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Nanomaterials make possible integrating gas sensors in wireless and ultralow power consumption motes

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Abstract

Power consumption is one of the most challenging issues that hamper the development of autonomous chemical and gas sensors. Here, we present the first prototypes of a new generation of fully autonomous gas sensor systems that combine self-heated nanosensors with wireless communications and energy harvesting systems for extended battery lifetime.

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1. Introduction

Power consumption is one of the most challenging issues that hamper the development of autonomous chemical and gas sensors. Recently, it has been demonstrated that conductometric nanosensors based on individual metal oxide nanowires [1] can help to dramatically diminish the power required to heat the active material up to the optimum temperatures for sensing [2, 3], which is the most significant power demand. Here, we present the first prototypes of a new generation of fully autonomous gas sensor systems that combine self-heated nanosensors with wireless communications and energy harvesting systems for extended battery lifetime. This result shows one of the first practical uses of nanotechnology in real world electronic systems.

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2. Experimental and Technical Details

To fabricate the sensors, individual SnO₂ nanowires [4] were electrically accessed with the help of a FIB equipment [5]. The signal conditioning and measurement subsystem was based on our previous findings reported elsewhere [6].

The control and communication functionalities were based on the Atmel ZigBit module with integrated 10-bit ADCs, 128KB of data memory and low power wireless communications based in the 812.15.4 protocol and working in the 868MHz frequency (Fig 1).

The sensor units (“motes”) were remotely controlled with the help of an application-specific PC program capable of setting the nanowire’s working conditions (applied current value and thus, self-heating temperature) and also recording its resistance changes over time (Fig 2).

The power processing subsystem relayed on a Si-based photovoltaic panel that stores its energy in a rechargeable Li-ion battery using a supercapacitor to improve the battery life and the number of charging cycles (inset Fig 3).

3. Results and discussion

The above-described configuration rendered power consumption values lower than 30\(\mu\)W using duty cycling techniques (Fig 3).

For years the need of heating the sensing materials has kept the power needed to operate conductometric gas sensors, such as the ones based on metal oxides, above the mW range. In previous works [2,3] it has been shown that the self-heating effect in nanowires reduces that value to a few \(\mu\)W. This minute power requirements made recently possible considering, for the first time, energy harvesting techniques as a suitable power sources for such applications[7]. Here, we demonstrate that it is also possible to keep the power consumption of a fully functional gas detector, featuring data acquisition and wireless communications, in the tens-of-\(\mu\)W range by using a self-heated gas sensor and duty cycling techniques.
From the sensing point of view, the system displayed an autonomous response to gases such as CO, NO$_2$, NH$_3$, temperature and humidity that could be recorded remotely with the help of a small embedded computer or a common PC (inset Fig 3 and Fig 4).

Stress test showed that the system can keep operating in real Sun illumination conditions continuously without component failure or power drain.

4. Conclusion

After the first proof-of-concept devices [7], we present here the first fully functional prototypes that integrate individual nanowires, wireless communications and energy harvesting and accumulation systems that feature fully autonomous operation. This result, which represents a breakthrough enabled by the use of nanotechnology in sensing applications, paves the way to yet unexplored possibilities in the field of chemical sensing such as multi-spot hazard detection, embedded systems and global awareness applications.

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