Nanosensors for sustainable cities: From fundamentals to deployments

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In the current context of environmental urgency amplified by climate changes, optimizing the workings of urban ecosystems in terms of resource preservation and quality of life is on the critical path toward a sustainable future. To achieve this, the massive monitoring of urban spaces via the so-called "internet of sensors" is proving its worth, guiding decision-making at every level, from global policies to individual actions. However, progresses are slowed by determining hardware, software and usage bottlenecks, such as power autonomy, network resilience or protection of privacy.

Nanotechnologies have long been proposed as key-enabling technologies to overcome the hardware bottlenecks of the Internet of Sensors, notably for improved sensing capabilities at lower cost and lower energy consumption. But concrete examples of real-life applications are few and far in between. This work investigates two of the main hurdles for actual deployments of nanosensors, namely reproducibility and reliability.

It reports notably on the development of a repertoire of nanocarbon-based sensors for strain, humidity and chemical sensing. In view of achieving real-life applications, a strong focus is placed on the topic of reproducibility as the key to both mechanisms understanding and subsequent electronic integration. Highly reproducible carbon nanotubes strain sensors were successfully deployed in the field for durability monitoring in concrete materials.

The concept of nanoreliability is also introduced as a mean to predict and optimize lifetime of nanodevices in their actual conditions of use with the development of nanodevice-compatible modelling and characterization tools. Namely, an experimental platform for multiphysic loadings under in-situ characterizations is nowav ailable to determine fatigue behavior of nanodevices and identify at the microscale weak spots that foster ageing. High resolution characterization tools complemented with data processing tools are used to further understand the nanoscale mechanisms of operation and of ageing. The outputs of both approaches are gathered to build accurate device models, which will be later used to predict lifetime. Overall, the reported results strongly support the worth of nanosensors for urban applications. The industrial transfer of nanocarbon-based sensors is now at a one-to-three year horizon. Nanosensors will actually get disseminated into the civil society in the near future, contributing to a more sustainable approach to urbanization.

As a direct consequence, the scientific community needs to ensure that the benefits of nanosensors in terms of sustainability are not overcome by the health and environmental risks nanoparticles may present. Toward this goal, the development and application of a methodological framework for nanosensor life cycle analysis is proposed.