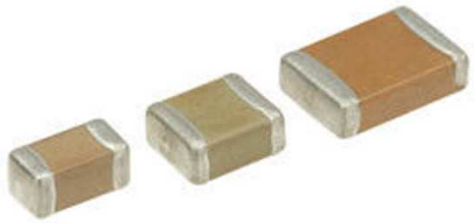
Thin Film rechargeable µbattery added value



Li-ion micro battery





surface mounted tantalum capacitor

- Safe & Reliable (100% solid state Lithium ion)
- Standalone component compatible with standard case packaging and low profile integration
- Bare Die for System In Package (above IC,3D, flexible foils)
- Compatible with 0 volt operation
- Compatible with assembly at > 250°C
- Ultra low self – discharge time (< 3% / an)
- Life cycles : 500 to > 10 000 cycles
- > 1mA/cm² peak capability
- Electronics friendly current or voltage charge

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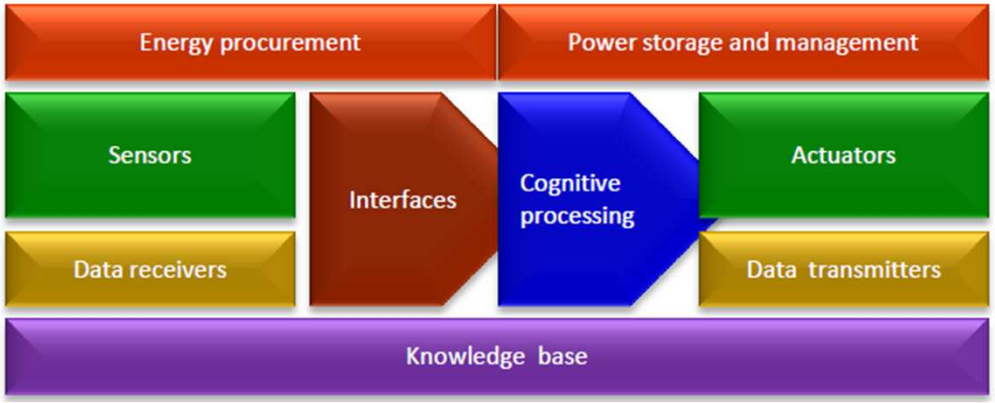
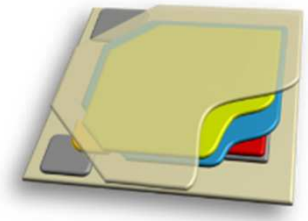
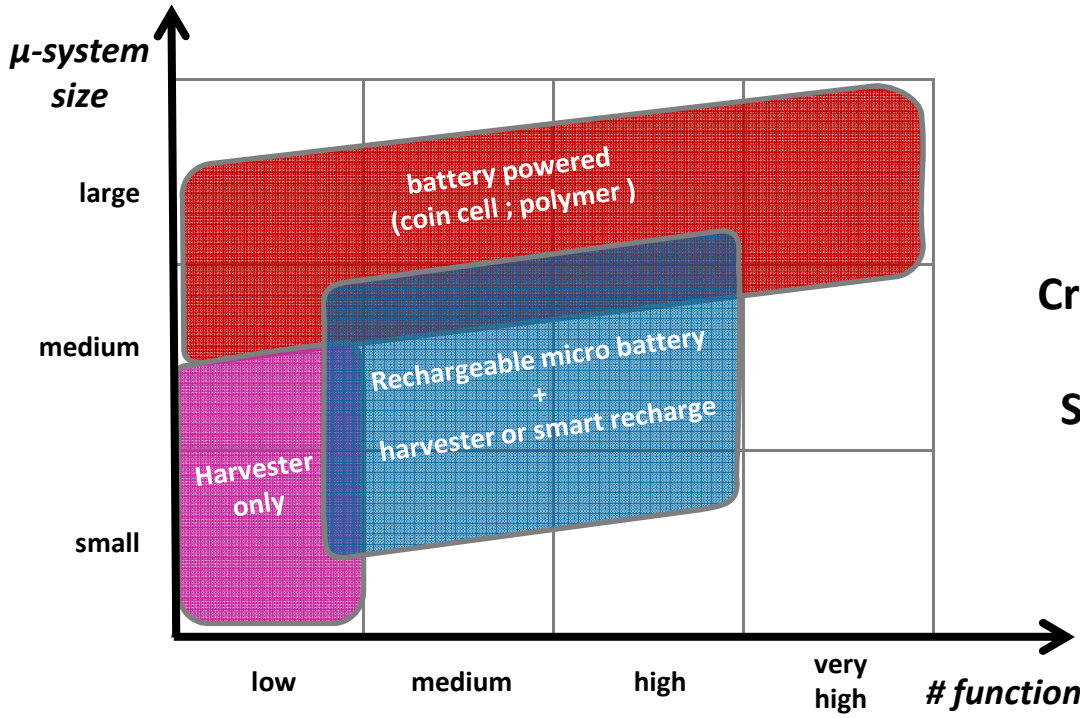
Embedded Solide State Rechargeable Micro Batteries : a Key Enabling Technology for Autonomous Smart Micro-Systems



µsystem block diagram, metrics and trends

$$\frac{\left(\begin{matrix}number\ of\\ functions\end{matrix}\right) \times \left(\begin{matrix}information\\ rate\end{matrix}\right)}{size}$$





Create innovative µsystem designs powered by SHAPEABLE and CUSTOMIZABLE rechargeable microbatteries

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Benchmark with competitive storage options

parameter	electrolytic capacitor	Super capacitor	Lithium – Ion batteries	Lithium – Ion micro batteries	*Lithium-Ion Micro Battery added value*
Solid-state electrolyte	NO	NO	NO	**YES**	• *Safety (explosion, chemical leakage), reliability, long life time* • *Operational temp. : -20°C to 70°C*
Voltage (V)	4 - 450	1.2 – 3.3	2.5 – 4.2	**1.5 – 4.2**	• *↗ energy efficiency and ↘ part counts of micro systems*
Capacity	1 F	0.1 F – 500 F			• *Capacity unit conversion : 10 m.Amp.hour = 36 Coulomb = 3.6 V x 10 Farad* • *1 RF zigbee pulse = 1 nAh* • *Stackable*
	0.5 mA.h @ 2V	25 µAh - 125mAh @1V	1 – 100 Ah	**3µAh – 20 mAh**	
Energy Density (Wh/l)	0.01 to 0.3	1 to 4	100 to 265	**20 to 50 @ 2' x 2' size**	
Recharge cycles	unlimited	> 10^5	500 to 10^4	**500 to > 10^4**	• *Amp.hour capability & long lifetime* • *charge time @60% capacity : ≅ 1 mn*
Self discharge time at 20°C	Short (day)	Middle (week)	Long (month)	**Very Long (year)**	• *systems with very long standby period w/o recharge possibility.*
Operating frequency	Medium	Low	Medium	**Medium**	• *> 1 mA / cm^2 peak current for pulsed data transmission*
Automatic PCB mounting	YES	SOME	NO	**YES**	• *Short-circuit compatible* • *Solder Reflow compatible*
Thickness & Surface	> cm > cm^2	> 1 mm 10 mm^2	> 1mm 10 cm^2	**≅ 100 µm** **10 mm^2 to 10 cm^2**	• *Low profile Heterogeneous Systems On Flexible Foil* • *System In package, Above IC* • *Compatible with standard IC packaging techniques*

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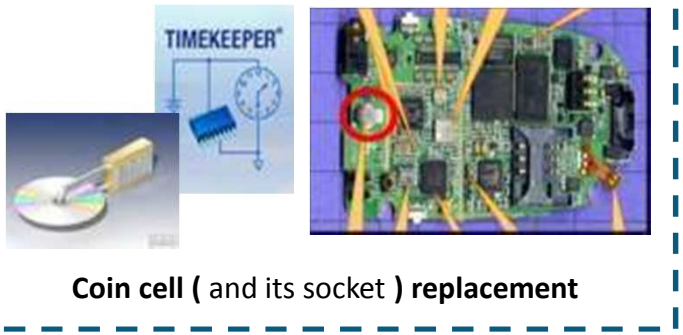
FROM MINIATURE AND RIGID COMPONENTS…

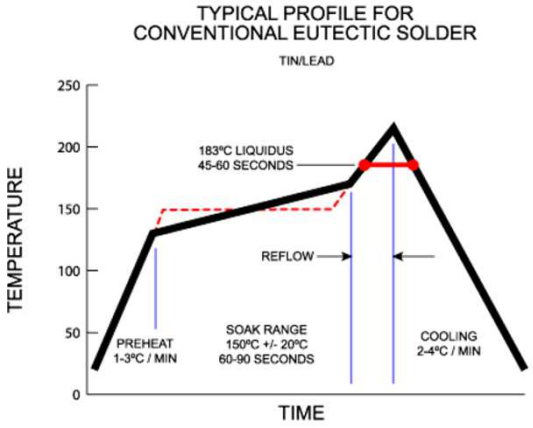
- Standalone Microbattery in standard microelectronics packaging (LGA, BGA) or bare die integration in System in Package or above IC solutions
  - Compatibility with standard bonding process (Lead free solder reflow, 260°C) and 0V tolerant
  - Applications : Real Time Clock, autonomous sensors….

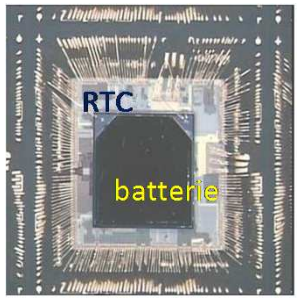


Coin cell (and its socket **) replacement**

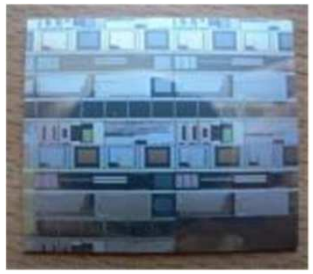
BGA 8x8 mm

LGA 5x5 mm





System In Package



Above IC

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… TO ULTRA-THIN AND FLEXIBLE SOLUTIONS

(a)

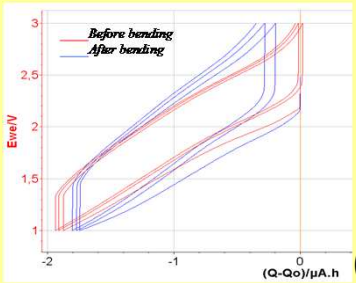
(b)

(c)

Manufacturing on flexible substrates :a) ceramic ; b) mica ; c) polymers…

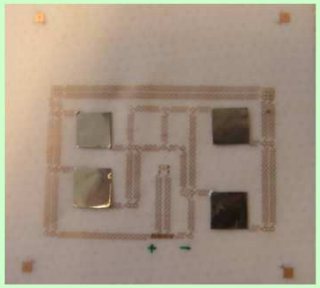
(a)

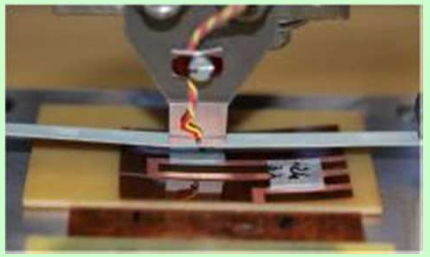
(b)



(c)

Flexion tests : a) credit card ; b) flexible foil ; c) voltage vs.charge variation under stress





Series / parallel interconnection of single µbattery cells in application specific power module

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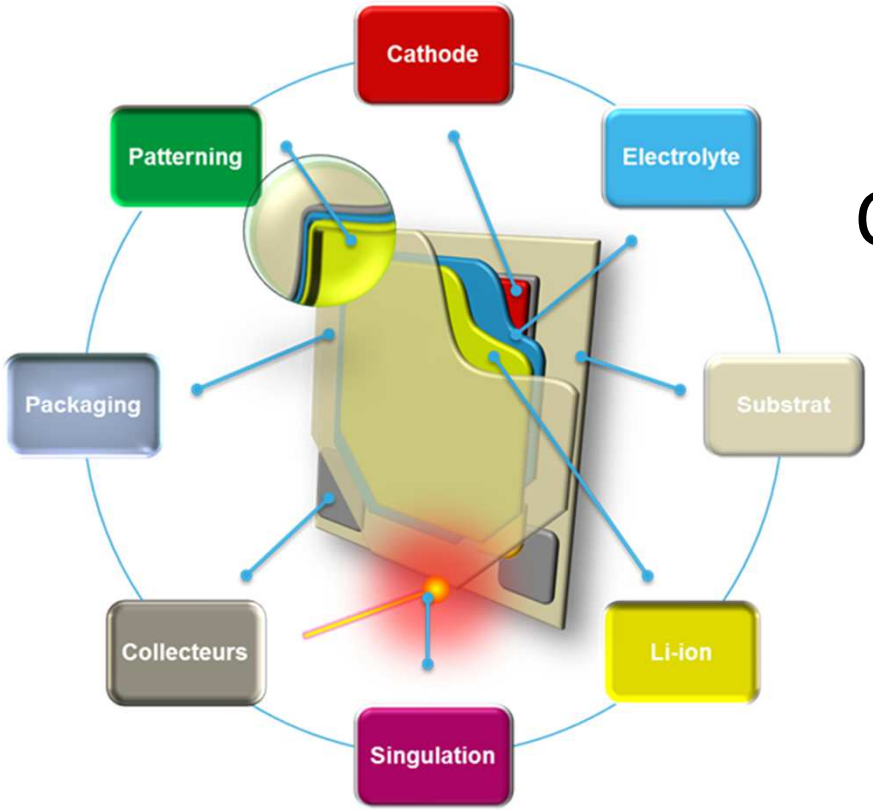
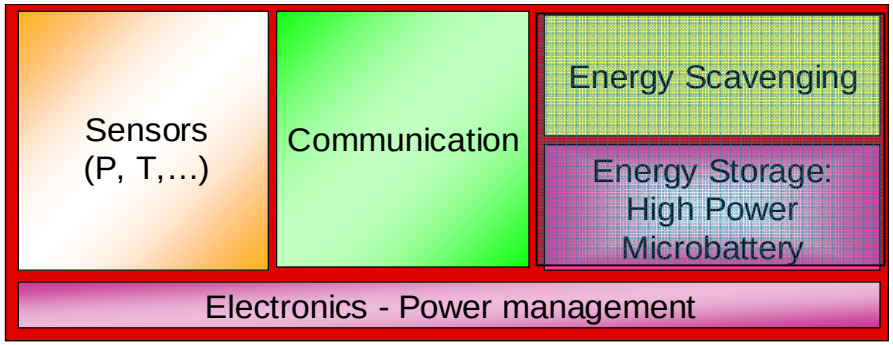
R&D on Thin Film Batteries: Thematics



Component

System



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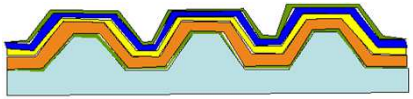
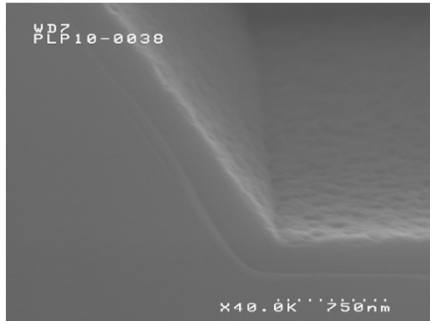
R&D on Thin Film Batteries: E-STARS project

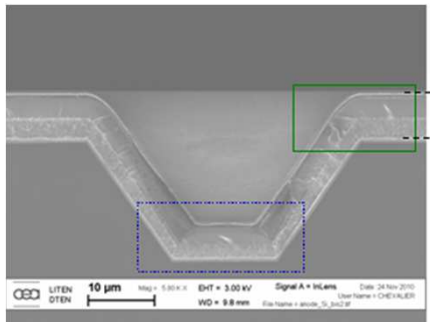


Low Aspect Ratio 3D Micro battery

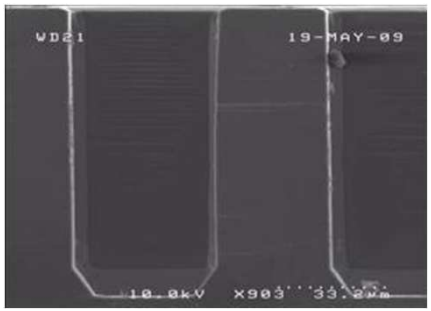
High aspect ratio 3D Micro battery



New MOCVD electrolyte



LAR 3D thin film battery with improved capacity



HAR substrate developments

SEVENTH FRAMEWORK PROGRAMME

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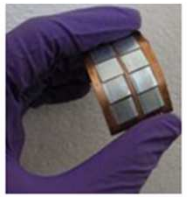
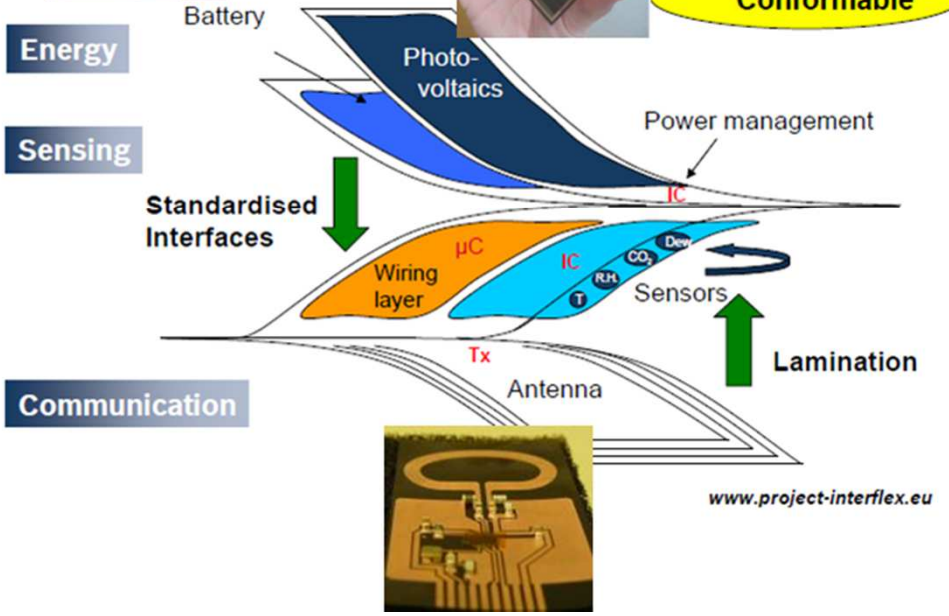
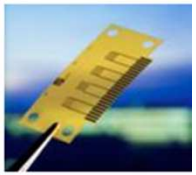
R&D on Thin Film Batteries: INTERFLEX project

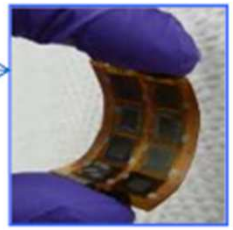
An Energy Autonomous and Wireless System-in-Foil for Air Quality Monitoring



Conformable







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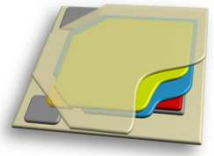
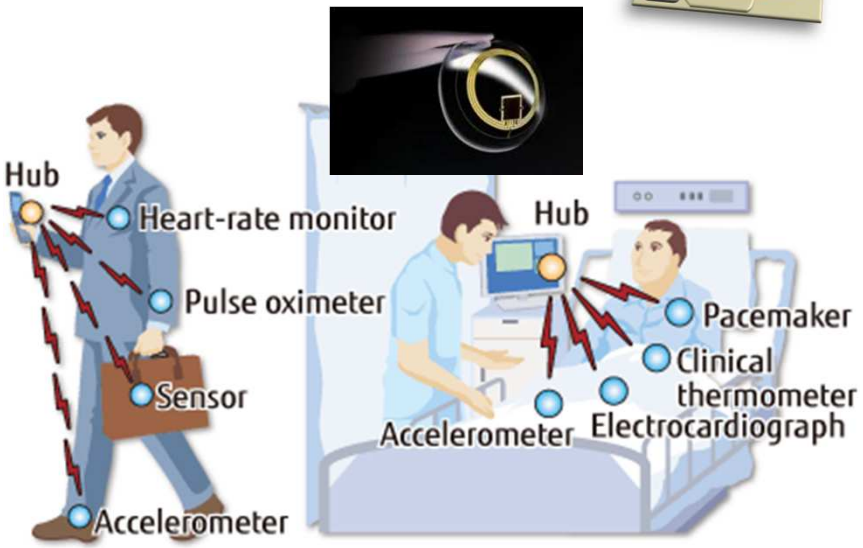
Microbattery targeted applications



real time clock

smartcards



Healthwear, sportswear

Sensor networks : Plant Supervision / Environment control

Internet of Things

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Technology maturity / Major inudstrial actors

- Thin film microbattery technology
  - Small volume commercialization (<<1Mu/an)
  - On going industrial devlopments for high volume
  - Important R&D for next product generation

- European Industrial actors
  - STMicroelectronics Tours (partnership with CEA-LETI)

- Worldwide Industrial actors
  - Start-ups using background from ORNL : IPS, Cymbet, FET
  - Korea : GS Nanotech

4mm x 5mm x 0.9mm DFN SMT Package

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High Volume Manufacturing

- ST/CEA partnership to develop a manufacturing pilot line in Tours

25/6/2014 Long-life Paper-Thin Batteries from STMicroelectronics to Power Tomorrow's Tiny Tech

life.augmented

News

Long-life Paper-Thin Batteries from STMicroelectronics to Power Tomorrow's Tiny Tech

Geneva
23 juin 2014

STMicroelectronics has begun limited production of its EnFilm™ advanced rechargeable batteries that are less than 0.25mm thick. These paper-thin batteries free designers from the constraints of standard battery sizes and are ideal for use in powering the next generation of personal technology and Internet-of-Things (IoT) devices.

EnFilm™: the Energy of Things
Thin-film rechargeable battery

At just 220µm thick and measuring 25.7mm x 25.7mm, ST's EFL700A39 EnFilm™ solid-state lithium thin-film battery is perfectly suited for use in ultra-low-profile devices. Surface-mount terminals allow direct attachment to the circuit board, which simplifies assembly and eliminates wires and connectors. Optional tape-and-reel packaging allows high-speed automated placement.

With 3.9V nominal voltage and 0.7mAh capacity, the EFL700A39 can power a wide range of applications. Its lithium technology recharges rapidly from a 4.2V charging circuit and displays low capacity loss as well as long cycle life allowing some 10 years of use if charged once per day. The EFL700A39 is RoHS compliant and UL[1] certified, satisfies UN[2] tests and criteria for battery transportation, meets IEC 62133 safety specifications, and meets the ISO7816/IEC10373 mechanical and flexibility standards for smart cards.

ST is ready to fulfill orders for engineering samples and small production quantities, targeting applications including wireless sensor nodes, RFID tags, smart cards, wearable technology, non-implantable medical monitors, and back-up or storage for energy-harvesting devices. The unit price is $30.00 for orders of five units.

For further information please visit: www.st.com/enfilm-nb

Click here for the high-resolution photo

[1] UL (Underwriters Laboratories) is a global independent safety consulting and certification company

[2] United Nations

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Conclusions

- Thin film battery technology: high added value for IoT (thin, rechargeable, flexible, safe, low self discharge…)
- Perfectly suited for hybridation with energy harvesting solutions
- On the market with increasing volume
- Still needs for capacity improvment

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Leti

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THANKS FOR YOUR ATTENTION

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