Embedding Energy Storage in SoCs using Solid State Batteries

PowerSoC'12

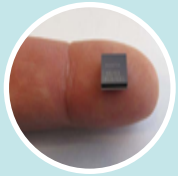
November 16, 2012

Key Trends Driving Innovation

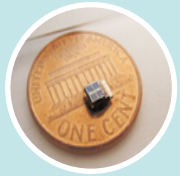
Ultra Low Power Processors

Smart Devices and Sensors Everywhere

Wireless is pervasive



Integration with other components



Miniaturization

Eco-Friendly and Renewable Energy

Key Trends Drive New Technologies in Many Areas

- New innovative products are smarter, smaller and wireless
- Smart devices with status indications
- There will be billions of new networked smart devices
- Body area networks, Personal area networks, Ad hoc nets

New Energy Storage Devices are Needed to Enable Key Trends

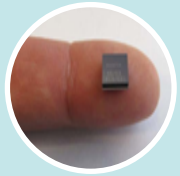
CYMBET™ CORPORATION

TRENDS

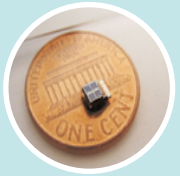
Ultra Low Power Processors

Smart Devices and Sensors Everywhere

Wireless is pervasive



Integration with other components



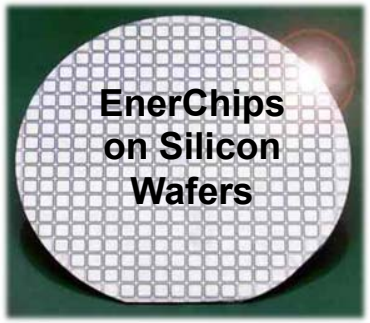
Miniaturization

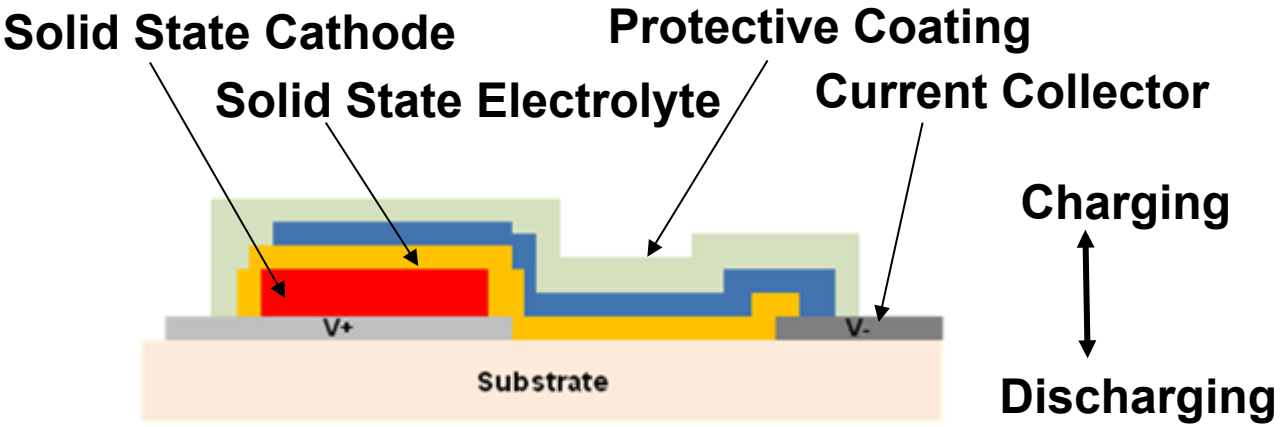
Eco-Friendly and Renewable Energy

CURRENT SOLUTIONS

- Bulky Size/Metal "coin" package
- Cannot be integrated with other electronics
- Low energy for Space used
- Not Eco-Friendly - Toxic Chemicals
- Transportation Safety Issues

Rechargeable Solid State Batteries
The EnerChip™ Solution





- **EnerChip Rechargeable Solid State Batteries are created on Silicon wafers using standard semiconductor fabrication processes and device packaging techniques**
- **As the battery is charged, ions move from the cathode through the solid electrolyte to the current collector. As the battery discharges, the reverse is true.**
- **EnerChips are 150 microns thick – less than two human hairs – and are 1/20th the thickness of a comparable battery.**

Solid State Battery Applications

Requirements

- Eco-Friendly Energy Storage
- Permanent and Reliable
- Low cost Automated Assembly
- Low profile; Small Footprint
- Embed at board or chip level
- Low total cost

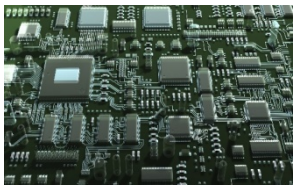
Embedded Power

EnerChip Bare Die

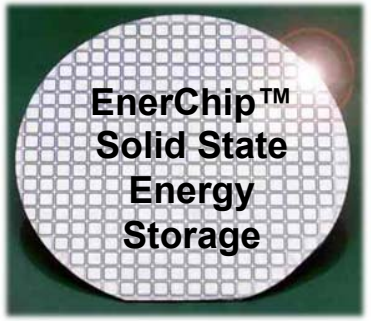
Back-up Power

EnerChip SMT Package

Pervasive Power



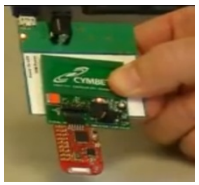
EnerChip CC Co-Package



EnerChip Advantages

- Simple “drop in” Power
- SMT/Reflow Tolerant
- No special disposal needed
- Rechargeable - No Replacement
- Broad Customer Acceptance
- Many applications, many industries

Energy Harvesting Data Devices



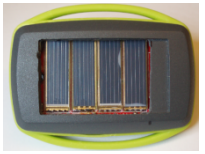
EnerChip CC Co-Package

Zero Power Wireless Nodes

EnerChip EH Modules

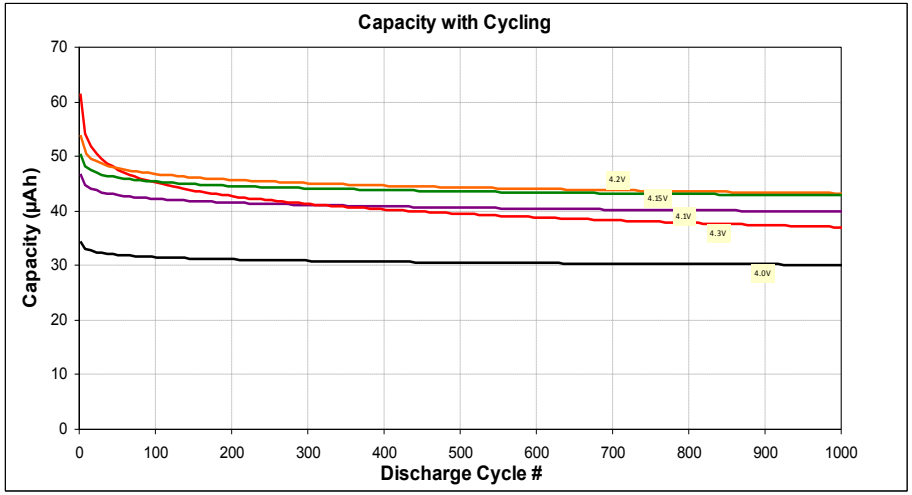
EnerChip EH Integrated Solutions

Energy Harvesting Building Controls

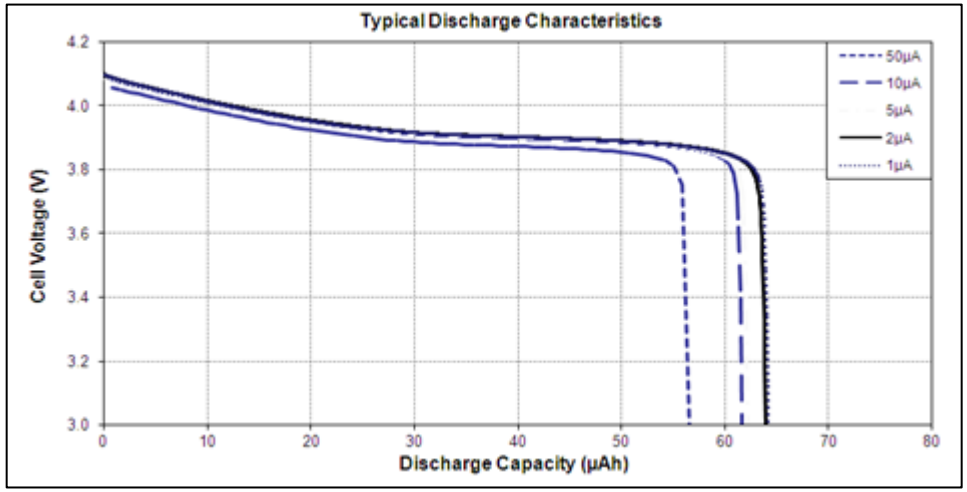


Solid State Battery Characteristics

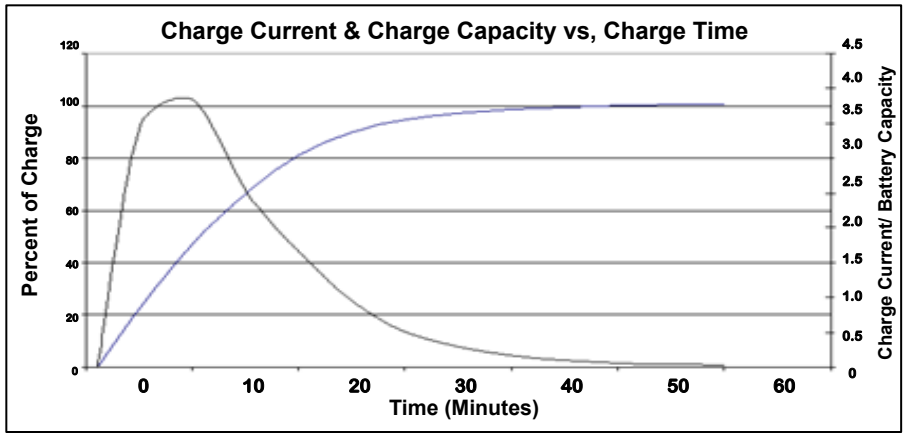
High Cycle Life



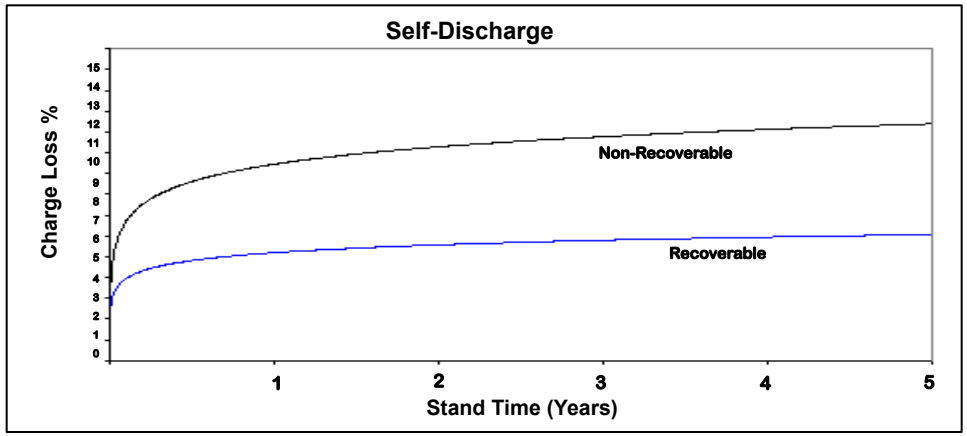
Flat Output Voltage Profile



Fast and Simple Charge



Low Self-Discharge

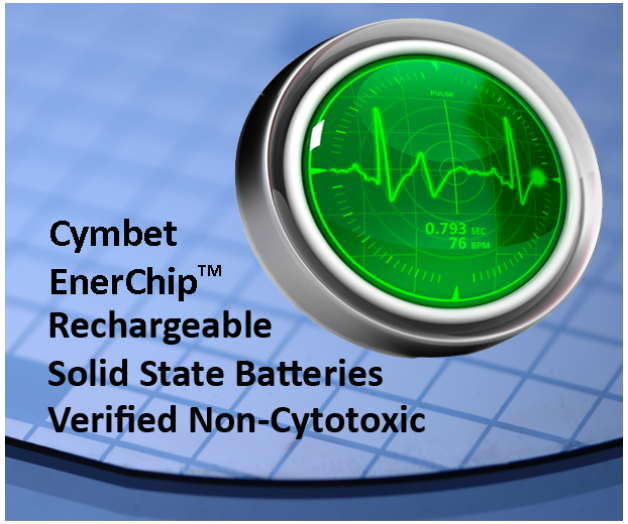


Meeting Safety and Environmental Regulations and Standards

Rechargeable solid state batteries are the only energy storage solution that satisfies all the following global regulations and certifications:

- RoHS
- China RoHS
- REACH
- CE Mark
- UL - Underwriters Laboratory
- JEDEC IC Packaging Standards and Tape and Reel EIA Standards
- IEC, NEMA/ANSI
- United Nations Transportation Air Safety Regulations
- WEEE Waste Electrical and Electronic Equipment Directive
- EU Battery Directive
- MSDS and OSHA Information
- Solid State Battery End-of-life Disposal Instructions
- In vitro Biocompatibility Test Standards for Cytotoxicity

EnerChips are Non-Cytotoxic



"The gamma sterilized Cymbet EnerChip™ bare die batteries were found to be non-cytotoxic (0% cell lysis) using both the Medium Eluate Method Eluation Test and Agar Diffusion Test feasibility screening procedures. The lack of any adverse biological responses in these very sensitive in vitro cell culture assays is indicative (although not a guarantee) of biocompatible test results in the other in vitro and in vivo aspects of biocompatibility as suggested by the ISO 10993-1 and FDA G95-1 guidelines."

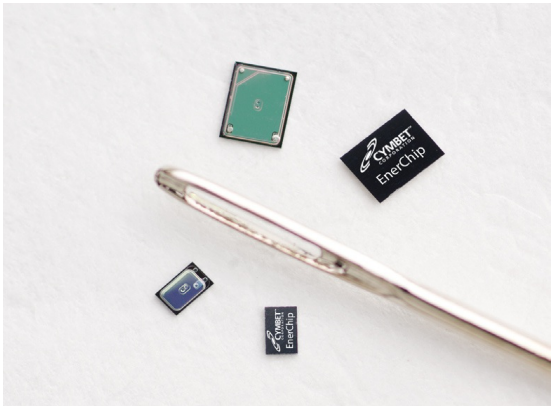
- In vitro biocompatibility tests show EnerChip bare die are non-cytotoxic

- Additional in vivo studies are in progress with crushed EnerChip bare die in a saline solution was injected into subject with no observed effects. Waiting for histology results

Why Embedding Energy Storage in SoCs is Important

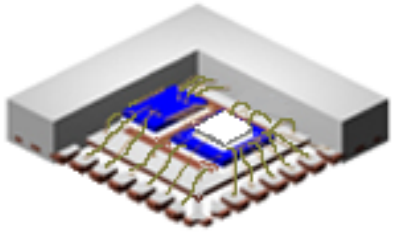
Enables Innovative Product Designs:

- "On-Chip" energy to save chip memory, time or self-power a sensor without a larger primary battery.
- Lowers the cost and profile of electronic devices
- Unique form factors enable power systems to conform to packaging
- Distributing power to the chip level enables new capabilities not available before in medical, wireless sensors, energy management, consumer, electronics, military, etc.
- Features:
  - Eco-friendly
  - Lasts for the life of the product
  - No harmful chemicals or hazards
  - No special recycling required
  - Extremely low self-discharge
  - Simple & safe charging algorithm

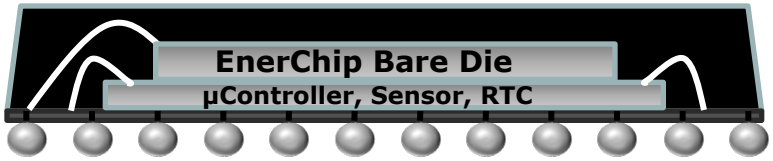


EnerChip Co-Packaging Options

- EnerChip side by side with co-packaged ICs using wire bonds



- Stacked Die with microcontrollers, RTC, or SRAM

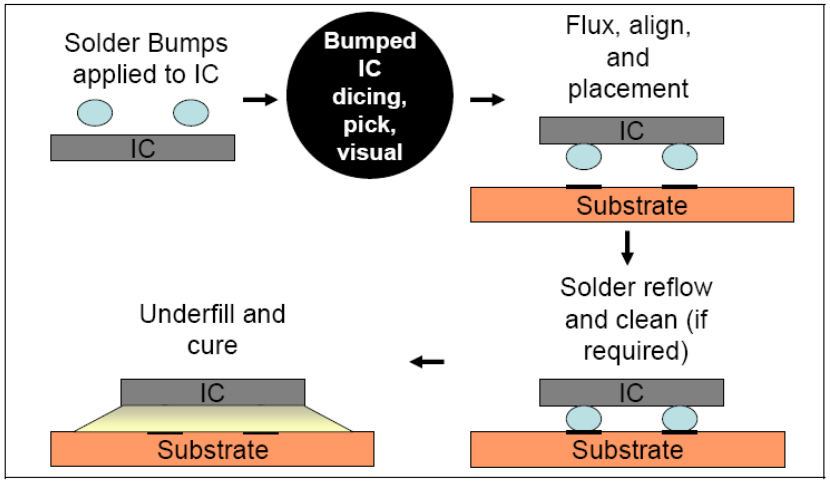


- System in Package using wire bonds or bumped die

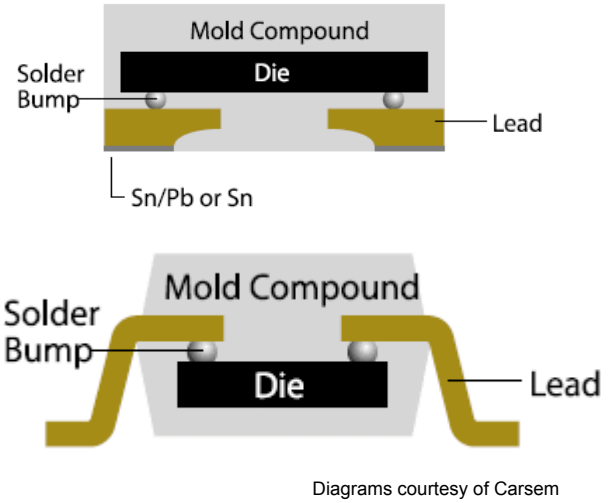
EnerChip™ Bumped Die

- EnerChip bare die are configured to accept solder bumps
  - Provides ability for dense packaging options
  - Can be integrated with ICs and passives
- Currently in prototype phase

Standard Flip Chip Configuration



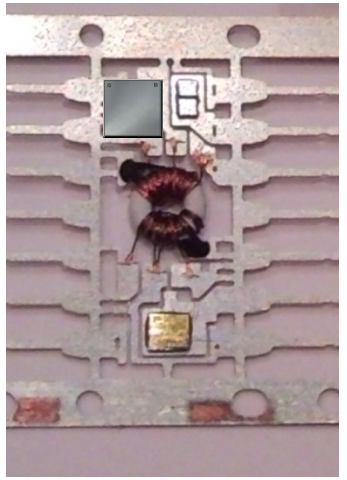
Flip Chip on Lead Frame Configurations

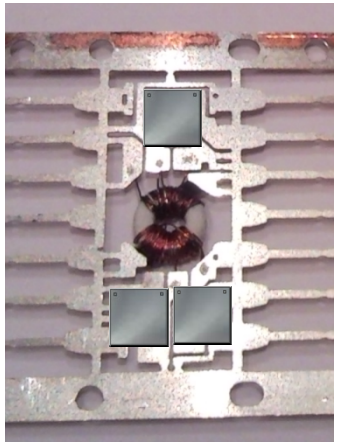


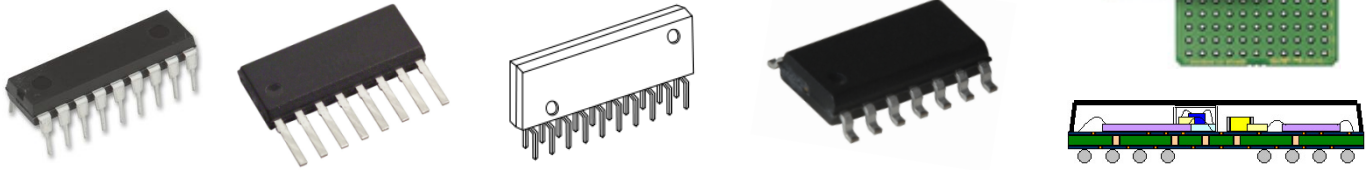
Diagrams courtesy of Carsem

EnerChip System in Package

- Advanced All-In-One Package:
  - Several 100's uAhr Capacity
  - Multiple EnerChip Die
  - Integrated Circuits
  - Integrated Inductor, Passives & Pulse Current Capacitor, etc
  - Package options: DIP, SIP, ZIP, SMT & BGA
  - Custom configurations



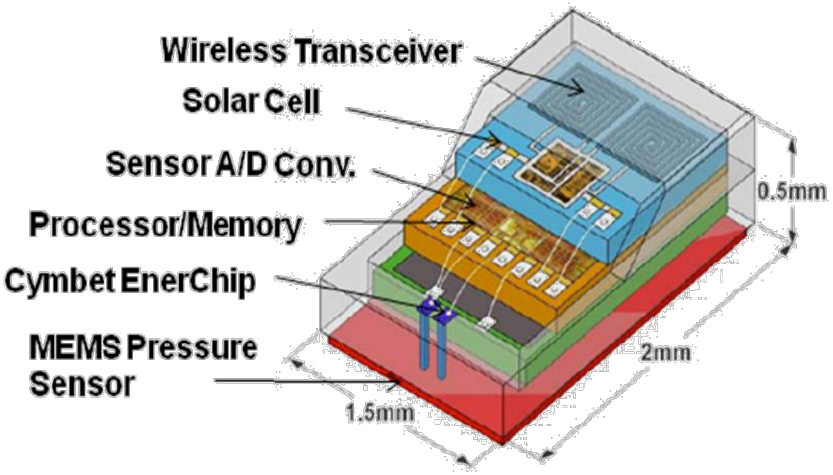


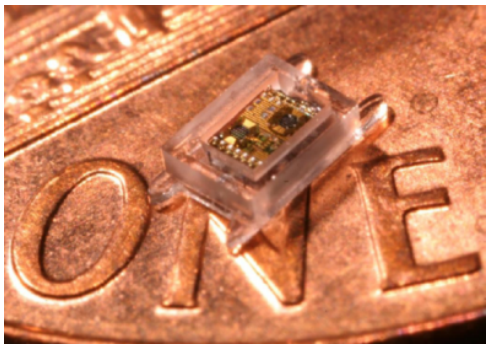


Intra Ocular Pressure Monitor

Tiny Wireless Sensor for Glaucoma Patients

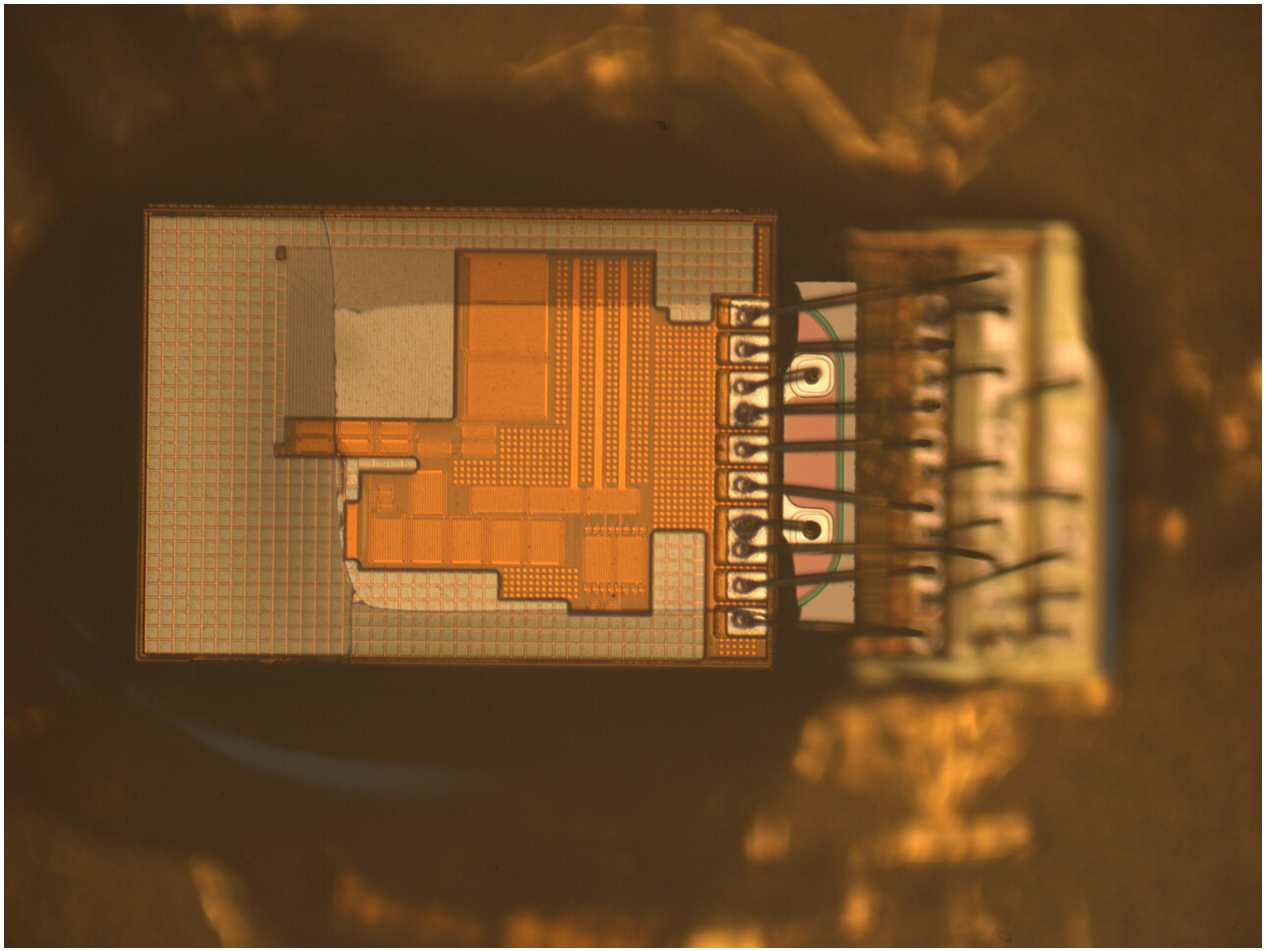
- Implantable Intraocular Pressure Sensor
- Function: Powers millimeter scale processor and sensor system by using solar energy harvesting, stores energy to sense pressure in the eye and transmit data to host
- Reasons for Design in: very small Form Factor, custom 1 mm x 1 mm battery, high-cycle life (charge/ discharge cycles), low self-discharge
- Current Status:
  - Built prototypes and published paper in 2011
  - Potential commercialization in 2013-2014



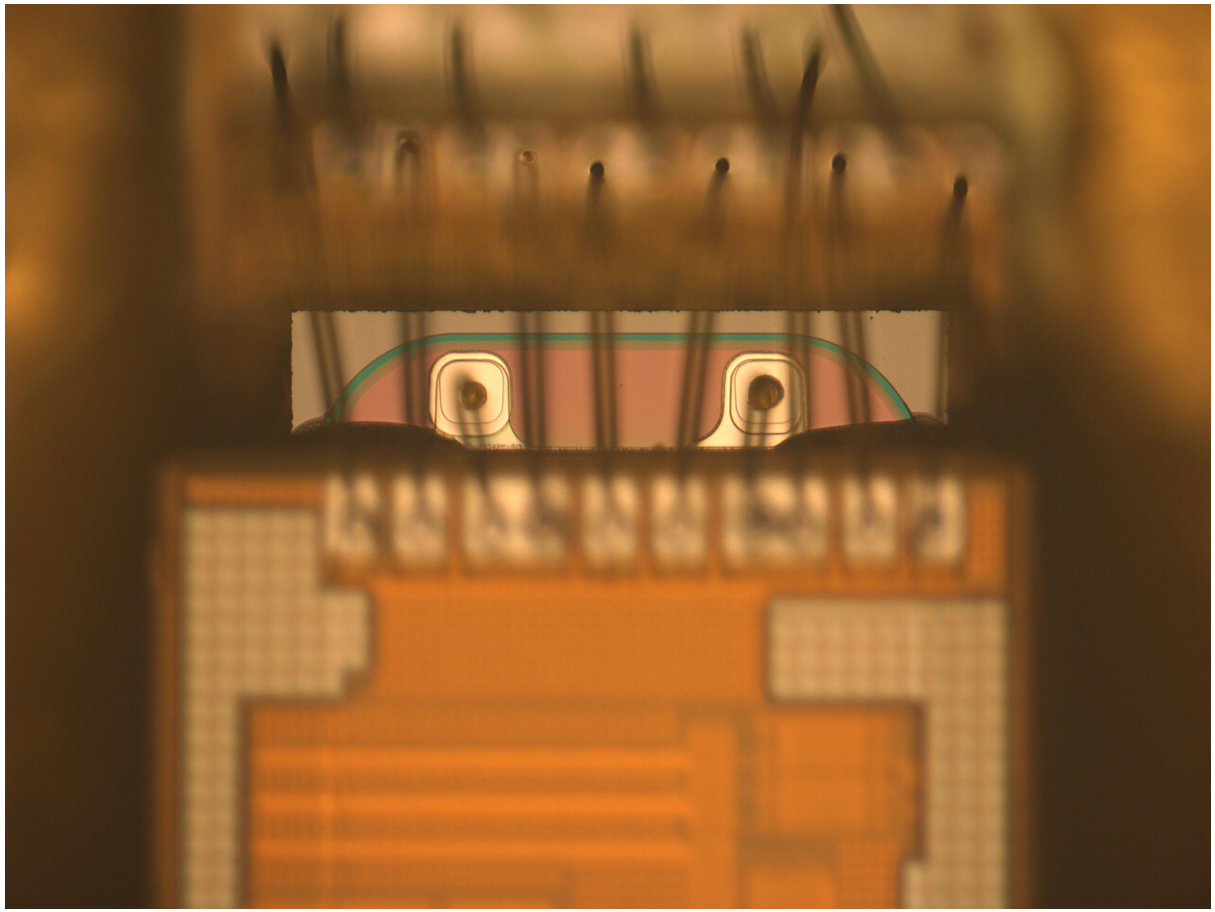


Note: University of Michigan ISSCC Paper: http://www.cymbet.com/design-center/wireless-sensors.php

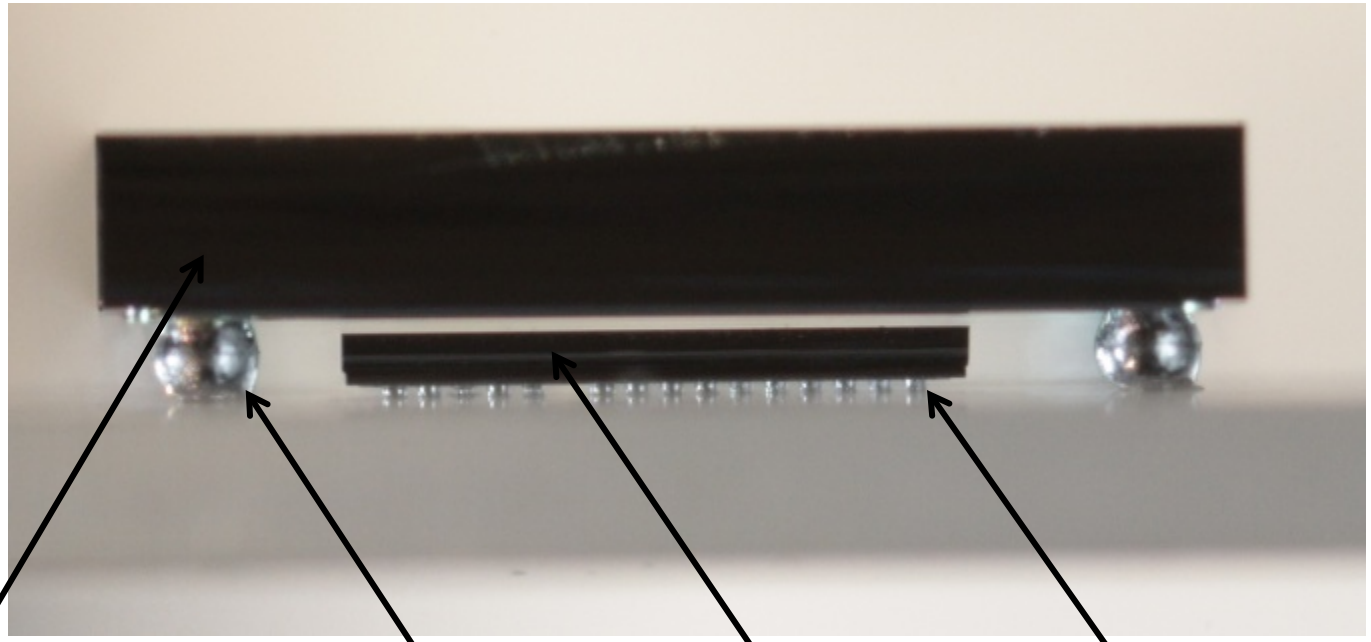
Intraocular Sensor Device Stack



EnerChip Die Wire bonds

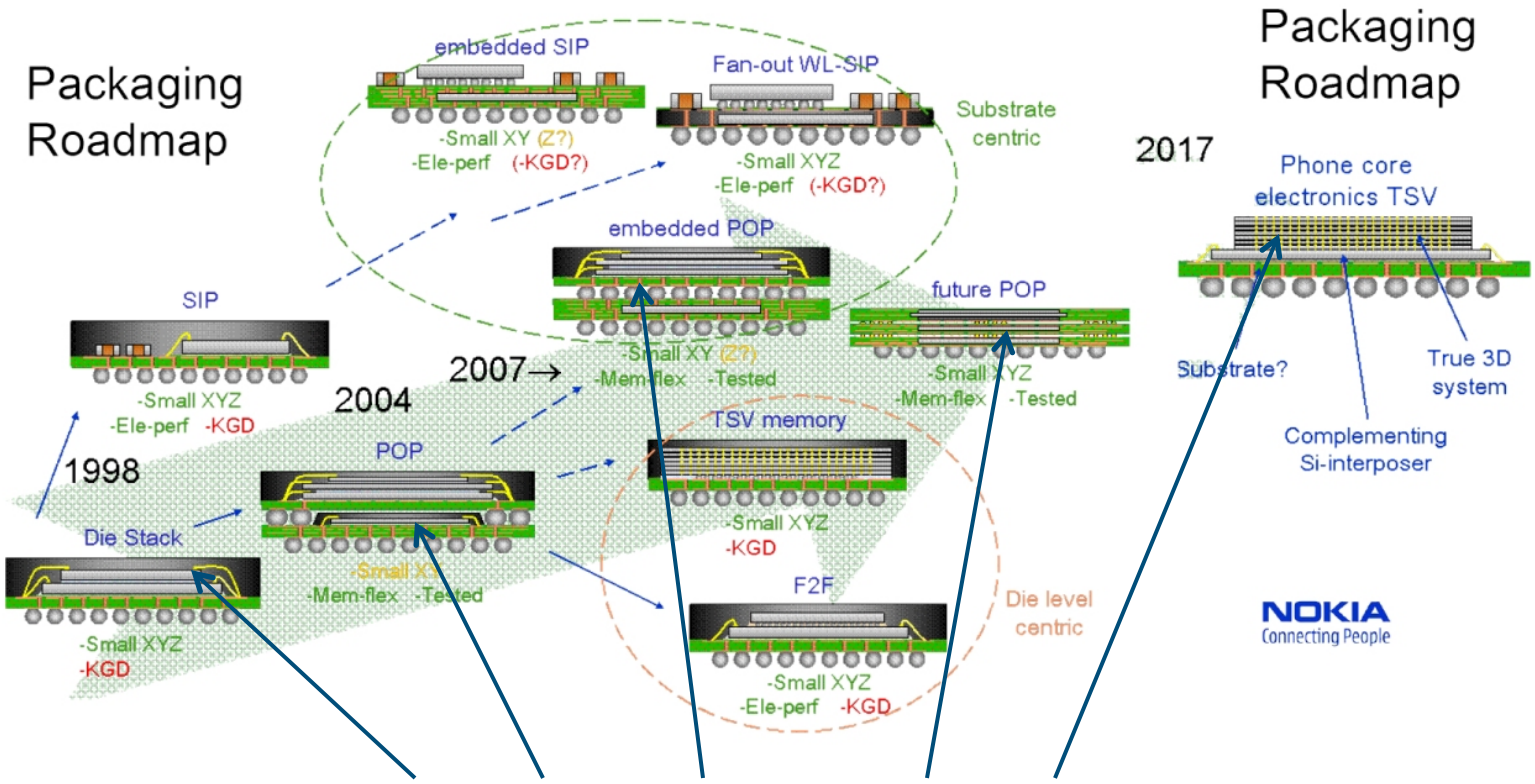


EnerChip Bare Die over ASIC



Solid State Batteries in Advanced Package Configurations

EnerChip Solid State Batteries in Bare Die form are the ideal devices for integrating energy storage in emerging System in 3D Packaged Systems EnerChips using wire bonding, solder bumps for flip chip or eventually Thru Silicon Vias can be integrated into Systems in Package, Package on Package, TSV stacks and other 3D configurations



EnerChip Bare Die Location Examples

Embedded Energy Summary

- Rechargeable solid state batteries are the ideal solution for adding energy storage to System on Chip devices
- Various die attachment mechanisms and packaging configurations can utilized to optimize SoC performance
- Solid State Batteries are eco-friendly, easy to assemble, safe to transport, lasts the life of the SoC device, non-cytotoxic and safe end of life disposal
- Additional information: www.cymbet.com