# Optical and electrochemical DNA nanobiosensors

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**In the past two decades, nanoscale advanced materials have been explored for biosensing molecules, so new horizons have opened up for identifying and quantifying biomolecules, and possible early diagnosis of diseases.**

**DNA nanobiosensors show promise. This article provides an overview on their optical and electrochemical aspects. We discuss recent progress in this field, describing basic concepts of molecular beacons and quantum dots as optical nano-imaging systems. Also, carbon nanotubes provide a platform for development and advancement of electrochemical DNA nanobiosensors, which are increasingly being implemented as robust tools for detection in biomedical sciences.**


*Keywords:* Carbon nanotube; Electrochemical DNA nanobiosensor; Field-effect transistor; Genosensor; Molecular beacon; Nanobiosensor; Optical DNA nanobiosensor; Piezoelectric DNA biosensor; Quantum dot; Surface-plasmon resonance

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## 1. Introduction

In recent years, the ultra-sensitive detection of biological compounds using nanomaterials has received great attention due to the unique optical, electronic, chemical and mechanical properties of these nanomaterials. Nanomaterials [e.g., quantum dots (QDs), gold and silver nanoparticles (AuNPs and AgNPs) and nanowires, carbon nanotubes (CNTs) and polymers (especially conducting polymers)] have been used to detect macromolecules (e.g., enzymes, antibodies, and nucleic acids) [1].

Basically, all molecular-based biosensors rely on highly specific recognition events to detect their target analytes. It is necessary to have a suitable sensing platform to facilitate formation of the probe-target complex, upon which the binding event triggers a detectable signal for electronic readout [2].

In general, biosensors rely on the intimate coupling of a biological recognition element with a physical transducer to convert the biological information into a detectable signal, proportional to the concentration of analytes [2]. Such signals may be due to changes [e.g., in proton concentration, release or uptake of gases (e.g., ammonia or oxygen), absorption or reflectance, light emission, heat emission, mass changes] [3].

DNA is especially well suited to biosensing applications due to its tremendous molecular recognition potential [2]. DNA biosensors exploit the preferential binding of complementary single-stranded nucleic-acid sequences. This system usually relies on the immobilization of a single-stranded DNA (ssDNA) probe on a surface to recognize its complementary DNA target sequence by hybridization (Fig. 1) [4].

In this article, we review current research activities that concentrate on optical and electrochemical aspects of DNA nanobiosensors for application in biomedical research.

## 2. Molecular beacons

### *2.1. Structures and properties*

Molecular beacons (MBs) are single-stranded nucleic acid probes comprising three functional domains – a stem, a loop, and a fluorophore/quencher pair (Fig. 2). Depending on the conformational state of MBs, fluorophore/quencher pairs, the signaling elements, produce on/off signals [2]. MBs are widely used in fluorometric

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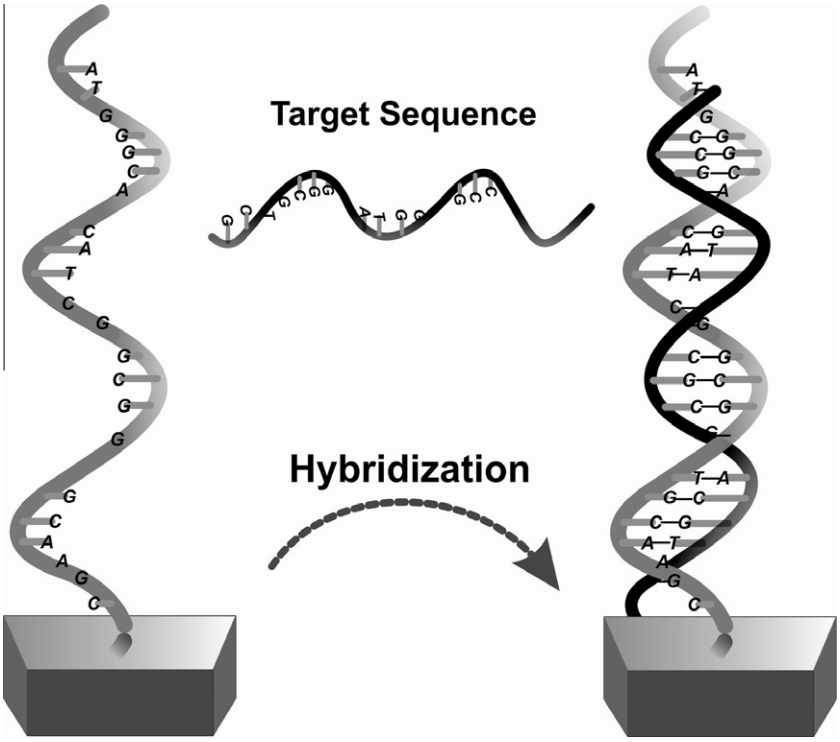


**Figure 1.** Immobilization of ssDNA probe and detection of the complementary DNA targets.

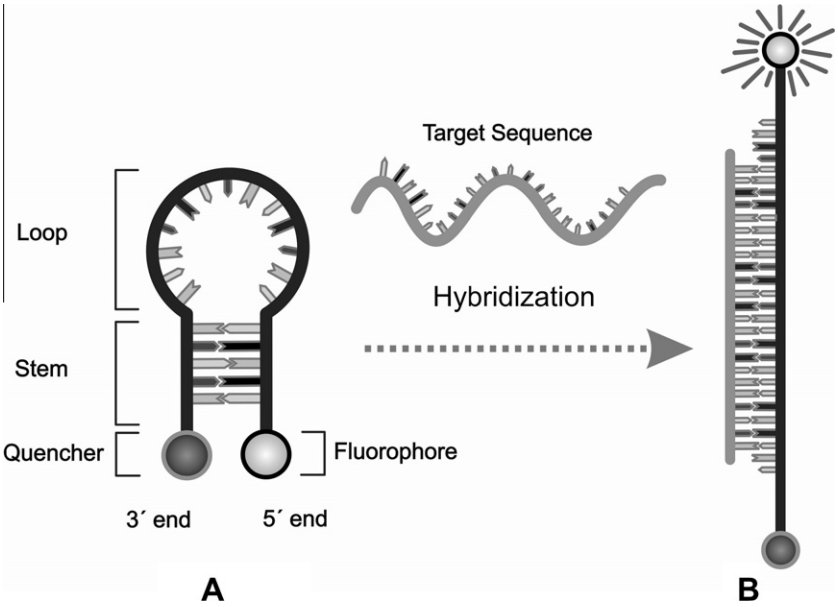


**Figure 2.** Schematic architecture of molecular beacon (MB). (A) Hairpin representation of MB with quencher-fluorophore pair. (B) Hybridized MB with targeted DNA.

analysis of nucleic acids [2]. As a result of huge efforts, several conceptually new MB probes have been developed, including a most recent design of quencher-free MBs [5]. However, all the recent advances in the design of quencher-free MBs are based on introducing a fluorophore at the stem terminus [5]. Ideally, a hairpin structure of MB comprising 4–7 nucleobase pairs (bp) in the stem region and 15–25 bp in the loop region are