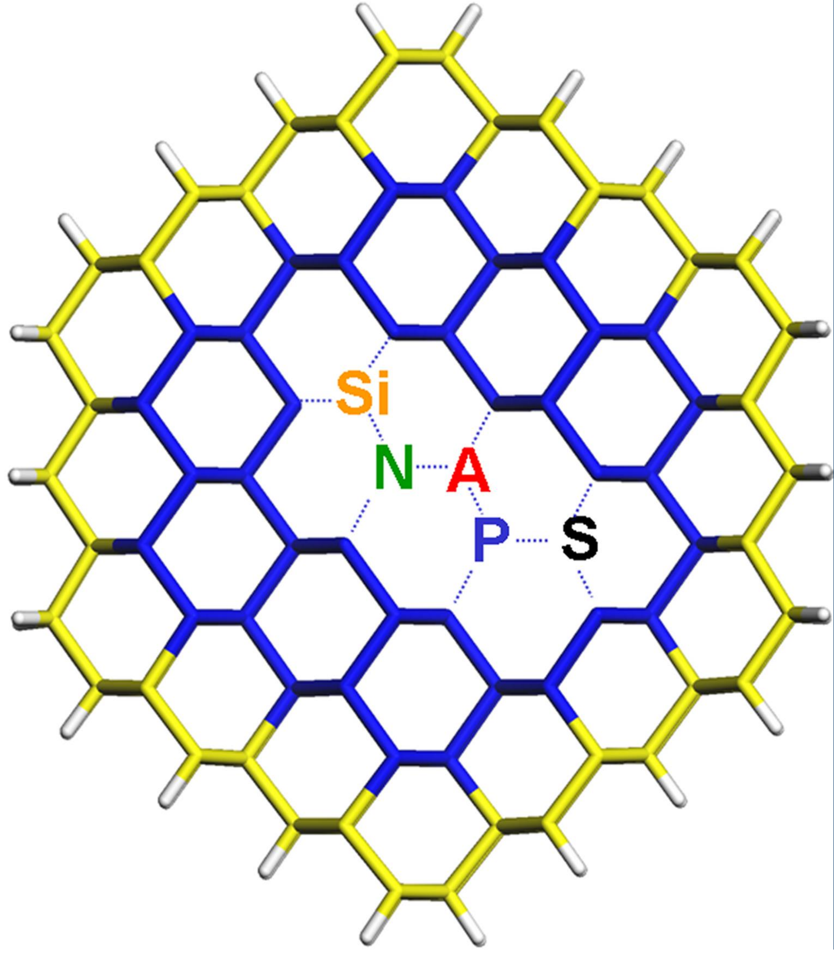

A miniaturised autonomous sensor based on nanowire materials platform: the SiNAPS mote

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The SiNAPS mote concept

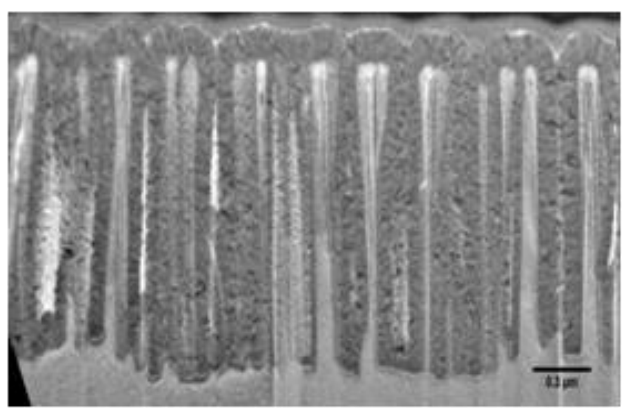
The objective of the SiNAPS project is to lay the foundations for building standalone dust-sized (sub mm^3) chemical sensing platforms that harvest energy from ambient light.

Current solutions in ICT are enabled by new materials at the nanoscale and SiNAPS aims:

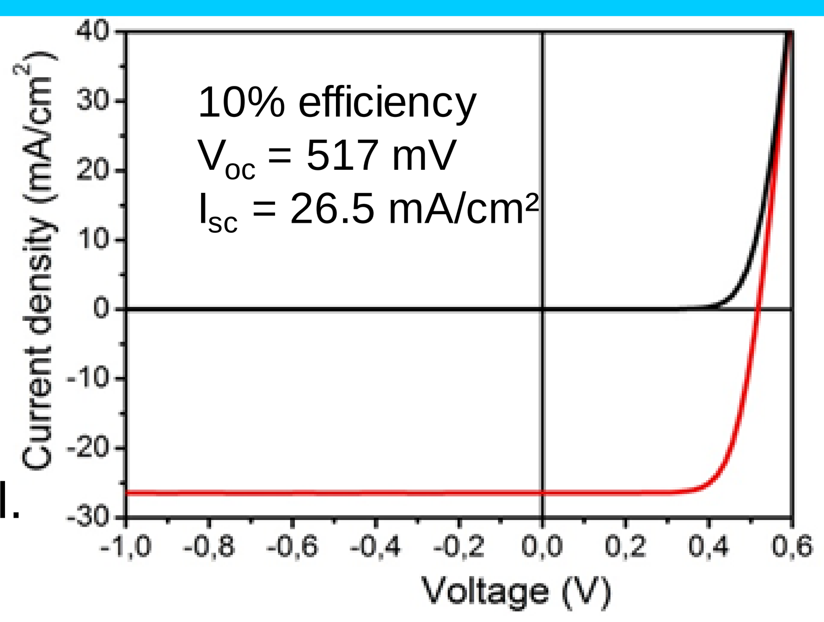
- to develop the capability of nanowires as nanotechnology-enhanced energy harvesters and (bio-) chemical sensors
- to design miniaturised CMOS electronics (power management and sensor interface units) for state-of-the-art low-power consumption.
- to integrate the various modules into a system that will demonstrate the proof-of-concept of the SiNAPS mote.

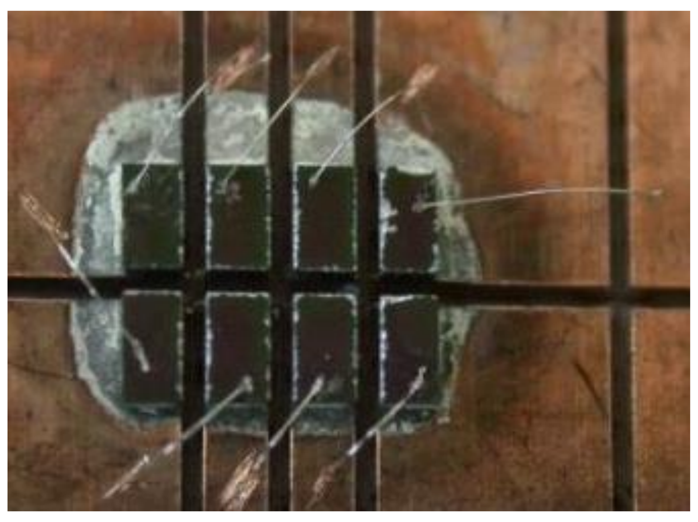
Applications can be found in healthcare (point-of-care diagnostics, e-Health, m-Health), pollution monitoring, building automation, logistics, supply-chain controls and chemical warfare. The project is funded by the EU under the FP7 ICT FET Proactive programme: "Toward Zero-Power ICT" and brings together 2 research institutes, 2 academic partners and 1 SME.

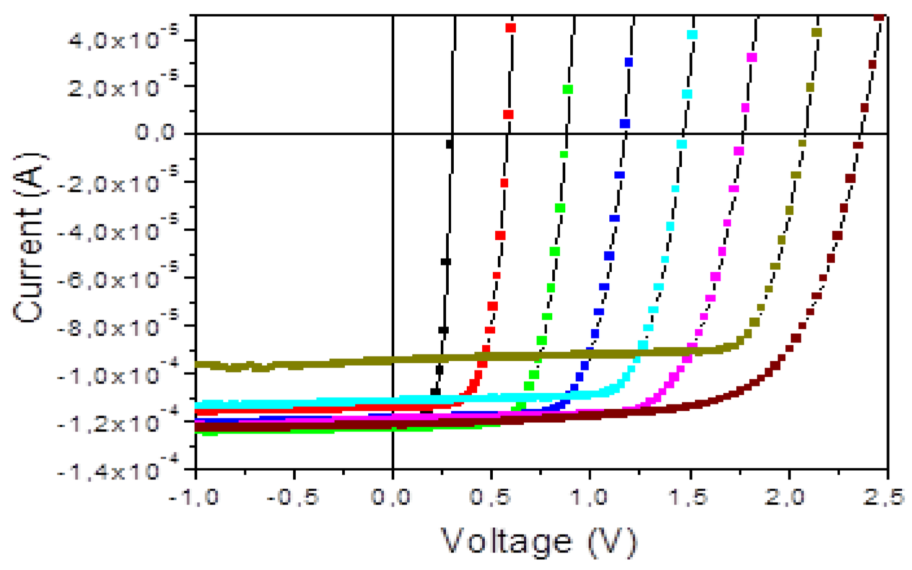
Energy harvesting module: nanowire solar cells



TEM cross section of nanowire solar cell.

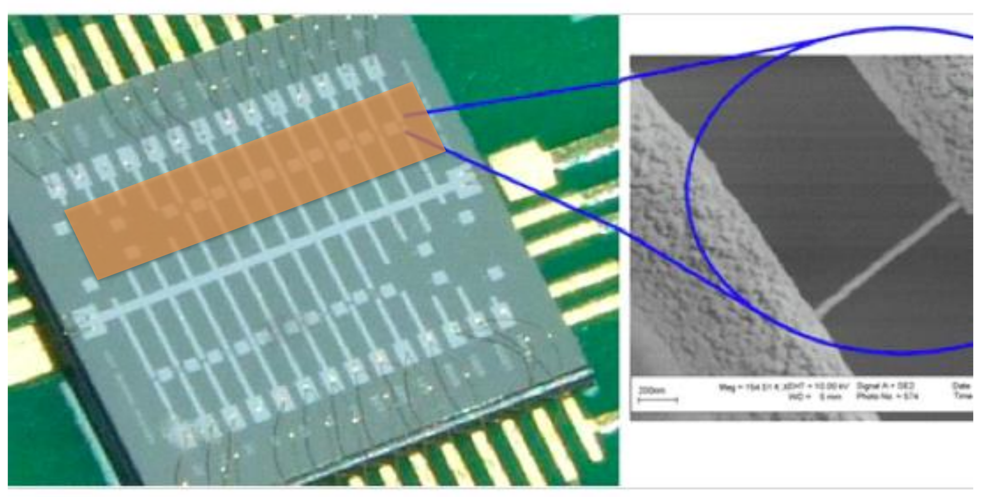


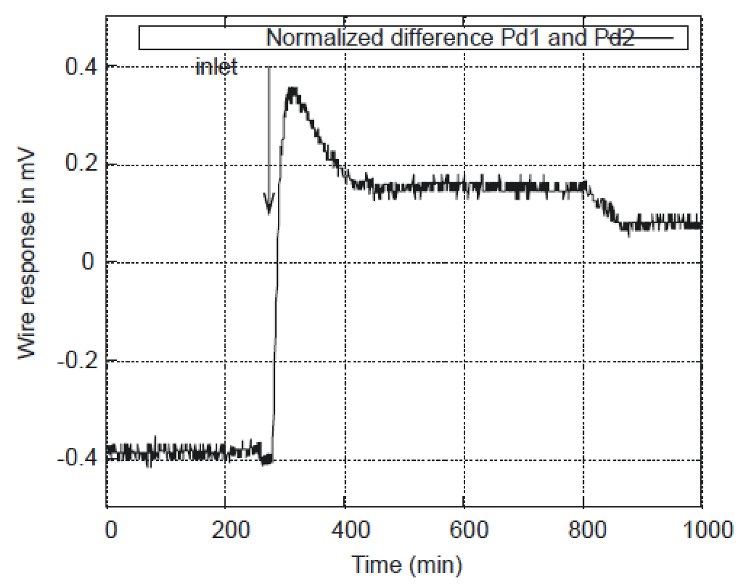




Simple minimodule with a total area of 7.8 mm² consisting of 8 nanowire solar cells connected in series by wire bonding and I-V curves under AM1.5 illumination of cells 1 to 8 of the module connected in series.

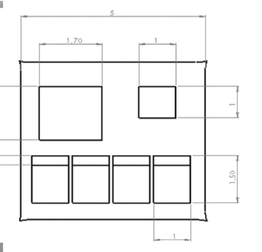
Sensor module: Hydrogen Pd nanowire sensor



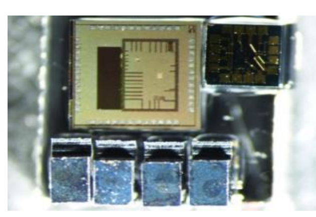


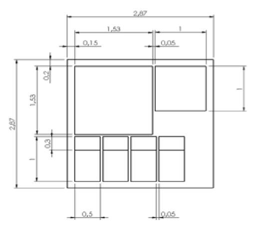
Pd nanowire chip (left). Compensated nanowire response and H_2 detection at inlet of 1200ppm.

Towards integration



Issue 2 Device



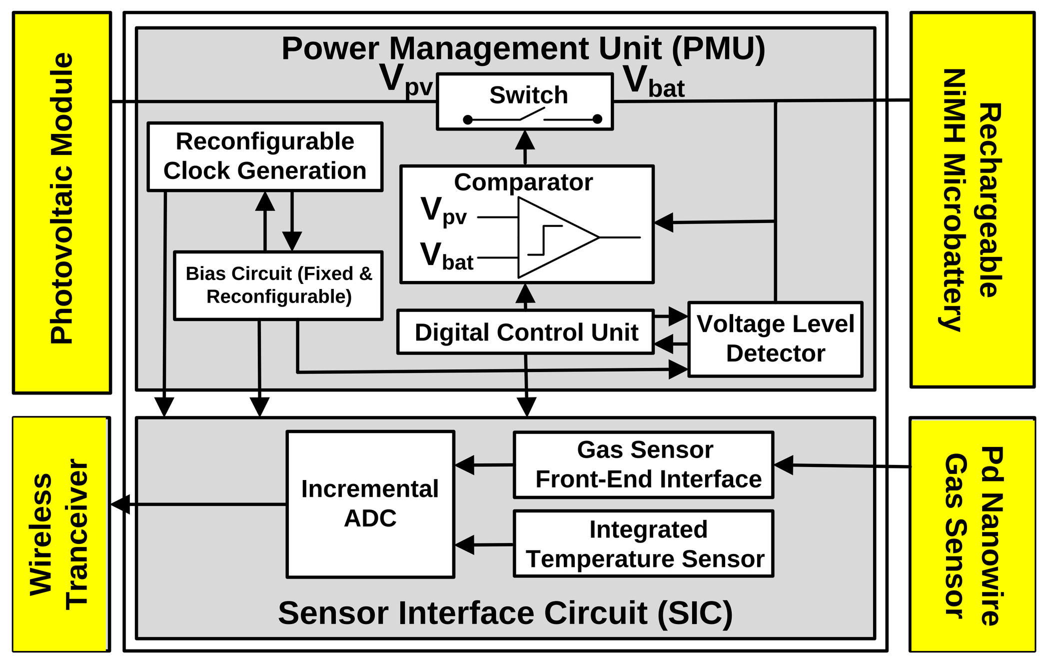


Issue 3 Device
Integration volume 2.87x2.87x1 mm^3!

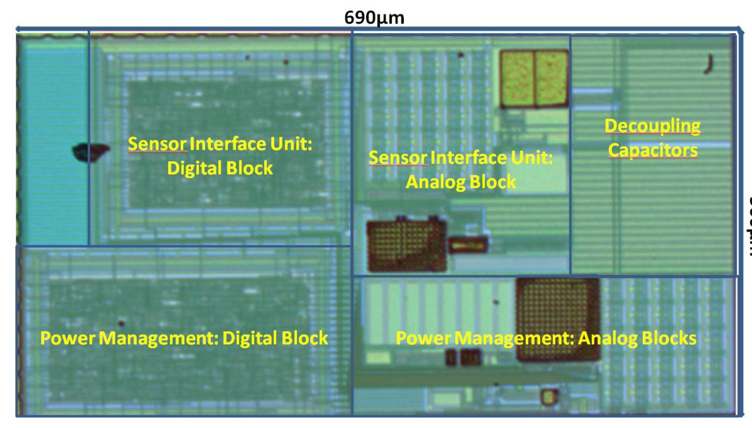
References

The project produced around 45 publications. Please contact the project coordinator for reprints on each of the topics.

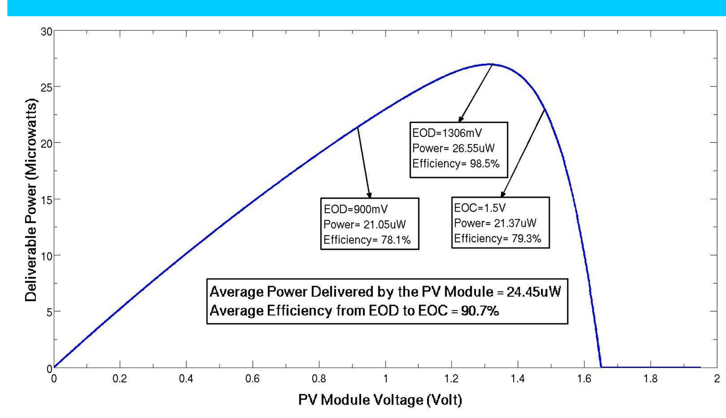
System architecture



Block diagram of the SiNAPS electronic circuit.



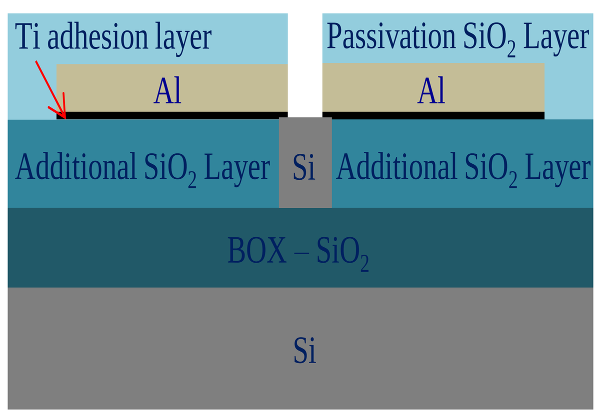
Electronics module: power management



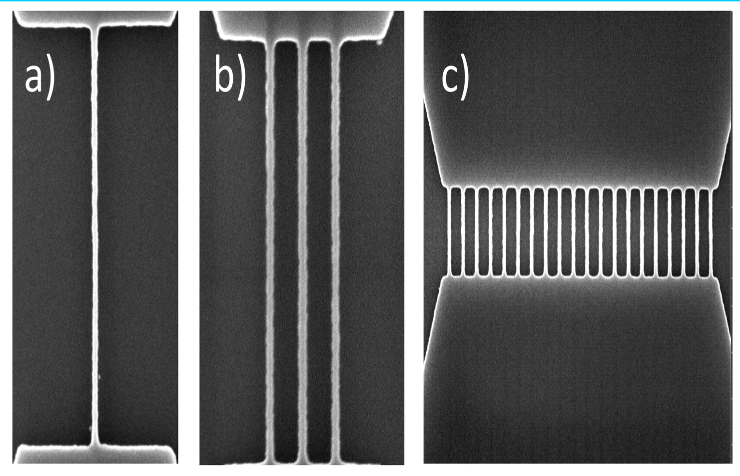
Power delivered to the battery under simulated 10% of AM1.5 illumination.

Block	Die Area (μm²)	Active Power (nW)	Average Power (nW)
Clock generator	14,400	165	165
Digital control unit	38,115	90	90
Bias circuit (10 nA)	2,832	35	35
Comparator	759	55	<1 nW
Level detector	31,960	520	<1 nW
SCBM	6,300	640	<1 nW
Sensor interface circuit	99000	1730	140

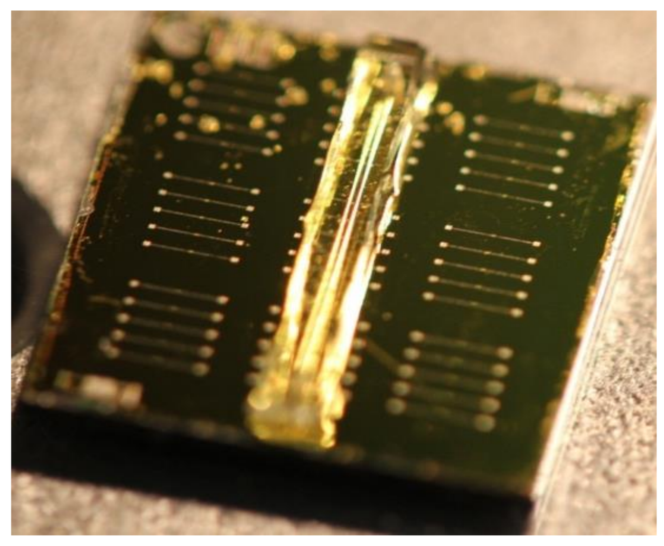
Sensor module: junctionless Si nanowire biosensor



Schematic representation of the sensing device in cross section (left).

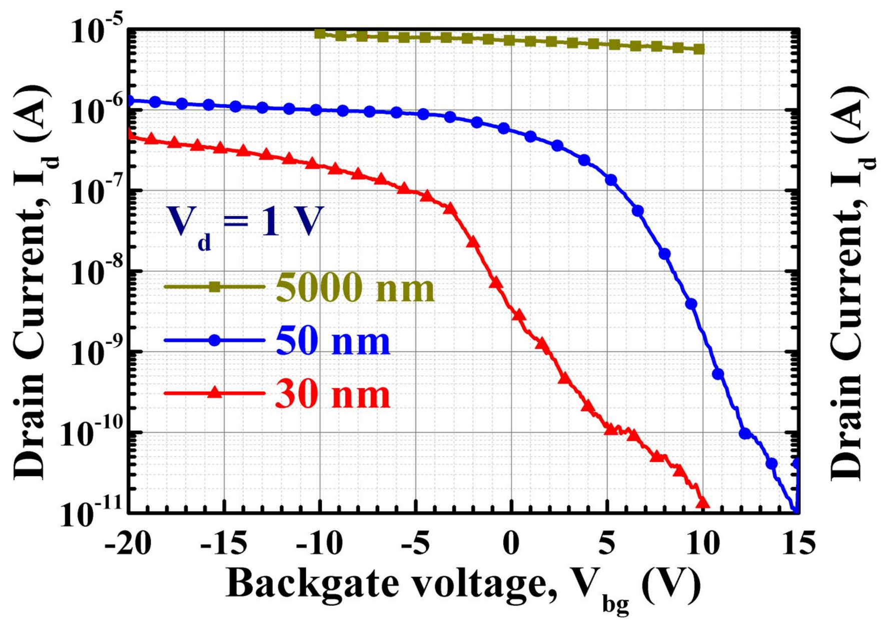


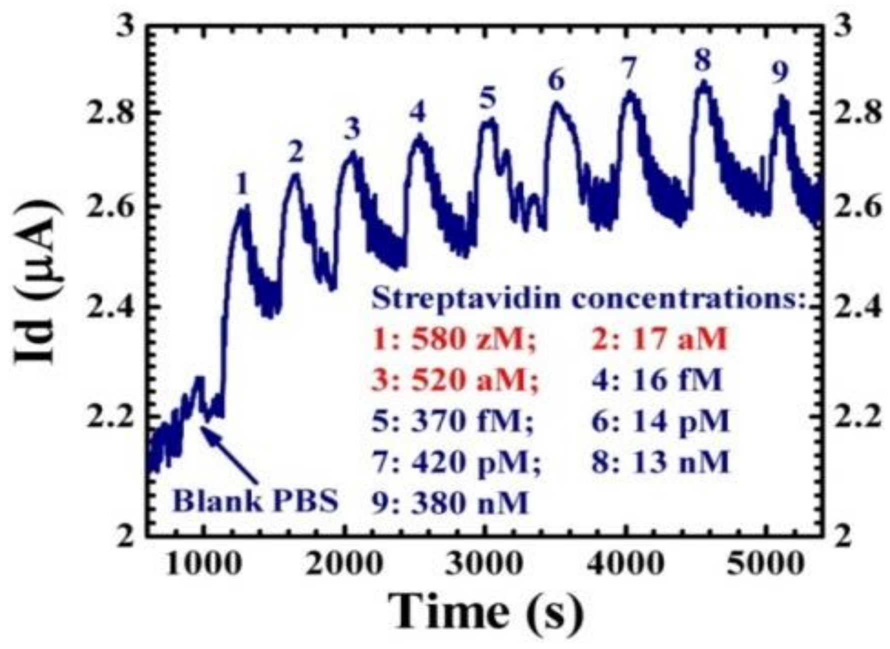
SEM images of devices composed of a) 1, b) 3 and c) 20 Si NWs. In each case the wires are 1 μm long and 20 nm wide (right).



A PDMS microfluidic stamp attached to a Tyndall device (right).

Figures Below
(left) I_d-V_{bg} curves of devices composed of single SiNWs of length 1 μm and widths of 30, 50, and 5000 nm.
(right) Drain current vs time measurements whilst increasing concentrations of streptavidin solutions were administered.





Summary and conclusions

- ✓ Achieved less than 350nW and 2.1 μW average and active power consumption for the SiNAPS mote using CMOS electronics on mm^2 area
- ✓ Demonstrated nanowire array solar cells (mm^2 area) with efficiencies up to 10% under AM1.5 illumination and open circuit voltages of 450-500mV
- ✓ Direct charging of target battery is achieved with end-to-end efficiencies up to 90% at AM1.5 illumination and 80% under 100 times reduced intensity (no MPPT!)
- ✓ Integrated low-power junctionless Si nanowire sensors with microfluidic channels on a ~1mm^2 area (active and passive fluid delivery for pH, ionic strength and streptavidin sensing)
- ✓ Low-power Pd nanowire hydrogen sensor platform (mm^2 area) to detect hydrogen gas concentration in the low ppm range and over a broad temperature range