Applications of Nano Electro Mechanical Sensors

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Abstract— **This work serves as a basic introduction to Nano Electro Mechanical Sensors and gives a brief look at some potential chemical and biomedical applications for these devices.**

***Keywords*— Carbon Nano tube , Nano-wire , NanoTechnology**

I. INTRODUCTION

Nano scale sensors are an extension of the more common Micro Electro Mechanical Sensors. The development of these devices has been driven by the need for more accurate, high quality, high sensitivity and low cost sensor technology. They are typically fabricated with dimensions less that 1 micro meter. There are several different types of Nano scale sensors each of which is based on different operating principals. Perhaps the most recognizable application of MEMS/NEMS sensor technology would be found in the blood sugar monitors used by diabetes patients. Other applications are rapid identification of proteins and ions by these devices when they are incorporated into Lab on a Chip Systems. This paper aims to demonstrate different NEMS sensors and discusses some chemical and biomedical applications of these devices.

Carbon Nano Tube Sensors

Carbon Nano Tube sensors are currently being investigated by researchers as a replacement to SI based sensors. Single Wall carbon Nanotubes have shown a large number of properties that have make them ideal for sensory applications including but not limited to the ability to select gaseous species depending on pore size of the particles. They have also demonstrated superior absorption capabilities due to their large surface area. In some experiments sensors have been fabricated that require 10000(100nW) less activation energy than traditional Silicon based NEMS Sensors [1]. One type of CNT sensor uses a transistor, structure to act as a sensing platform. In this configuration the Single Walled Carbon Nano Tube acts as a very thin wire. When ions are deposited on the CNT, the chemical and biological conductivity of the channel formed between the gate and the source changes. A voltage is applied to the gate to modulate the flow of current between the drain and source. The conductance between the two electrodes is a function of time. Carbon nano tubes can be doped with polymers and other impurities to achieve even greater selectivity.

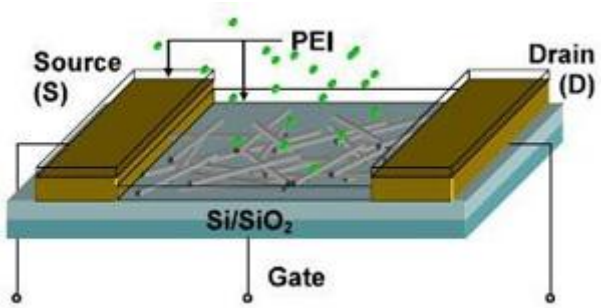

Fig.1 Transistor Based Carbon Nano Tube Sensor Ions implanted on the device effectively lower the Fermi energy and decrease the band gap making the CNT channel a better conductor .

Silicon Nano Wire Sensors

Silicon Nano wire sensors are very similar in operation to CNT sensors. Nano wires are also excellent for sensory applications due to their large surface area to volume ratio. This fact is particularly important since a large surface area to volume ratio means that more of the reactant can be absorbed in a given time and this results in an increase in sensitivity .These devices rely on the conductivity of the wire to measure the specific amount of a given anolyte present within a system. SINW sensors are usually comprised of an array of silicon nano wires

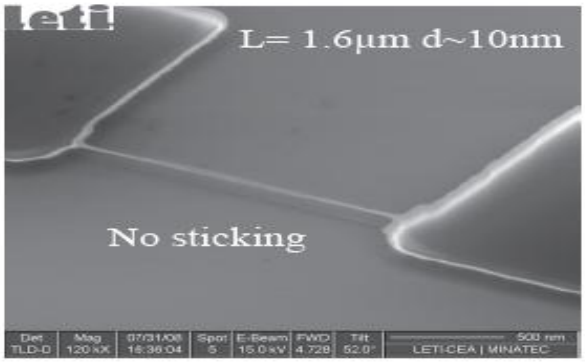

Figure 1.2 Silicon nano Wire Sensor with a nano wire less than 10 nano meters in diameter [2]

NEMS Resonant Sensors

Advances in fabrication technology have allowed for sensors with very High Quality factors to be fabricated. The resonant frequency of these devices are dependent on the stiffness and the mass of the structural material from which they are made . A popular implementation of a NEMS resonant sensor is the Micro Cantilever structure. This application is based on the principal of force sensing. Molecules that are attracted to the to the beam cause stress which results in deformation of the structure. The resulting mass loading causes a shift in the resonant frequency of the structure [4] .The frequency is given

$$f_0 = 2\pi\omega_0 = \frac{1}{2\pi}\sqrt{\frac{k}{m^*}}$$

by

A piezoresistive layer is added to the beam to convert the change in mechanical stress to an output signal which can be measured .Traditionally NEMS sensors have been fabricated using Silicon wafers but recent advances in the field have utilized Diamond substrates. These substrates have the advantage that due to their stiffness they can achieve very high Q factors .

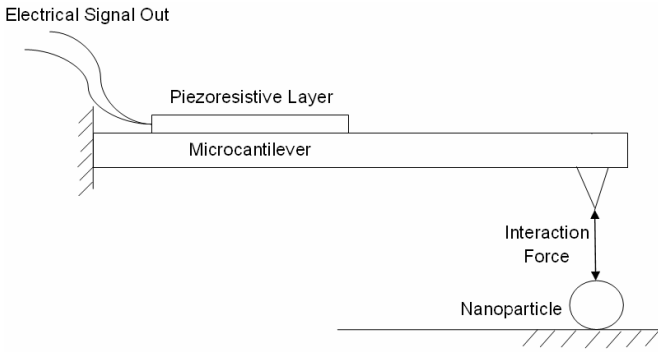

Fig 1.3
Micro cantilever structure with piezoresistive layer used to detect the presence of nano particles [5]

Another key advance in the field has been the use of surface treatments to achieve selectivity [2] . Self Assembled mono layers are and organized layer of molecules in which one end is attracted to the substrate and the other end is used to attract the molecules being sensed. These .SAMS are used in application to select amino acids , DNA samples and Ions .

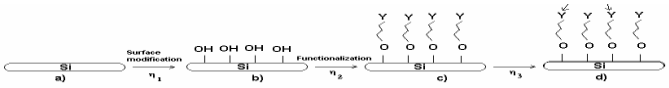

Fig 1.4
SAM used to aid the selectivity of NEMS cantilever Sensors

Applications

CNT tubes have been used to detect gas molecules in the atmosphere. In this case a simple sensing system, in which a single semiconducting SWNT was kept in contact with titanium and/or gold metal pads at the two ends .In this application the sensor was used to measure the specific amount of N02 present within a given sample[3]. NASA has also demonstrated the detection of gaseous particles using CNT Sensors. In addition to gaseous detection CNT sensor have been used to detect glucose and ions.

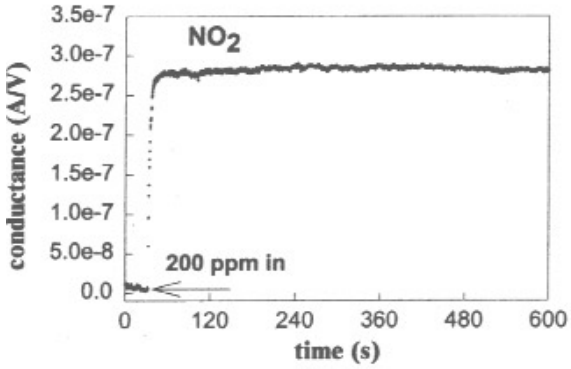

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Fig 1.4 The conductivity of a SWNT used as a sensor for detecting the presence of NO2.[2]

In 1999 Researchers at the Georgia Institute of Technology used a CNT tube based frequency sensor to detect the mass of gaseous ions
Finally Silicon Nanowire Sensors have been coated with SAM and used to detect PH.

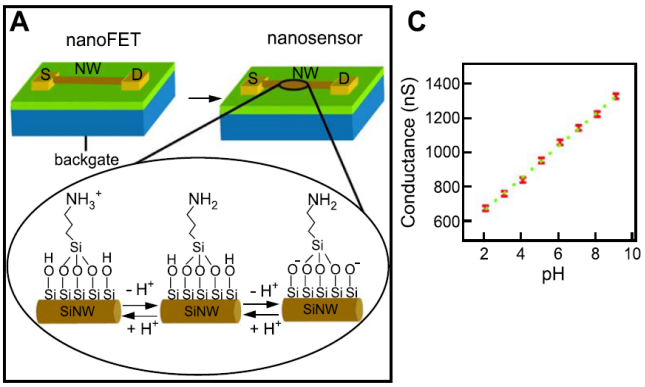

Fig 1.6 Nanowire Sensor with SAM used to detect PH [3]

Challenges

There are tremendous challenges associated with NEMS sensors not least of which is cost. The cost associated with the fabrication of NEMS sensors means that they cannot easily be commercialised. Cost also serves as a hindrance to greater research . Packaging of these sensors is also a difficult problem to solve. In many applications the sensing platform needs to be in contact with the particles being sensed,, this also exposes the sensor to potential damage. This problem is further complicated if the sensors will be implanted into the human body. In this case the packaging needs to be biocompatible and be able to protect the sensor from damage by amino acids and ions present in blood. Due to the potential for human harm the regulations on human trials also make the testing of these devices a long process Surface treatments such as the application of Self assembled mono layers cannot always be uniformly applied to the surface of NEMS sensors .NEMS resonant sensors also suffer greatly from a reduction in the quality factor in a liquid medium due to the damping effects and loss of energy.This fact presents a challenge to integrate these sensors successfully in Lab on a chip and or micro fluidic systems

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