Inkjet printing of nanobiosensors: limits, challenges, and opportunities

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Electrochemical sensors, biosensors, and nanobiosensors are fundamentally composed of basic electronic components such as electrodes, conducting lines, contacts, and insulators. Therefore, it should not be surprising if the most advanced nanobiosensors are typically fabricated by standard microelectronic methods (also known as clean room based methods) such as photolithography and others.

If on one hand these methods allow for reproducible and ultra-high resolution 3D structures with a wide variety of materials, on the other hand they are very expensive. In fact, they require keeping the working environment completely dust free (possible only in specific spaces called clean rooms) and using high profile equipment.

Simple sensors and biosensors may also be fabricated with easier and out-of-the-cleanroom methods such as sputtering, screen-printing, and other additive fabrication methods. However, biosensors taking advantage of nanomaterials or nanostructures, i.e. nanobiosensors, are complicated to be fabricated with these methods without employing long and difficult decoration protocols.

Inkjet printing emerged in the past years as a promising alternative to both clean room and other printing methods for the fabrication of electrochemical nanobiosensors. This method, combined with nanomaterials-based inks (nanoparticles, 2D flakes, etc.) allows the fabrication of thin-film metal electrodes (100 nm – 1 µm) with a XY resolution in the micrometer range on both rigid and flexible substrates. The drop-on-demand strategy permits saving ink without the need of any mask and allowing for an ultra-short concept to prototype time.

Despite these appealing characteristics, inkjet printing is still struggling to permeate the biosensors market because (i) the equipment devoted to research is still very expensive, (ii) the printing performance depends on the substrate, the ink, and the printing parameters, (iii) the post-printing treatments (drying, sintering, annealing, etc.) are often complicated, time-consuming, or not compliant with many substrates such as paper, textile, and plastics.

In our group, we have proved that consumer (low-cost) inkjet printer can be successfully used for the fabrication of electrochemical biosensors on flexible plastic substrates without any post-printing treatment using metal nanoparticles-based inks [1-3], even with multi-material real-time printing. Furthermore, we have introduced a simple heater that can facilitate the printing on different substrates improving the ink adhesion and that can be printed itself with the same printer [4].

The design of the biosensors is extremely easy and can be performed on any drawing software, including MS Paint. The loading of the ink and printing are simple and straightforward as well. The perspective of our work is to be able to take not the biosensor but it's fabrication at the point of care, replacing the current paradigm of centralized fabrication to a more distributed one that we call ubiquitous printing. This will allow our society to be more resilient to supply chain disruptions (as during the COVID19 pandemic).

References

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Figures

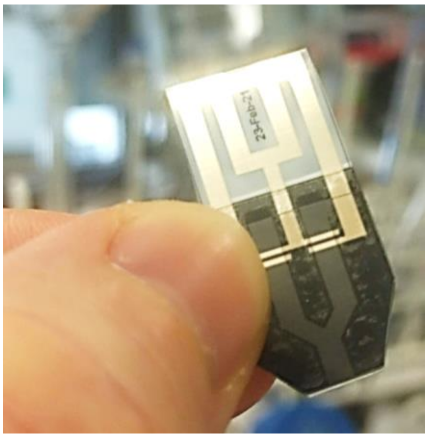

Figure 1. Inkjet printed differential electrochemical interdigitated impedance-based biosensor.