Industry Session 15: Energy Harvesting

Batteryless Monitoring System for Real-World Automotive Applications

Presented By –
Marcus Taylor, CEO
Silent Sensors Ltd
marcus@silentsensors.com

Wednesday, March 20, 2019
Profile

- Embed electronics in rubber and elastomers
- Locations
  - London (HQ)
  - Sedgefield (design)
  - Swindon (product development)
- 11 staff, growing rapidly
- UK SME supported with expertise from Government grant agencies
- Solution Engineering
  - Materials development
  - Antenna and sensor designs
  - Device manufacture
  - App and Cloud software
  - Support services
- Applications
  - Asset tracking with RFIDs
  - Development agreements
Smart Materials for Rubber, Elastomers and Polymers

- Encapsulation – ARTIS
- RFID (UHF and NFC) – Funded by EU H2020
- Piezo Energy Harvesting – CPI, UoBath funded by InnovateUK
- Vibration Energy Harvesting – Tyndall Institute
- Energy Storage and Triboelectric – Partnership with Comberry
- Power Management, Radio and TPMS Sensor
- Sensor Arrays - SSL
- Six Access motion
- Auto location
- Auto Configuration
- Solid State Microphone
- Atomic Mechanics
- nanoAI – Artificial Intelligence with Bragi GMBH
Tyre Industry

Mission
Design & Manufacture
High Quality and Safe Tyres
With Low Environmental Impact

Regulatory Requirements
Mandatory
RFID and Traceability

Market Need
• RFID Tags & Inlays
• TPMS Sensor

Competition
• Costly
• Bulky
• Battery

Silent Sensors
• Low Cost
• Thin, flexible, stretchable
• Self-powered
• Wide Temperature range
Technology Contributions

- Silent Sensors Limited (SSL)
  - System Integration / Smart Materials
    - Speciality in Embedding in Elastomers & Polymers
    - Industrial Temperature Range Compliance
  - Ability to Harvest Ambient Energy (i.e. – Energy Harvesting or EH)
    - EH-source Agnostic
    - Maximize Battery Life with Intermittent Energy Sources
  - Power Management / Optimization
  - Intelligent Sensor Systems
  - Radio Frequency (RF) Data Transceiving
  - High-value Add-on Feature Enablement
    - RFID, Intelligent Patches, Etc.
Technology Contributions

- **Silent Energy**
  - *Thin-film, Flexible Energy Storage*
    - Pseudosupercapacitor (Can Be Made to be More Supercap-like or More Battery-like)
    - Industrial Temperature Operating Range
    - Scalable
  - *Joint Venture Between SSL & Comberry, based in UK*
Technology Contributions

- **Ecosystem Partners**

  - **tesa**
    - Worldwide Leader in Specialized Adhesives Development

  - **e-peas**
    - Differentiating Power Management IC (PMIC) & Microcontroller Supplier Specializing in Energy Harvesting Applications

  - **Alta Devices**
    - Producer of High-efficiency, Thin-film GaAs Photovoltaic (PV) Cells
Technology Contributions

- General Energy Harvesting (EH) Comparison Matrix
  - Comparing EH Technologies
    - Electrodynamically (Dynamic)
    - Photovoltaic (PV)
    - Thermoelectric (TEG)
    - Piezoelectric (PZ)
    - Radio Frequency (RF)
    - Vibrational (Vibe)
    - Triboelectric (Tribo)

<table>
<thead>
<tr>
<th>EH TECH</th>
<th>Thin</th>
<th>Flexible</th>
<th>Energy Density</th>
<th>Raw Electrical Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic</td>
<td></td>
<td></td>
<td>✓ ✓ ✓</td>
<td>AC</td>
</tr>
<tr>
<td>PV</td>
<td>✓</td>
<td>✓</td>
<td>✓ ✓</td>
<td>DC</td>
</tr>
<tr>
<td>TEG</td>
<td>✓</td>
<td>✓</td>
<td>✓ ✓</td>
<td>DC</td>
</tr>
<tr>
<td>PZ</td>
<td>✓</td>
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<td>✓ ✓</td>
<td>AC</td>
</tr>
<tr>
<td>FC</td>
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<td></td>
<td>✓ ✓</td>
<td>DC</td>
</tr>
<tr>
<td>RF</td>
<td>✓</td>
<td>✓</td>
<td>✓ ✓</td>
<td>AC</td>
</tr>
<tr>
<td>Vibe</td>
<td></td>
<td></td>
<td>✓ ✓</td>
<td>AC</td>
</tr>
<tr>
<td>Tribo</td>
<td>✓</td>
<td>✓</td>
<td>✓ ✓</td>
<td>AC</td>
</tr>
</tbody>
</table>

NOTE: A check implies this EH tech is capable of that characteristic, but does not imply it applies absolutely.
Technology Contributions

- General Energy Harvesting (EH) Comparison Matrix
  - Example Applications

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>EH TECH</th>
<th>STORAGE</th>
<th>EXAMPLE LOAD (mW)*approx.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tire Pressure Monitoring System (TPMS)</td>
<td>PZ</td>
<td>Supercap, Micro Battery</td>
<td>10</td>
</tr>
<tr>
<td>RFID / Security Tag</td>
<td>PV, RF, Tribo</td>
<td>Supercap</td>
<td>0.01</td>
</tr>
<tr>
<td>Asset Tracking</td>
<td>PV, TEG, PZ, RF</td>
<td>Supercap, Micro Battery</td>
<td>0.1-50</td>
</tr>
<tr>
<td>Smart Tape</td>
<td>PV, TEG, PZ, RF, Vibe, Tribo</td>
<td>Supercap, Micro Battery</td>
<td>0.05-5</td>
</tr>
<tr>
<td>Telematics</td>
<td>PV, TEG, PZ, RF</td>
<td>Supercap, Micro Battery</td>
<td>0.5-100</td>
</tr>
<tr>
<td>Smart Card</td>
<td>PV, RF, Tribo</td>
<td>Micro Battery</td>
<td>0.02-0.05</td>
</tr>
<tr>
<td>Industrial Monitoring</td>
<td>PV, TEG, RF, Vibe</td>
<td>Supercap, Micro Battery</td>
<td>1-100</td>
</tr>
<tr>
<td>Preventative Maintenance</td>
<td>PV, TEG, RF, Vibe</td>
<td>Supercap, Micro Battery</td>
<td>1-100</td>
</tr>
</tbody>
</table>
Automotive Application Opportunities

- Vehicle-to-Vehicle (V2V)
- Autonomous Vehicles
- On-Board Sensor Networks
  - Tire Pressure
  - Oil/Water Temperatures
  - Fuel Level
  - Passenger Telemetry
- Embedded PV External Paneling
  - Roof
  - Windows
- Kinetic/Vibrational/Thermal Energies EH
Automotive Application Challenges

- Weight
- Cost
- Power Consumption
- Amount of Data
  - VALUE of Data
- Security
- Slow Development / Qualification
- Mature Supply Chains
The Ecosystem
What is an Intelligent Tyre?

Are the future
- Unique Identity
- Measure and Monitor
- Communicate
- Act on information

Must be able to
- Self-power
- Survive super-heating
- Integrate with infrastructure
- Be on all the time
- Cover the last millimetre
Reducing Lifecycle Costs

- Increased Safety
- Lower Costs
- Lessens Environmental Impact
- Requirements for autonomous vehicle operations (Intelligent)

Value-added ROI for today’s Smart Tyres increases with tomorrow’s Intelligent Tyres
Structure of a Tyre

- Steel belts
- Tread
- Sidewall
- Body ply
- Bead
- Liner
- Chafer
The new RFID design will enable us to produce PZT piezoelectric materials on same PE substrate with same process.

**Thin Film Energy Storage material**

**Tyreless Piezoelectric Harvesting material**

**Material being tested**

**Material attached to tyre**

**Graph showing output varying at different frequencies**
Wheel and Tyre Installation and Monitoring

- 4 off PZT Harvesters attached to inside of wheel using cyanoacrylate adhesive (after preparation of tyre surface)
- Multicore cable brought through steel Volvo wheel to provide connection to 3 of the PZT using miniature connectors
- PZT types were:
  - MFC
  - Murata disc
  - MIDE
- Tyre part assembled to rim; connections to PZT made; and final assembly of tyre onto rim
- Cable connection to Monitoring unit which is strapped to centre of rim
Sensor Module Prototype

- Tire Pressure Monitoring System (TPMS)
  - Self-Powered
  - Thin, Flexible
  - Industrial-Grade Temp
Demonstration Concepts

**EH-agnostic Sensor System**
- Wireless Sensor System Disaggregated from Power Source
  - Separate Power & System Planes
  - Same System Plane Can Service Multiple Applications
  - Printed Circuit Assemblies (PCA) Integrated with Connectors
Demonstration Concepts

- **EH-agnostic Sensor System**
  - Wireless Sensor System Disaggregated from Power Source
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[Diagram of demonstration concepts with various components labeled, such as PMIC/BMS, PZT, TEG, PV, and various sensors and connectors.]
Application Tools

- **Design Calculator/Tool**
  - Cloud-based Tool to Facilitate Customer Design/Brainstorming Process
    - Database of Characterized Components
    - Options/Guidance for Matching EH to Application
    - Web Interface for Easy Access
    - Supply Chain Integration

- **Model Library**
  - Part/Assembly Models for Assorted CAD Usage
    - Mechanical
    - Electrical
    - Physics-Based Simulation
The Future

• Transformative business models, from supply to service

• Sentient Tyres for autonomous driving, information on road conditions

• 3D printing of rubber combined with embedded electronics

• Securely integrated sensor platform and Cloud based data sharing
Thank you for your time!