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Short Communication Open Access

Boron Nitride Nanotube as a Nano-mechanical Biosensor: A Computational Approach

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Short Communication

The nanostructures based biosensors are increasingly in demanded for fundamental biological studied, health conditioning, drug delivery and clinical diagnosis [1-3]. Based on the nature of the transduction signal, biosensors can be classified into optical, electrical and mechanical [4]. In mechanical biosensors, the resonance frequency is measured and related to estimate the mass change due to the binding of the additional element on the sensor surface. Nanomechanical biosensor is a subclass of mechanical biosensors, which is having size of nanoscale at least in one of their dimensions [5,6].

As per classification in Figure 1, it is clear that optical and electrical transduction based research on biosensors more dominated and it is expected that the emerging trends in nanotechnology will help in the research based on mechanical biosensors upto the nanoscale level. Recent developments in nanotechnologies enable to achieve increasingly smaller mechanical biosensors of size of nanoscale. This subcategory of mechanical biosensors is referred as nanomechanical biosensors [5-8]. The increasingly smaller size of nanomechanical sensor systems can be used to outstanding mass resolution on the verge of single atoms. Nanomechanical biosensors can be divided into static and dynamic; depending on the static displacement or the resonant properties of the sensor systems. Several configurations of nanomechanical systems can be used for biological detection that includes the cantilevers, doubly clamped beams and membranes [4]. When, the biological particle adsorbed on a nanomechanical sensor system, the mass effect on the resonance frequency strongly depends on the adsorption position and the used vibration mode. Based on, the recent developments in the field of material science on nano scale, the mass detection of biomolecules has become a growing field in the biological and biomedical applications. It is recognized as one of the key technologies for predictive and preventive medicine [9]. The common strategy for prediction of disease is based on sensing the corresponding biomolecules. It is reasonable to believe that biosensors with real-time sensing capability and ease of use can change the future of disease detection and health monitoring (Figure 1).

The higher value of Young's modulus (similar to the CNTs) of BNNTs make them superior chemically and thermally stable materials [9]. The excellent piezoelectric properties make them superior to those of piezoelectric polymers [9]. Such properties furnish BNNT as a potential material for a wide range of applications in the field of nano-science and nanotechnology [10-12] (Figures 2 and 3).

The resonant frequency variation based analysis suggests the possible mass sensitivity limit of 10^{-8} fg can be achieved using BNNT as nanoresonators [10,12,13]. The molecular structural mechanics based simulation approach can be effectively utilized to model the different atomistic finite element (FE) model BNNTs like, zigzag, armchair, chiral, pristine and defective [11,14-17].

The resonant behavior of almost all types of possible atomic structures of nanotubes suggests, the possible detection of masses of nano-scale level like acetone molecules, biological objects like DNA components, bacterium/viruses, etc. [17-19]. The structural molecular mechanics based resonant frequency based analysis may be useful to practically realize the future BNNT based biosensor systems for the real time detection of biological objects and chemical molecules for the future health monitoring. Also, using multiphysics approach, a more robust sensor systems using BNNTs can be proposed to incorporate the piezoelectric properties along with their vibrational characteristics.

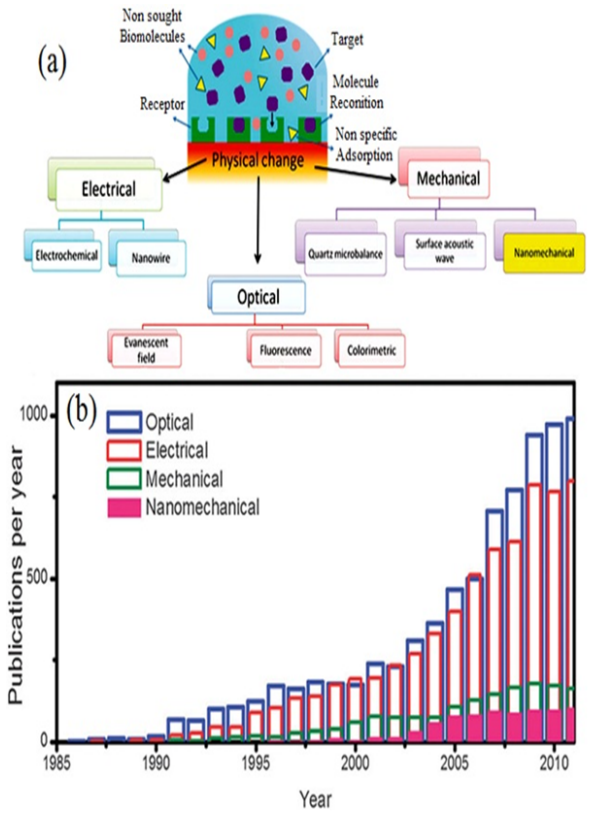

Figure 1: (a) Schematic of biosensor and biosensor subclasses, and (b) chronogram of the publication rate in optical, electrical and nanomechanical biosensors.

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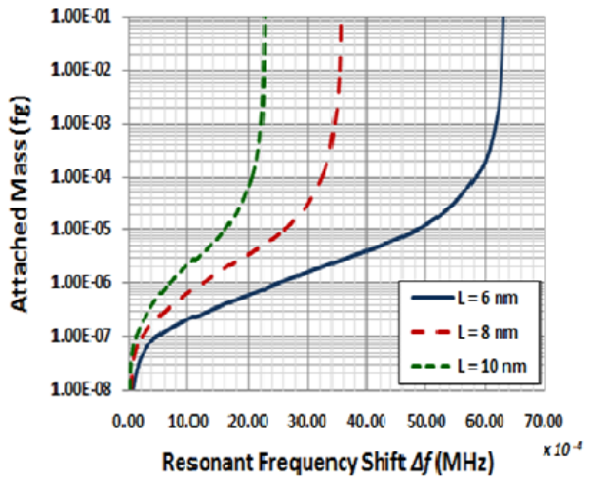

Figure 2: Resonant frequency shift Δf due to attached mass at the tip of the nanotube of cantilevered configuration of nanotube.

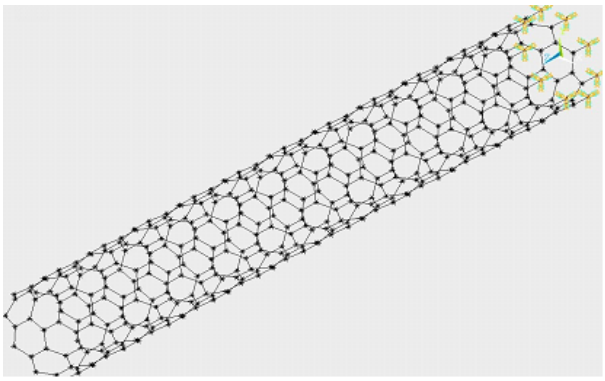

Figure 3: Molecular structural mechanics based finite element (FE) model of single walled BNNT.

The binding energy of the different biological objects or the chemical molecules of nano-scale mass can be enhanced using dopants in the base atomic structure of the BNNTs to enhance the capabilities of BNNT based biosensor systems.

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