

NANOWIRE-FET: ROLE IN HEALTHCARE APPLICATIONS

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Abstract

Nanomaterials like carbon nanotubes (CNTs), nanowires, including nanoparticles, have revolutionized biosensing because of their unique quantum properties, which enhance the sensitivity of sensors. Their small size, comparable to that of biomolecules, allows for precise detection, making them invaluable in various applications. Nanowires are important for sensor technologies because of their electrical controllability and chemically reactive surfaces, which allow for sensitivity and multiple sensors measuring properties associated with a detection target. Field-effect transistors (FETs) have existed since the 1930s and have a prominent role in today's technology; they are primarily used in a metal-oxide-semiconductor (MOSFET) transistor. These FETs are especially pervasive in digital technology because they are easy to design and can be produced at low cost. Transistor technology has seen scales between 1-2 μm and even smaller. The art and science of producing smaller transistors does not necessarily mean the performance has continued to improve, which has led to research and development in novel, advanced technology. Nanowire Field Effect Transistors (NW-FETs) are an exciting choice to produce unique nano-material sensors in healthcare applications that have the highest sensitivity and flexibility. Nanowire FETs could allow researchers to find biomarkers, infectious viruses, and even DNA. An extremely small yet highly sustainable sensor has potential for diagnostic use, drug discovery, and real-time monitoring. NW-FETs may dominate future thinking and capabilities in medical diagnostics and personalized medicine. This chapter looks at how NW-FETs can be exploited for NANOWIRE. FET technology can be valuable in healthcare for virus detection, finding biomarkers, DNA and drug development. We will show how NW-FET technology can marry theoretical principles to practical application via improved diagnostics and therapeutic advantages from improved sensing that is more accurate, reliable, fast as we need for healthcare technologies.

Keywords: Renewable energy; Solar energy; Solar panel; Energy meter, IoT; Blynk server

6.1 Introduction

Nanostructures create 2D layers, 1D nanowires (NWs), or 0D nanoclusters by shrinking bulk materials in one, two, or three dimensions, respectively [1]. Over time, considerable advancements have been made in nanowires, which are incredibly thin structures on the nanoscale. nanowires, nanofibers, nanotubes, nanorods and whiskers generally represents single-dimensional nanostructures. It was first reported in 1998 that silicon nanowires may be successfully synthesized by a growing process. Eventually, a group of researchers released a number of articles detailing their advancements in the preparation of Si and other

semiconductor nanowires and development of lab-scale devices using them, like silicon nanowire transistors. The majority of methods for fabricating nanowires are based on the vapor-liquid-solid (VLS) crystal growth mechanism.

Synthesized nanomaterials, such as carbon nanotubes, nanoparticles, quantum dots including nanowires, have contributed significantly in different sectors, including biological sensors, in past ten years. On comparing with bulk materials, nanoparticles' high surface area-to-volume ratio significantly boosts their sensitivity. The usage in drug discovery and the detection of viruses, DNA, and biomarkers are the main topics of this review. Nanomaterials are also employed in photonics, data storage, chemical and biological sensing, drug delivery, and energy storage [2], [3]. Further advancements in the creation, description, and incorporation of nanowires may lead to innovations in a number of domains, including flexible electronics and biomedicine [4]. Due to their small size and adaptable characteristics Nanowires have great promise for extensive range of technological applications.

Nanowires are highly effective structures for modern nano electronic devices, offering the ability to precisely control their diameter during fabrication. In recent years, scaling of MOSFET technology has enabled integration of a large number of field-effect transistors (FETs) onto a single chip. Gordon Moore suggests that number of transistors on a chip will double every two years, has proven accurate. International Technology Roadmap for Semiconductors (ITRS) forecasts that CMOS technology scaling will continue for the foreseeable future. Over the past four decades, advances in integrated circuit (IC) technology have brought transistor sizes down to the nanometre scale, with the introduction of 22 nm process technologies. Today, transistors are typically fabricated using gate lengths ranging from 22 nm to 45 nm. Leading companies like Intel, AMD, and IBM have showcased p-channel FETs with gate lengths as small as 6 nm. Nanowires, with their one-dimensional structure, are essential for the development of various nanoscale semiconductor devices, including FETs, photodetectors, LEDs, and biosensors. Nanowires, created through techniques such as electrospinning and vapor deposition, possess remarkable mechanical, optical, and electrical properties that make them highly suited for a extensive range of applications, particularly in fields of nanoscale electronics, drug delivery, and chemical sensing. The precision provided by advanced synthesis methods, including vapor-liquid-solid (VLS) and template-assisted techniques, allows for custom fabrication of nanowires with specific characteristics. This capability provides opportunities to apply nanowires for intracellular signalling, providing an efficient pathway for specific drug delivery, both of which are necessary to improve precision medicine.

Biomedical areas where nanowires have biopharmaceutical applications are particularly exciting; biomedical imaging, neural interfacing, and tissue engineering are just a few examples. As far as potential multipurpose applications are concerned, nanowires have tremendous potential; notwithstanding the issues of biocompatibility and the feasibility of manufacturing, these challenges could be addressed because nanowires could provide multifaceted characteristics and functionality, leading to innovated diagnostic, biosensing, and regenerative medicine methodologies. In addition, nanowires are expected to play an importance in next generation of point-of-care medical technologies.

In drug delivery, nanowires display great promise for precision therapy. For example, iron oxide nanowires can hold chemotherapeutic agents, and then heat the nanowires with an external magnetic field for targeted chemotherapy for cancer [5]. In addition to their potential to provide targeted treatment, nanowires, such as nanowire arrays, are able to provide continuous and controlled drug release in a manner that elicits consistent therapeutic effects

[6]. Other uses for nanowires that have great promise include nanowires for neurotrophic drug delivery targeting brain inflammation, and hollow nanowires for delivering insulin for diabetes treatments, with possibilities for self-regulated treatments [7][8]. Furthermore, nanowires are being explored for their ability to accelerate tissue regeneration, with growth factors released from the nanowires promoting wound healing and tissue repair [9]. Nanowire stents have further applications in the vascular field, as they stimulate endothelial cell growth, which facilitates the formation of new blood vessels [10]. Even though nanowire drug delivery systems are still in the beginning stages, they have the potential to reduce systemic side effects, and allow for personalized therapies for diseases such as cancer, cardiovascular diseases, and diabetes, which will lead to better patient outcomes [11].

Because of their remarkable properties, specifically their high sensitivity and ability for label-free detection, nanowires have excellent opportunities to develop biomedical imaging modalities. Their attributes enable accurate quantification of biomarkers, allowing the diagnosis of disease at earlier stages and with more reliability [12]. An example is iron oxide nanowires, which can serve as MRI contrast agents to aid the rate of non-invasive imaging; thus, providing improvement in imaging versus surrounding tissues [13]. Additionally, nanowires can help enhance guided photosensitive tumor resections by eliminating larger portions of tumor during surgical procedures when they are combined with proteins, quantum dots, and/or fluorophores [14]. Fluorescent nanowires allow for continuous in vitro monitoring of gene regulation, which also relates to cellular metabolic processes or efficiency, via oligonucleotide delivery tracking [15]. Nanowire neural interfaces represent another domain of this integration for training purposes; where higher resolution or a more accurate design could enable one to study single-neuron calorimetry, improving our ability to measure metabolic processes, whilst also improving methodology in characterizing neuronal networks refractory to potential neurochemical systems modelling of neurological disease [16]. Albeit these methods are yet to be fully investigated, they represent potential milestones in an otherwise biomedical imaging field that remains deficient of possibilities for standardized diagnostic utility for neuronal mapping, improved imaging of targeted cancers, or diagnosing disease molecular signatures at all [17].

Nanowires have the potential to model the behavior of cells in artificial tissues, therefore being important for tissue engineering. Nanowire scaffolds can also be arranged by electrospinning and 3D bioprinting to control the linear growth of cells and orientation of the extracellular matrix deposition by specific axes [19]. These wire structures have the potential to be designed and applied individually or stacked to create complex biostructures with all possible design decisions affecting the tissue adaptation process by controlling its mechanical properties, degradation rates, and bioactivity variables [20]. Furthermore, nanowire structures could provide clues to stem cells, guiding the path to specific cell lineage [21]. When engineered surface nanostructures are manipulated in their application, they may represent the in vivo cellular microenvironment, influencing cell adhesion, proliferation, differentiation, and other critical life cycle behaviors further refining the engineering process. It has been demonstrated in a number of different areas in tissue engineering including neural, cardiac, cartilage, and bone that nanowire structures can generate biomimetic signals that encourage tissue regeneration instead of fibrosis or scarring [22], [23]. Although these advances are promising, it is important to note that we do not know all of the potential risks such as cytotoxicity and additional studies need to be done to ensure the safety of nanowire biomimetic scaffolds in the clinical setting.

Future revolutions in nanotechnology and healthcare might be influenced by the multifunctional characteristics of nanowires [24]. This smooth integration into biological

systems has the ability to impact the technologies of biosensing and diagnostics altogether. For example, the ability to increase the efficacy of regenerative medicine, when coupled with controlled stem cell proliferation, by using nanowire scaffolds could have vast implications in tissue repair and repair solutions. Additionally, the development of a nanowire thermos responsive system is providing possibilities for cancer therapies, such as therapies that can be targeted by temperature change [25]. In addition, their precise and adaptable drug delivery mechanisms could pave the way for next-generation point-of-care treatments, offering personalized and timely interventions. Nanowires can be possible tool to accelerate clinical translation of nanomedicine as developments progress, but achieving their full potential in healthcare applications would require resolving issues with biocompatibility and scalable manufacturing.

6.2 Basics of Field-Effect Nanowire Transistors

Traditional planar field-effect transistors (FETs), made up of gate, source, drain, and body, gave rise to nanowire FETs, a kind of sensor (Fig. 6.1). On the body, metallic materials are used to build the source and drain at micro or nanoscale. Gate is a thin layer of isolation, such as SiO₂, positioned between the source and drain. The conductivity between source and drain is regulated by the gate's creation of changes in electric potential. Usually, an external voltage triggers these potential changes. Furthermore, by adhering to the gate, species that are chemically or biologically charged can affect gate's potential and conductivity. Decades ago, the buildup of charged species was hypothesized as the basis for this detection technique [26]. Though, the low sensitivity of planar gate FET sensors necessitates large sample volumes for detection, limiting their use in many applications.

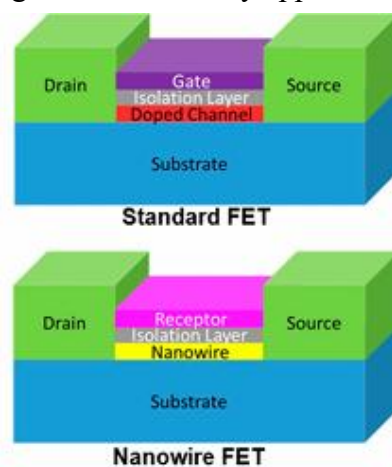


Fig. 6.1 Diagrams showing the distinctions between conventional and nanowire field-effect transistors provide an understanding of field effect transistors (FETs)

Nanowires and receptors, respectively, take the place of conventional doped channels and gates in nanowire field-effect transistors (FETs) (Fig. 1a). Notwithstanding structural variations, the fundamental idea behind nanowire FETs is the same as that of conventional FETs: external changes brought on by charged species regulate the conductivity of the nanowires, which serve as the doped channels. Silicon and silica nanowires are the most often utilized varieties of semiconductor nanowires, while they can be made from a variety of materials. Their strong compatibility with conventional CMOS (complementary metal-oxide-semiconductor) technology, which has long been the mainstay of contemporary semiconductor manufacture, is the main reason for this. Both silicon and silica nanowires' usefulness in device applications is further increased by their capacity to naturally form an

oxide layer that acts as an efficient isolation layer on their surface and by how simple it is to alter their surfaces.

While biomolecules themselves are charged, simply accumulating on the isolation layer of a nanowire does not alter the conductivity of the nanowire, since the silicon and silica surfaces are not inherently sensitive to biomolecules [27]. To overcome this limitation, it is essential to functionalize the surface of the nanowires with specific receptors that can bind the target charged species, such as DNA, RNA, viruses, and other biomolecules. The functionalization process involves modifying the nanowire surfaces so that they can chemically interact with and capture these biomolecules. The process of functionalization creates a bridge between the nanowire surface, which is coated with an isolation layer, and the specific biomolecules being detected (Fig. 6.2).

Once the receptors on the nanowire bind to the biomolecules, they induce an electric field in the nanowires. This, in turn, alters the conductivity of the nanowires, which is the core principle behind the detection mechanism. In this way, the receptors on the nanowire FETs effectively play a role similar to the gate in traditional FETs by converting the input signal in this case, the binding of charged species) into a change in the device's conductivity. As a result, the presence of specific biomolecules can be detected through the electrical response of the nanowires.

A typical process for functionalizing the nanowire FETs is illustrated in Figure 1b, where 3-aminopropyltriethoxysilane (APTES) is used as a receptor for DNA, peptide nucleic acid (PNA), and antibodies. APTES reacts with the silicon surface to convert the silicon-oxygen bonds to a silane chemistry layer (Si–O–Si–X). This silane layer can also be modified or linked with a specific receptor meant for specific biomolecules. The functionalization step is fundamental, as it allows for the nanowire FETs to recognize and sense selective target molecules with sensitivity and specificity for biosensing purposes. With these modifications, the nanowire FETs can be functionalized for a variety of diagnostics and analyses and will have an important role to play in healthcare, environmental monitoring, and chemical analysis.

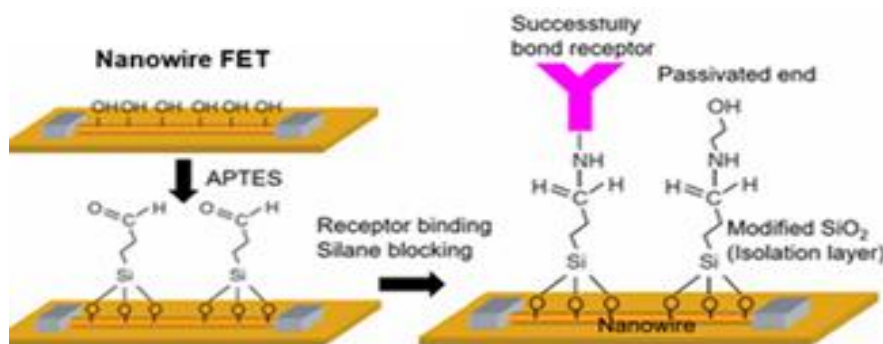


Fig. 6.2 Conceptual overview of field effect transistors (FET).

6.3. MOS Transistor

The field-effect transistor's (FET) working principle was first proposed in 1930. Since then, MOSFETs have been used extensively in integrated circuits (ICs). As circuit complexity increases and device dimensions decrease, IC technology has developed. Discrete atomistic effects (DTE) in doping, bandgap problems, quantum confinement at the interface, and tunnelling through the gate terminal are examples of small-scale effects that have surfaced.

These difficulties result in issues like thermal effects and dispersion, especially when high-power densities (HPD) are present.

The MOSFET continues to be the core component of microprocessors and VLSI circuits. In CMOS technology, the gate terminal is composed of n-type and p-type polysilicon with silicide, which reduces the series resistance of the gate terminal. The high circuit density in CMOS technology is managed by shallow trench isolation (STI) technology. Deep and shallow implants are combined to generate the source and drain. Because doping concentration affects a MOSFET's threshold voltage, which decreases as doping increases, MOSFETs with shorter gate lengths can be manufactured.

i. Scaling of MOSFET

Ever since the MOSFET was invented, integrated circuit technology has seen rapid and exponential growth, largely driven by the downscaling of MOSFET dimensions, a concept first proposed in 1974. Two primary scaling methods are used: constant voltage scaling and constant field scaling. The packing density of MOSFET devices has steadily increased over the last forty-five years. According to the International Technology Roadmap for Semiconductors (ITRS), the gate length would be lowered to 7 nm by 2018. As device dimensions have reached the nanoscale, new challenges in modelling and simulating carrier transport have emerged, particularly due to the influence of quantum mechanical effects. The most commonly used model for simulating carrier transport is derived from the Boltzmann transport equation. In recent years, transistor performance has improved with reductions in size, supply voltage, and gate oxide thickness. As MOSFET dimensions continue to approach nanometer scale, quantum physics phenomena must be considered to account for new effects. To maintain continuous improvement, scaling and modifying the devices is essential. At these reduced scales, various phenomena, known as short-channel effects, become significant and must be addressed for the continued advancement of transistor technology.

ii. Advance MOSFET Structure

According to the ITRS, semiconductor devices will need channel lengths of about 10 nm by 2015 due to the ongoing downscaling of field-effect transistors. As new semiconductor materials emerge, novel nanoscale devices have been developed, necessitating further scaling down to achieve 10 nm gate lengths. The advancement of multi-gate field-effect transistors, such as double-gate MOSFETs, Pi-gate FETs, omega-gate MOSFETs, tri-gate MOSFETs, and surrounding-gate MOSFETs, calls for further progress in fabrication techniques to support these innovations.

iii. Double-Gate (DG) MOSFET

An ultra-thin silicon layer is positioned between the front gate and the rear gate, the two gate terminals of a double-gate MOSFET (DG MOSFET). Both symmetric and asymmetric DG MOSFET architectures have been created. These devices can operate in two modes: three-terminal and four-terminal. Many research groups have developed analytical and compact models to describe the behaviour of DG MOSFETs, advancing the understanding of their performance and potential applications in modern semiconductor technology.

iv. Surrounding-Gate MOSFET

Gate terminal of a surrounding-gate MOSFET completely encircles the channel, offering enhanced channel control and a notable decrease in leakage current. Numerous surrounding-gate MOSFET models have been created to facilitate circuit modelling. In order to improve device performance, a charge plasma process is employed for constructing graded channel; while doping-less technique has been introduced to design graded-channel nanowire MOSFETs. According to studies, nanowire FETs perform better than DG MOSFETs in terms of sensitivity and response, which has led to their proposal for usage in photosensors. Furthermore, a three-gate metal nanowire MOSFET has been created especially for photosensing applications.

Comparative studies have indicated that carbon nanotube (CNT) FETs offer superior performance compared to nanowire FETs, demonstrating enhanced efficiency and faster response times in various applications.

v. FinFET

FinFET is a variant of the double-gate MOSFET and serves as an effective alternative to conventional MOSFETs. Its fabrication is relatively straightforward because of its simple structure. Various experiments have shown that FinFETs experience fewer short-channel effects compared to traditional MOSFETs. Researchers have developed different FinFET structures, including symmetric and asymmetric designs, to optimize performance and address specific challenges in semiconductor technology. These advancements demonstrate the potential of FinFETs to improve device efficiency and scalability in modern electronics.

6.4. Issues at Nanoscale Level

With transistor channel lengths below 50 nm, new ways of fabricating devices are required to address problems encountered by varying physical phenomena. At the nanoscale, classical physics fails to adequately characterize electron behaviours, leading to issues such as short-channel effects. The issue of quantum tunnelling where charge carriers can penetrate thin oxide layers from source to drain is a real problem, but in addition to quantum tunnelling, potential changes in threshold voltage due to quantum confinement can impose further limitations on electronic device performance.

Material dimensions clearly affect their electronic behaviours. However, a suitable method for fabrication of nanowires < 10 nm is not yet common place. As technology nodes continue to advance towards sub-10 nm dimensions, new strategies to control and manage charge carrier transport will be needed, specifically for nanostructures such as nanotubes and nanowires. Building seriously contributes towards furthering these devices, and seeing respect for better understanding the basic physics that govern the disposition and characteristics of one-dimensional nanostructures.

To push the boundaries of what is possible at the nanoscale, new material classes, fabrication approaches and better understanding of quantum mechanical behaviours will be required to continue scaling and improve the performance of our future electronics.

6.5. Nanowire for biomedical applications

Sensors that are extremely sensitive, allow for disease detection when diseases present in their earliest stages, and timely diagnosis. At nanoscale, when the size of the material drops down to nanometre order ($\sim 10^{-9}$ m), the substance's physical and chemical characteristics are going to be largely influenced by factors such as the high surface area-to-volume ratio and quantum effects, which are totally different from macroscopic materials. As the size of a material decreases, the ratio of surface area to volume increases meaning that a much larger

proportion of that material structure is in contact with the target. Because there is a bigger surface area, it will allow more promote interactions with the surrounding environment as well. Also, in nanostructures, electrons flow under the influence of quantum effects and these quantum effects confine their behaviour and interactions. There is high significance for nanowires for biomedical applications when thinking about everything from disease diagnosis to drug discovery, because they are very useful for identifying and characterising chemical and biological species/Surprisingly, semiconductor nanowires directly measure electrical signals coming from bio/chemical interactions without labelling. This means that nanowires therefore represent an extremely potent tool for the continuation of the evolution of diagnostic processes, and research into therapeutics.

6.6 Identifying Viruses

Infections are the main cause of disease in humans and there is an increasing fear of the use of infections as biological weapons. Improvement of detection of viruses can enhance health and safety of the public. Silicon nanowire sensors can detect many harmful viruses, such as dengue, influenza A, H3N2, H1N1, and HIV. Silicon nanowire sensors can detect viruses at the single-virus level. Specific antibodies that target a virus are selected and then attached to a surface of a nanowire FET sensor which is fabricated, in order to detect a target virus. When a specific virus comes into contact with the sensor, the antibodies attach to the nanowires and this changes the conductivity of the nanowires.

Detection of smallpox is one of the most important uses of nanowire sensors, as it is a highly fatal disease and poses a significant biological weapon threat. Nanowires have been used to more than detect smallpox, they have detected many other harmful viruses, including Dengue, H3N2, H1N1, and HIV. The antibodies over the surface of the nanowire used for detection attach to targeted viruses in a precise, detecting way that changes electrical conductivity of the nanowire.

Additionally, nanowires have been used in Ebola detection, with a recent study achieving a limit of detection (LOD) of 6.25 nm after only 30 minutes of incubation—six orders of magnitude better than conventional ELISA methods. As the need for real-time, point-of-care diagnostics grows, nanoelectronics will increasingly play a critical role in the detection and monitoring of emerging and epidemic diseases [28].

6.7 Detection of Biomarkers

Recent developments in genomics research have led to the discovery of several biomarkers that show great promise for detecting infections. Nonetheless, considering the variability of infections such as cancer, relying on a single biomarker is often not sufficient to yield suitable diagnostic results. This issue has created an increasing need to turn to multiple biomarkers for improved detection. One major advancement is using p-type silicon nanowire sensors as one of the first enable electrical detection for proteins in solution. This innovation is extremely valuable for real-time diagnostics and monitoring disease biomarkers, as it presents high sensitivity and specificity aspects relative to the detection process summary map in diagnostic systems (as depicted in Fig. 3). In recent years, numerous research groups have focused on developing integrated systems capable of continuous or direct detection of infections from biological samples, such as blood.

These platforms have not only able to detect a particular class of biomarker, but have also expanded to different types of biomarker and biomarkers associated with cardiovascular health and other diseases. For instance, Shahad et al. [29] created a nanowire based diagnostic system that uses the breath volatolome as input for the detection of disease. Breath analysis provides non-invasive detection of disease biomarkers which offers a valuable mechanism for early diagnosis or monitoring of infections. This work identified the tremendous impact of nanowire-based biosensors that may be able to change the landscape of medical diagnostics using quicker, more precise and less invasive detection technique.

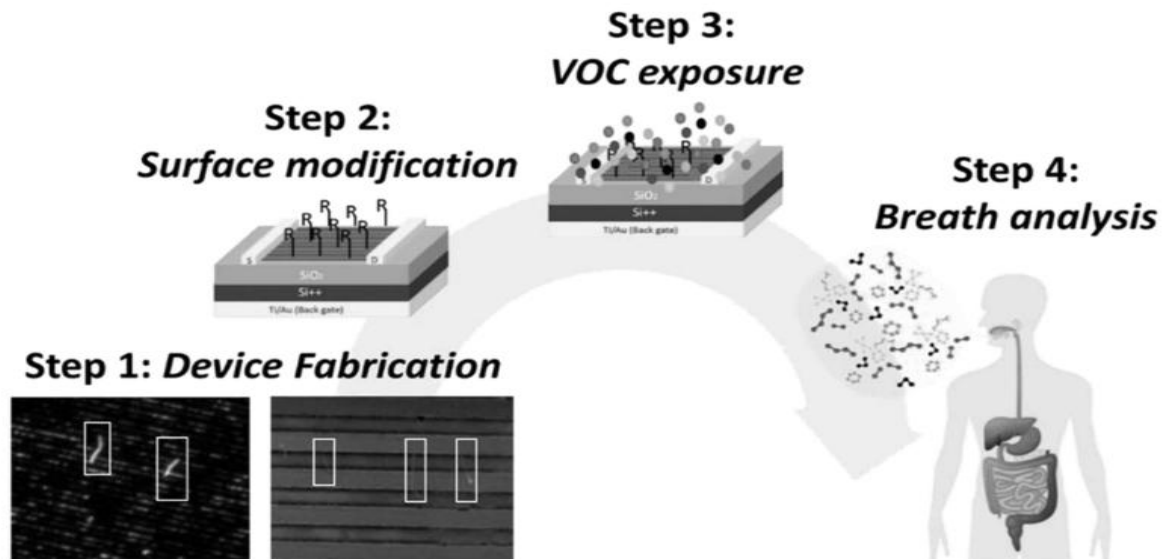


Fig. 3 Biomarker detection using a nanowire FET sensor

6.8 Detection of DNA and RNA

Nanowire field-effect transistor (FET) sensors are an efficient and sensitive platform to quantify specific DNA sequences. The sensors use reciprocal single-stranded peptide nucleic acid (PNA) sequences as receptors (probes); complementary DNA strands on the surface of silicon nanowire FETs bind with PNA receptors, and provide an extremely specific identification of DNA and RNA sequences whose detection limits extend to femtoliter concentrations. As mentioned before, nanowire sensors provide a more efficient identification and identification DNA compared to traditional approaches such as quartz crystal microbalance, surface plasmon resonance, and nanoparticles-enhanced resonance.

More than simply using nanowires to detect DNA, other applications include the detection of nucleic acid-associated proteins and protein-protein interactions. And ultimately develop sensors to detect RNA to enhance genetic applications.

Nanowire biosensors have been applied to virus biosensing in the biotechnology industry, improving diagnostic detection speed and sensitivity. Nanowires-based DNA sensors for cancer biomarkers, such as telomerase and carcinoembryonic antigen, are one area of application. The current development stage of multiplexing; measuring multiple markers at the same time; appears promising because of its ability to alter the standard or norm of clinical diagnostic procedures. Being able to measure a variety of analytes from a single sample simultaneously would change the pressures on clinical diagnostics due to speed and accuracy shown. Nanowire sensors combined with machine learning (a branch of artificial intelligence) and natural language processing could implement several steps in the diagnostic

protocol creating a more automated and timely diagnostic procedure with real time data analysis. Combining the nanowire sensors, machine learning, and natural language processing could provide new levels of disease detection and treatment in providing a path for precision medicine.

6.9 Medication Discovery

Nanowire FET biosensors offer many desirable qualities which makes them particularly suitable for drug discovery and medical diagnostics. It is possible to detect low concentrations of biological markers through these devices, a critical feature in developing new drugs. Nanowires can also be used as drug carriers as their unique properties allow targeted therapy to local parts of bodies. An ability to accurately control drug release makes them ideal therapeutic agents for treatment of certain disease types, fictionalize and in personalized medicine.

Nanowire FET biosensors cannot only be useful in drug delivery, but also making and measuring electrophysiological signals, thereby allowing real-time monitoring of biological activity. For example, monitoring cellular response to a drug or monitoring changes in signalling pathways that occur due to a drug, and if these were used alongside an advanced monitoring system could provide researchers with detailed information about how a drug works, or toxicity for example. Nanowire FET biosensors therefore are not only a powerful tool in drug discovery, but are a means, but also enable the development of better, and more effective therapeutic approaches.

6.10. Conclusions

The intersection of nanotechnology and healthcare is accelerating faster than anticipated, generating tremendous opportunities for novel advances in nanomedicine. Continued experimentation with and development of nanowires and aspects unique to them prepare us to tackle relevant issues while enhancing human health. Utilizing nanowire field effect transistor (FET) biosensors in particular is proving to be a tremendous resource for both biomedical research and clinical applications. They offer a remarkable sensitivity and specificity for an extensive variety of diagnostic and therapeutic applications.

Nanowire FET biosensors will have a huge advantage and be prominently useful in drug discovery. These sensors can be used to detect an extensive number of biologically relevant markers and could help find a drug target that can be quantified at the molecular level. Researchers are also exploring the use of nanowires as drug delivery vehicles by creating targeted drug delivery systems. These systems could potentially improve the efficacy of a therapeutic treatment while minimizing side effects in the patient. These sensors can create and detect electrophysiological signals, and they can also measure cellular responses in real time. The ability to monitor cellular responses makes these sensors an immediate necessity for measuring drug effects in relevant cellular and molecular systems.

In this chapter, we discuss a more complex structure of a MOSFET and its role in healthcare, focusing specifically on the role of nanowire FETs in biosensing. We discussed the applications of these technologies in detecting viruses, identifying biomarkers, analyzing DNA, and drug discovery. Nanowires, with an enormous aspect ratio and controlled synthesis methods, are changing the face of biomedicine by making possible nanoscale electronics, localized drug delivery, and tissue regeneration. These advances will fundamentally increase

the potential impact of healthcare technologies, offering a potential pathway towards personalized medicine and next-generation diagnostics.

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