Semiconducting Nanowire Platform for Autonomous Sensors

SiNAPS

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Semiconducting Nanowire Platform for Autonomous Sensors

- Vision
- Project Objectives
- Highlights
- Impact
ICT and consumer electronics account for approximately 15% of global residential electricity consumption

Data: IEA report (2009)

**Comparing Energy Use**

Comparison of a typical television set-top box configuration with Energy Star-rated appliances and devices.

<table>
<thead>
<tr>
<th>Average Kilowatt-Hours a Year</th>
<th>HD Set-Top Box</th>
<th>HD DVR</th>
<th>Time in Use Each Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical HD television set-top box configuration</td>
<td>446</td>
<td>171</td>
<td>275</td>
</tr>
<tr>
<td>Refrigerator (21-cubic-foot)</td>
<td>415</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCD television (42-inch)</td>
<td>181</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desktop computer</td>
<td>175</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compact fluorescent light bulb (15-watt)</td>
<td>17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Natural Resources Defense Council

THE NEW YORK TIMES
By 2030, energy use by household ICT and consumer electronics will triple consuming 1,700 TWh.

Maps: http://en.wikipedia.org
Data: IEA report (2010)
Reduce energy consumption per chip

Eric Pop group
Harvest ambient energy efficiently

Images: http://en.wikipedia.org
Manage efficiently power at the nano- and macro-scale

"It's a hybrid."

© Original Artist
Utilise resources effectively
A cost-effective technology enabling material platform
- Nanotech-based solar energy harvesting (generation II, III PVs)
- Energy-efficient ICT
- ICT for energy efficiency
Semiconducting Nanowire Platform for Autonomous Sensors

Vision

Project Objectives

Highlights

Impact
<table>
<thead>
<tr>
<th>Science &amp; Technology objectives</th>
</tr>
</thead>
</table>

**S&T1: Nanoscale energy harvesting system based on SiNWs**
- develop core-shell semiconducting nanowires for efficient light absorption and charge separation
- fabricate high-efficiency PV mini-modules

**S&T2: Power-efficient, highly-selective/sensitive NW-based chemical sensing**
- develop surface functionalisation schemes on nanowires for selective binding
- demonstrate sensing of streptavidin using immobilised biotin

**S&T3: Microfluidics for miniaturised nanowire-based chemical sensor**
- develop a microfluidic delivery system to be integrated with the chemical nano-sensor.

**S&T4: Efficient power management and data processing for micron-sized devices**
- develop a low-power complete CMOS electronics sensing interface with an embedded energy management concept

**S&T5: Integration into a single device of dimensions < 1mm³**
- integrate the individual modules into an Autonomous Platform with a target volume at and well beyond the state-of-the-art, namely, 4mm³ and an ultimate target of smaller than 1 mm³.
Vision

Project Objectives

Highlights

Impact
properties of a-Si:H from first-principles

D.V. Lang et al, PRB 25, 5285 (1982)

log of DOS vs energy (eV) for aSi:H (12%H)

M. Legesse, M. Nolan and G. Fagas, unpublished
A miniaturised solar cell with 7.29% efficiency was studied. The cell has the following characteristics:

- **Contact area:** 7.02 mm²
- **Efficiency:** 7.29%
- **Open circuit voltage:** 476 mV
- **Current density:** 27.03 mA/cm²
- **Filling factor:** 0.562

The voltage-current characteristic is shown in the graph, with data points represented for AM 1.5 and dark conditions. The graph highlights the performance of the cell under different illuminations.

PV mini-modules

$V_{OC} = 1.83 \text{ V}$
Active area $\approx 5.9 \text{ mm}^2$
$P_{out} > 150 \mu\text{W}$
Miniaturised microfluidic delivery platform

nanowire array

microfluidic channel

1 x 1 mm

Second generation device

Device 3
150 μm CW

Device 4
100 μm CW

Scale bar 500 μm
CW = Channel width
surface functionalisation demonstrating biotin-streptavidin binding

XPS-data

attached dye-conjugated streptavidin
### Power Management Electronics

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value and/or Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Chip Size</td>
<td>~ 500µmX700µm excl PADs inc test structures</td>
</tr>
<tr>
<td>Mini@sic Chip Area (including PADs)</td>
<td>1525X1525µm²</td>
</tr>
<tr>
<td>Mini@sic Chip Area (without PADs)</td>
<td>1100X1100µm²</td>
</tr>
<tr>
<td>Average Power Consumption (Power Management)</td>
<td>0.3µW</td>
</tr>
<tr>
<td>Average Power Consumption (Integrated Temperature Sensor)</td>
<td>2µW</td>
</tr>
<tr>
<td>Package</td>
<td>CLCC 44</td>
</tr>
</tbody>
</table>
fundamentals of efficient and accurate simulation tools

M. Iakovidis, GF in preparation

D. Sharma, H. Arefi, GF, submitted
## miniaturisation roadmap & integration

### Issue1
- Targets easy experimenting

### Issue2
- Targets miniaturization while maintaining specifications
- Test bed helps with proof of principle
- Chip size 25x25 [mm]
- Integration based on PCB
- Horizontal Single Substrate or Horizontal Multiple Substrate (depending on project phase)
- Just intended for R&D testing

### Issue3
- Targets miniaturization while losing minimal functionality
- Proof of concept first SiNAPS Node
- Chip size 2x2 [mm]
- Integration based on Polyimide or Ceramic substrate
- Single Substrate with support for 3D integration with battery and radio
- Target Date for Integration M22

### Integration
- Integration based on CMOS Die
- Integration based on CMOS Die
- Single Substrate with support for 3D integration with battery and radio
- Target Date for Integration M30

### Test bed
- Helps with proof of principle
- Proof of concept first SiNAPS Node
- Chip size 2x2 [mm]
- Integration based on Polyimide or Ceramic substrate
- Single Substrate with support for 3D integration with battery and radio
- Target Date for Integration M22

### Large Bonding Area for conductive adhesive

### Thin flexfoil

### Radio chip

### Towards issue 2
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the team!