

## Nanostructured ZnO for Electrochemical Biosensors

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### Editorial

Biosensors have become important and practical tools in pathogen detection, molecular diagnostics, environmental monitoring, food safety control, and homeland security. Of these, electrochemical biosensors are of particular interest due to several combined advantages such as low cost, ease of operation, and miniaturization capability. A current goal for these types of biosensors is of becoming point-of-care diagnostic devices. Much effort has been put into improving key performance parameters, such as sensitivity, specificity, recognition rates, and multiplexing capabilities for parallel recognition, to allow this possibility.

Over the last fifteen years efforts have focused on the use of nanotechnology to develop nanostructured materials (e.g., as nanowires, nanotubes, nanoparticles and nanorods) as biomolecule immobilizing matrices to improve electrochemical detection [1]. Nanoscale structures like these offer many unique features and show great promise for faster response and higher sensitivity at the device interface than offered by planar sensor configurations. Their nanometer dimensions, being in the scale of the target analyte, show an increased sensing surface and strong binding properties, thus allowing a higher sensitivity. The interest in developing these nanostructures for biosensing applications has resulted from the development of new synthesis methods and improved characterization techniques, allowing for new functionalities to be created.

Recently, metal oxide nanomaterials, based on metals such as zinc, tin, copper, titanium, and nickel, has been the focus of many efforts in the development of improved electrochemical biosensors [2]. Of these, ZnO has attracted much attention because of its unique properties, suitable for biosensing applications. For instance, ZnO is a well-known n-type non-silica direct wide band gap semiconductor from group II-VI, with band gap energy of 3.37 eV and a large excitonic binding energy of 60 meV at room temperature. Its direct wide band gap makes it a good candidate for optoelectronic applications and its large exciton energy helps to employ the excitonic recombination process as a lasing mechanism. ZnO is a polar borderline semiconductor material with two crystallographic planes having opposite polarity and different surface relaxation energies that lead to a higher growth rate along the c-axis, e.g., formation of nanorods like vertical structures. It exists in a wurtzite crystal structure, at ambient temperature and pressure, with a hexagonal lattice, having two interconnecting sub-lattices of  $\text{Zn}^{2+}$  and  $\text{O}^{2-}$ , with the zinc ion surrounded by tetrahedral oxygen ions, and vice versa. This tetrahedral coordination gives rise to a polar symmetry along the hexagonal axis, which is responsible for a number of physical and chemical properties of ZnO, including piezoelectricity and spontaneous polarization. The large piezoelectric coefficient of ZnO allows the development of surface acoustic wave devices that can operate at higher frequencies. The variation in electrical properties such as conductivity is dictated by the presence of oxygen vacancies, a shallow interstitial zinc donor, hydrogen donor impurity and other donor type point defects. Moreover, the ZnO near-surface region can be highly conductive, due to H donors in this region and a large density of near-surface electrons. The high electron communication feature,

biocompatibility, and chemical stability with high isoelectric point ( $\sim 9$ ) make ZnO an attractive matrix for biosensor applications.

Researchers have reported a myriad of ZnO nanostructures for biosensor applications synthesized through various physical and chemical routes. These include nanowires, nanorods, nanotubes, nanocombs, nanoforks, nanofibers, nanoflakes, nano-waxberries, nanobundles, nanospheres, nanocomposites, nanotetrapods, nanoparticles, nanorod spheres, nanoflowers, and nanosheets/disks [3]. It is expected that each of these nanostructures should show variations in fundamental electrical, optical and physico-chemical properties, great promise for faster response and higher sensitivity compared to other configurations.

The polymorphic capability of ZnO for the synthesis of nanostructured materials offers a great potential for fundamental studies in the roles of dimensionality and size based physical properties. Nanostructured ZnO has proven its potential as materials for biosensing applications. The ease of fabrication using low cost processes, which can yield a wide range of nanostructures, makes ZnO-based matrices a promising platform for low cost biosensors. Moreover, the biocompatible nature of ZnO and compatibility with MEMS technology will play a major role towards the use of this material in designing miniaturized, wireless and implantable biosensors. Further characterization of these nanostructured materials is essential to advance the field of electrochemical biosensors and reach the goal of a sensitive, fast and inexpensive point-of-care diagnostic device.

### References

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