Microstockage d’énergie
Les dernières avancées

S. Martin
(CEA-LITEN / LCMS Grenoble)
• What is a microbattery?

• Microbatteries developed at CEA
  – Description
  – Performances
  – Integration and Demonstrations
  – On going developments

• Overview of worldwide developments
  – Main competitors
  – Prototypes
What is a microbattery?

- **Lithium battery**
  - Physics similar to classical lithium battery

- **Solid state electrolyte**
  - No liquid
  - No leakage
  - High Temperature stability
  - Integrable

- **Thin film battery**
  - Realized with thin film deposition facilities
  - Overall thickness: 5-20 µm
Different solutions to fit requirements

- Li metal or Li-ion
- Low Temperature process
- Output voltage from 1 to 4 V

Anode electrode Li, Si$_x$Ge$_{1-x}$ (0.1 to 5 µm), thermal evaporation or sputtering

Solid electrolyte LiPONB (1 to 2 µm), sputtering

Cathode electrode TiS$_x$O$_y$, LiCoO$_2$, V$_2$O$_5$ (2 to 4 µm), sputtering

Current collector W, Ti, Pt (0.2 to 0.5 µm), sputtering

Substrate 4 to 8” Si wafers
Polymers, Ceramic
Microbattery Performance

Standard TiOS/Lipon/Li

Voltage (V)

S = 25 mm²
2.5 µA

Capacity (µAh/cm²)
Microbattery Performance

Standard TiOS/Lipon/Li

Cycle number

Capacity (µAh/cm²)

C/10 = 10 µA/cm²

30C = 3 mA/cm²

10 µA/cm² during 10 h

3 mA/cm² during 50 s

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High duty cycles
Standby current: 25 µA
Pulse current: 2.5 mA/cm²

Result

- 4080 High duty cycles
- 28 µAh/cm² to 1V discharge
Processes involved

**Barrier layer:**
- PECVD: Conformal, low Temperature

**Polymer buffer**
- Wet chemistry or Polymer Evaporation
  - High dep rate, good Mechanical properties

**Active Layers**
- RF or DC sputtering
  - Density, Adhesion, thickness control, low temperature

**Processes involved**
- High dep rate, good Mechanical properties
Main developments at CEA

Integration
(QFN Package, autonomous sensors, µUAV...)

Encapsulation
Barrier properties
Flexibility

Active Stack
Materials
Process

Substrate
Texturation
Flexibility

Patterning
Shadow Masks
Maskless Process

Main developments at CEA
High barrier required → Thin Multilayer stack required
Microbattery manufacturing

- Process development on industrial tool (200mm substrates)
- Patterning: from Shadow Mask to maskless process
Substrates

- **Flexible substrates**
  - Polyimide substrates (low T process)
  - Large area for high capacity

- **Textured substrates**

- **Stacking of microbatteries**

http://www.estars-project.eu
• Electronic market requires possibility to use energy storage as any other component
  – Capability to sustain high temperature step for connection (SR)

  – Microbattery Technology can fulfill the requirement
  • Microbattery cycling before and after 3 Lead free Solder Reflow
High voltage photolithography microbatteries

- **Objectives:** High voltage (> 30V) energy source for rf MEMS
  - Connections in series of 16 V$_2$O$_5$ based microbatteries
  - Photolithographic process
    - Standard clean room environment
    - 100 x 100 µm$^2$ microbatteries
Objectives: High voltage energy source for actuators

- Technology fusion between silicon actuators and microbattery

- Applications: µUAV, avionics
Integration: Above IC capability

- Microbattery on integrated circuit for smart card application: security improvement

![Microbatteries (23 mm²)](image)

40 mm
Microbateries are perfectly suited for these kind of requirements
  – Thin film, integrable
  – High number of cycles w/o lose of capacity
  – Low self discharge
  – Pulse capabilities
  – Generic storage solutions for several energy harvesting systems: PV, thermoelectricity, piezo…
### Available Microbatterie characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Capacity</strong></td>
<td>Up to 300 µAh/cm²</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>Up to 5 mW/cm²</td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
<td>Between 4.2 and 1 V</td>
</tr>
<tr>
<td><strong>Cyclability</strong></td>
<td>&gt; Thousands of cycles</td>
</tr>
<tr>
<td><strong>Thickness</strong></td>
<td>&lt; 15 µm (with packaging)</td>
</tr>
<tr>
<td><strong>Surface</strong></td>
<td>- From 20 mm² to large area (shadow mask)</td>
</tr>
<tr>
<td></td>
<td>- Down to 100 x 100 µm (photolithography)</td>
</tr>
<tr>
<td><strong>Substrate</strong></td>
<td>IC (Si), polymer, ceramic, PCB…</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td>Solid state – not flammable – no leakage</td>
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</tbody>
</table>
Evolution of CEA Microbatteries prototypes

From 2 cm² to 25 mm² microbatteries (4” wafer, Thick encapsulation)

First Prototype (4” wafer, Thick encapsulation)

First Integration of Microbatteries on IC

First microbatteries with thin film encapsulation (4” wafer)

Microbatteries on flexible substrate

Microbatteries in 8x8 BGA package

Microbatteries on 6” wafers

Microbatteries on 8” wafers

100 x 100 µm Microbatteries array for high voltage

Microbatteries SR compatible

2002

2004

2005

2006

2007

2008

2009

2010

2011
Conclusions

• **Microbattery Technology**
  – Available with different packaging solutions
  – Solder Reflow compatibility for some of them
  – Industrialization on the road

• **Microsensors powering**
  – Hybrid system with energy harvesters
    • Depending on applications