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A Review of Recent Research on Nanosensors

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Abstract: Biological and chemical species identification is fundamental to many fields of healthcare and life sciences, from disease detection and treatment to the development and screening of new drug molecules. Hence, the development of new tools that allow these organisms to be studied directly, sensitively and quickly could have a major impact on humanity. Nanowire-based devices are emerging as a powerful and general class of ultrasensitive, electrical sensors for direct biological and chemical species detection. Central to identification is the transduction of the signal associated with selective recognition of an important biological or chemical species In this diverse and interdisciplinary field of science and technology, nanostructures such as nanowires and nano-cristals offer new and sometimes interesting possibilities. The diameters of these nanostructures are comparable to the sizes of biological and chemical organisms being sensed, and thus intuitively reflect excellent primary transducers for generating signals that ultimately interface with macroscopic instruments there are special electrical and optical properties of inorganic nanowires and Nano-crystals that can be used for sensing. Together with their highly stable emission properties, the size-tunable colors of semiconductor nano-cristals open up opportunities for biological species labeling and optical-based detection that give advantages compared to traditional organic molecular colors commonly used today.

Keywords: Fluidics, MEMS, Nanotechnology, Nanowire, Detection, Sensors,

INTRODUCTION

Many reports of Nano-sensors concentrate on a specific type of sensors, such as Nano biosensors, optical Nano-sensors and magnetic Nano-sensors, with many technical details. Here they provide an overview of all Nano-sensors, showing parallels between the different categories and fundamental differences [1]. The goal of this review is to provide an overview that suits beginners to understand the will importance of this area. Nano-sensors are sensing devices with at least one of their sensing dimensions being not greater than 100 nm. In the field of nanotechnology, Nano-sensors are instrumental in (a) tracking physical and chemical processes in hard to reach regions; (b) biochemical detection in cellular organelles; And (c) measurement of nano-scopic particles in industry and atmosphere Needless to say, even greater numbers can be predicted if a full keyword search is performed to include all Nano-sensor publications. Technological development is inevitably accompanied by advance in scientific understanding.

Due to the need to detect and measure chemical and physical properties in hard to reach biological and industrial systems in the Nano-scale region, Nano-sensors are gaining growing interest This analytical analysis discusses various Nano-sensors grouped into three broad types: optical, electromagnetic, and mechanical Nano-sensors. With reference to their applications, the sensing principles and their related advantages are discussed [2]. While sensors have a long and illustrious history, there is a relatively new field of Nano-sensors. Figure 1 summarizes a milestone chart on the production of different Nano-sensors in 1994 and 2005 inclusive. The various

Nano-sensors can be loosely grouped into three broad categories of Nano-sensors:

- **(i)** Optical Nano-sensors,
- **(ii)** Electromagnetic Nano-sensors, and
- **(iii)** Mechanical and/or vibrational Nano-sensors, bearing in mind other Nano-sensors that do not fall into the above-mentioned categories.

Figure 1: Milestone Chart of Various types of Nanosensors

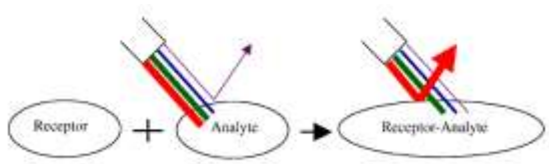

Figure 2: Conceptual Schematics of a Luminescent Dye for Intracellular Sensing

Optical Nano-Sensor:

The first documented optical Nano-sensor was focused on fluorescein that is trapped within a nanoparticle of polyacrylamide and used for measuring pH [2]. Fluorescent chemo sensors are, in the most basic concept, molecules made up of at least one substrate binding unit(s) and photoactive component(s). The luminescence effect is a mechanism by which a fluorophore absorbs light from a certain wavelength followed by a quantity of light with energy corresponding to the energy difference between the ground and the excited states. Figure 2 displays computational schematics for a standard luminescent sensor, whereby when the receptor connects with the analysis, the reflected light changes color. The alteration of photo-vibrational properties underlies the principle of sensing.

Electromagnetic Nano-sensors:

We have two types of sensors under the category of electromagnetic Nano-sensors based on their physical mechanisms:

(a) Detection by electrical current measurement

(b) Detection by magnetism measurement

The specific sensing technique of magnetic nanoparticle sensor technology allows for fast target detection without extensive sample purification or amplification of the signal Because light is not used (as compared to opto-chemical, mechanical, absorbance, etc.) it does not affect the outcome of the test, so testing can be carried out in turbid, light-impermeable media such as cell suspension, lipid emulsion, blood, culture media and even whole tissue. In addition to the application of bioscience, magnetic Nano-sensors – based on magneto-resistance (MR) – have potential application for the electronics industry [3]. MR is the process by which a metal or semiconductor's electrical resistance changes (either increases or decreases) as a consequence of applying a magnetic field. Three orders higher version of this phenomenon was called colossal resistance magnet or extraordinary resistance magnet (EMR).

Mechanical Nano-sensors:

The first mechanical Nano-sensor used to test a Nano-sphere's vibrational and elastic characteristics connected to a tapered cantilever. This work is important in microelectronic devices for application in components of Nano-devices and subassemblies of a Nano-scale.

NANOWIRE NANOSENSOR

The electronically switchable properties of semiconducting nanowires provide an exceptionally attractive sensing modality – direct and label-free electrical readout – for many applications Signals from electrically based devices can be redirected directly to the outside world, electronic Nano-devices are readily incorporated into miniaturized structures and direct electrical detection often dispenses with time-consuming chemistry for labeling. Together with ultrahigh sensitivity, these characteristics suggest that nanowire devices can revolutionize many areas of sensing and detection in biology and medicine. How to assemble nanowires into devices that provide these apparently extraordinary capabilities?

Nanowire Field Effect Transistor:

The underlying mechanism for nanowire sensors is a field effect that is transduced using field-effect transistors (FETs), the microelectronics industry's ubiquitous switches [4]. A semi-conductor such as p-type silicon (p-Si) is attached to metal source and drain electrodes through which a current is applied and stored, respectively, in a typical FET illustrated in figure 3. The semiconductor conductance between source and drain is turned on and off by a capacitive coupled third gate electrode via a thin dielectric layer [5]. In the case of p-Si or other p-type semiconductor, applying a positive gate voltage depletes carriers and decreases conductivity, while applying a negative gate voltage results in carrier aggregation and increased conductivity. The conductance dependency on gate voltage allows FETs ideal candidates for electrically dependent sensing because the electrical field arising from the attachment of a charged species to the dielectric gate is similar to the application of a voltage using a gate electrode. This concept was proposed many decades ago for sensing with FETs, although the limited sensitivity of these planar devices has prevented them from having a large effect.

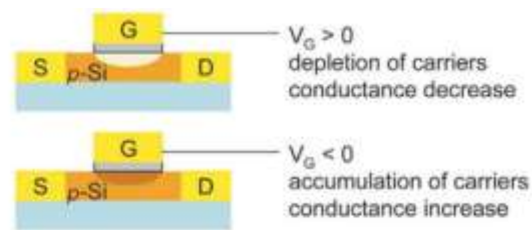

Figure 3: Schematic of a Regular Planar FET device, where S, D, and G Correspond to Source, Drain, and Gate, respectively

As illustrated in Figure 4, where precise sensing is accomplished by connecting a recognition group to the nanowire surface, a general sensing system can be built from the high performance, field-effect nanowire transistors. Since there are comprehensive data available for chemical modification of silicon oxide or glass surfaces from planar chemical and biological sensors, Si nanowires with their natural oxide coating make this receptor association straightforward [7]. When the sensor system with a surface receptor is exposed to a solution that contains a macromolecule such as a protein that has a net positive charge in aqueous solution, precise binding can result in an increase in the positive charge on the surface and a decrease in conductivity for a p-type nanowire [8].

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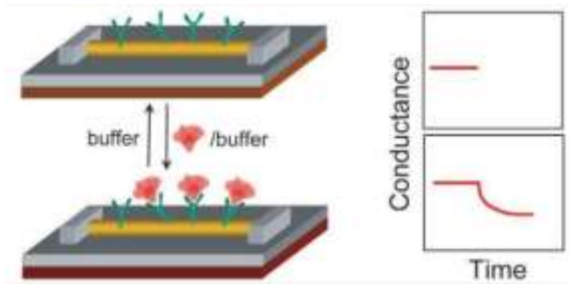

Figure 4: Schematic of a Si nanowire-based FET Device Configured as a Sensor with Antibody Receptors (green), where binding of a Protein with Net Positive Charge (red) Yields a Decrease in the Conductance

A Model Case: pH Sensing:

In 2001, for the case of hydrogen ion concentration or pH sensing, the first example demonstrating the ability of nanowire field effect devices to detect species in liquid solutions was demonstrated [9]. A simple p-type Si nanowire system was transformed into such a sensor by modifying the silicon oxide surface with 3-aminopropyltriethoxysilane, which yields amino groups at the nanowire surface along with the oxide groups of the naturally occurring silanol (Si-OH), as shown in figure 5.

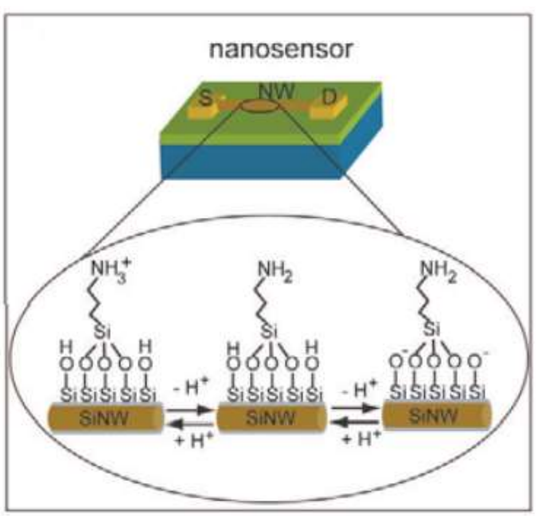

Figure 5: Schematic of an amino-functionalized nanowire device and the protonation/deprotonation equilibrium that change the surface charge state with pH

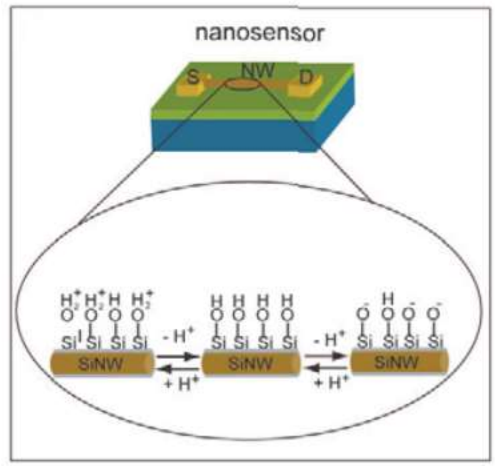

Figure 6: Schematic of a Si Nanowire-based FET Device Configured as a Sensor with Antibody Receptors (green), where binding of a Protein with Net Positive Charge (red) Yields a Decrease in the conductance.

In this case, as shown in figure 6, only the group of silanol can act as a hydrogen ion receptor. In addition, the pH-dependent conductivity shifts are in excellent alignment with previous pH-dependent surface load density measurements derived from silica [10]. The analogy in these early experiments clearly showed that the sensing process was indeed the result of a field effect similar to the use of a conventional gate electrode to apply a voltage.

CONCLUSION

A wide range of Nano-sensors were tested, classified and analyzed according to their operating process, which was then contrasted with their applications It may be noted that optical Nano-sensors are usually very useful for the detection of chemicals within a single cell, and that electromagnetic Nano-sensors are found to be appropriate for both chemical and electromagnetic-mechatronic measurements; while mechanical Nano-sensors are useful in determining physico-mechanical properties and measuring motion. The advances made in this field have been impressive, despite the relatively short history of Nano-sensors. With continued progress in nanotechnology techniques and growing insight into the phenomenon of Nano scale, more development in the field of Nano-sensors can be anticipated by improving the performance of existing Nano-sensors and new Nano-sensors based on new mechanisms.

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