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# Various Technological Aspects of Nano Electro Mechanical Systems-A Review Report

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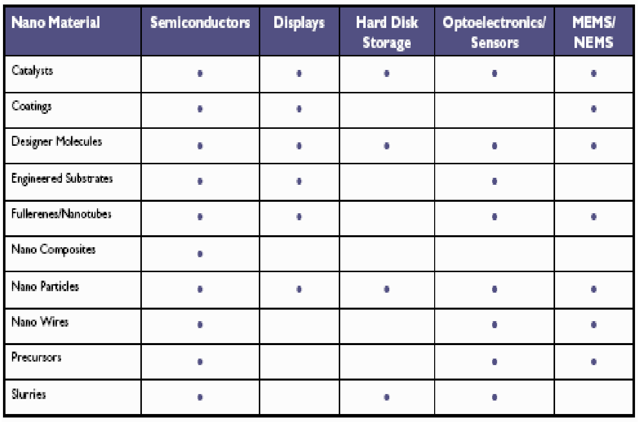
***Abstract*— NEMS or nano electro mechanical systems are similar to MEMS or micro electro mechanical systems but smaller. They hold promise to improve abilities to measure small displacements and forces at a molecular scale, and are related scale. Nanoelectromechanical systems, or NEMS, are MEMS scaled to submicron dimensions . In this size regime, it is possible to attain extremely high fundamental frequencies while simultaneously preserving very high mechanical responsivity (small force constants). This powerful combination of attributes translates directly into high force sensitivity, operability at ultralow power, and the ability to induce usable nonlinearity with quite modest control forces. The possibility of simple, low cost fabrication, made possible by developments in Nano Imprint Lithography (NIL). This paper discusses the manufacturing aspects of NEMS considering the latest trends in miniaturization with the attention on materials used for nanoscale components. Further it overviews the current applications in the engineering, military, medical applications. The paper also gives the various design aspects like modeling, characterization, simulation, and control for some of the applications along with the packaging aspects nanoscale systems and its components. This paper also provides the environmental impacts of Nano Electro Mechanical Systems.**

***Index Terms*—** Nano technology, Nano Electro Mechanical System, MEMS, high force sensitivity, Nano Imprint Lithography (NIL).

## I. INTRODUCTION

Nanotechnology is likely to be extremely important in the future as it allows materials to be built up atom by atom. This can eventually lead to the development of new materials that are better suited for the current requirements. The differences in NEMS and MEMS are emphasized, and NEMS are smaller than MEMS. For example, carbon nanotubes (nanostructure) can be used as the molecular wires and sensors in MEMS. Different specifications are imposed on NEMS and MEMS depending upon their applications. For example, using carbon nanotubes as the molecular wires, the current density is defined by the media properties (e.g., resistivity and thermal conductivity). It is evident that the maximum current is defined by the diameter and the number of layers of the carbon nanotube. Different molecular-scale nanotechnologies are applied to manufacture NEMS (controlling and changing the properties of nanostructures), while analog, discrete, and hybrid MEMS have been mainly manufactured using surface micro-machining, silicon-based technology (lithographic processes are used to fabricate CMOS ICs). To deploy and commercialize NEMS and MEMS, a spectrum of problems must be solved, and a portfolio of software design tools needs to be developed using a multidisciplinary concept. In recent years much attention has been given to MEMS fabrication and manufacturing, structural design and optimization of actuators and sensors, modeling, analysis, and optimization. It is evident that NEMS and MEMS can be studied with different level of detail and comprehensiveness, and different application-specific architectures should be synthesized and optimized.[1]

NEMS integrate different structures, devices, and subsystems. In a large-scale NEMS there is an integration of : • Thousands of nodes of high-performance actuators/sensors and smart structures controlled by ICs and antennas; • High-performance processors or superscalar multiprocessors; • Multi-level memory and storage hierarchies with different latencies (thousands of secondary and tertiary storage devices supporting data archives); • interconnected, distributed, heterogeneous databases; • High-performance communication networks



| Nano Material | Semiconductors | Displays | Hard Disk Storage | Optoelectronics/ Sensors | MEMS/ NEMS |
|---|---|---|---|---|---|
| Catalysts | • | • | • | • | • |
| Coatings | • | • |  |  | • |
| Designer Molecules | • | • | • | • | • |
| Engineered Substrates | • | • |  | • |  |
| Fullerenes/Nanotubes | • | • |  | • | • |
| Nano Composites | • |  |  |  |  |
| Nano Particles | • | • | • | • | • |
| Nano Wires | • |  |  | • | • |
| Precursors | • |  |  | • | • |
| Slurries | • |  | • | • |  |

## II. NANOFABRICATION TECHNIQUES

NEMS devices are fabricated according to two approaches. Top-down approaches, which evolved from manufacturing of MEMS structures, use submicron Lithographic techniques, such as electron-beam lithography, to fabricate structures from bulk materials, either thin films or bulk substrates. Bottom-up approaches fabricate the nanoscale devices by sequentially assembling of atoms and molecules as building blocks.

**Typical Technologies involved in Nanofabrication**
•Thin Film Deposition-PVD (physical vapour deposition)-CVD (chemical vapour deposition) •Patterning –Lithography- Optical, E Beam •Film Modification–Etching- Wet etching, Dry etching [3]

**Advanced Lithography Technology**
•E-Beam Lithography •X-Ray Lithography •Focused Ion Beam Lithography Alternative Lithography •Soft-lithography
•Imprinting lithography [3]

**Surface micromachining** –It can build structures by adding materials layer by layer on top of a silicon substrate. Various desired device structures, such as cantilevers and gears are formed by the selective oxide removal of SiO2 layers by etching. The material used for sacrificial layer is phosphorous-silicate glass (PSG), SiO2, porous silicon, poly-Si, polyimide, AuAl and the material used for functional layer is Poly-Si, SiO2, TiNi, NiFe, W etc. The devices made by this process are accelerometer and pressure sensors.[3]

**The LIGA process** - (a German acronym for lithography –electroplating - molding) is a non-Si technology, utilizes radiation (initially x-rays) to deep etch structures. A synchrotron light source is required for the process. This process is important for creating taller (versus wider) structures. LIGA technology is especially suited for the production of simple micro-structure elements with high aspect ratio. However, in its classical form it cannot provide Microsystems. To overcome this limitation, LIGA-based processes have been integrated into Si-technology.[2] **Electrostatic manipulation –** The Scanning Tunnel Microscope (STM) can be used to make atoms slide over a surface in order to move them into a desired arrangement by electrostatic forces. Resolution is effectively the size of a single atom but the process is exceptionally time consuming and requires special conditions to prevent movement of atoms out of place.[3]

**Pattern Electron Beam Lithography -** Surface micromachining can be conducted at the nanoscale using electron beam lithography to create free standing or suspended mechanical objects. An electron beam can be used for scanning a desired pattern in the resist. Dip pen lithography uses an atomic force microscope (AFM) probe tip to deposit a layer of material onto a surface, much as a pen writes on paper. A pattern can be drawn on a surface using a wide range of — "inks" such as thiols, silanes, metals, and biological micro molecules. This technology can be used in biosensor fabrication. [1]

**Self Assembly** - At the nanoscale, the self-assembly of molecules is a favored mechanism as it relies on natural forces to create highly perfect assemblies. Snow flakes, salt crystals and soap bubbles are all examples of self assembly. Simply controlling environmental conditions and molecular components are required for a very cost efficient manufacturing scheme. [3]

**Nanoimprint lithography -** is a method of fabricating nanometer scale patterns. It creates patterns by mechanical deformation of imprint resist and subsequent processes. The imprint resist is typically a monomer or polymer formulation that is cured by heat or UV light during the imprinting. Adhesion between the resist and the template is controlled to allow proper release.[1]

**Silicon on insulator Technology (SOI) -** The use of SOI **(**Silicon on insulator) technology can simplify the complexity of a fabrication process for free standing structures considerably. The reason behind this is the buried oxide layer provides an etch stop for both, front side etching and backside etching. Further on, an excellent isolation to the substrate by a high quality buried oxide between device layer (functional Si) and handle wafer is provided .[3]

## III. MATERIALS FOR NEMS

NEMS technology generally uses materials like carbon based, carbon nanotubes and graphene. The mechanical properties of carbon (such as large Young's modulus) are fundamental to the stability of NEMS while the metallic and semiconductor conductivities of carbon based materials allow them to function as transistors. Carbon Nanotubes (CNTs) are allotropes of carbon with a cylindrical nanostructure. They have been constructed with length-to-diameter ratio of up to 132,000,000:1, significantly larger than any other material. These cylindrical carbon molecules have novel properties, makes them useful in many applications in nanotechnology, electronics, optics, and other fields of materials science, as well as in architectural fields. Both graphene and carbon exhibit high Young's modulus, excessively low density, low friction and large surface area. Along with the mechanical benefits of carbon based materials, the electrical properties of carbon nano tubes and graphene allow it to be used in many electrical components of NEMS. Nanotransistors have been developed for both carbon nanotubes as well as graphene. Metallic carbon nanotubes are used for nanoelectronic interconnects since they can carry high current densities. This is a very useful property as wires to transfer current are another basic building block of any electrical system.

Some of the difficulties of Carbon nanotubes are - i) they exhibit a large change in electronic properties when exposed to oxygen, ii) their high surface area which can easily react with surrounding environments, iii) CNT's have varying conductivities. Due to this, very special treatment must be given to the nanotubes during processing, in order to assure that all of the nanotubes have appropriate conductivities. Graphene also has very complicated electric conductivity properties compared to traditional semiconductors as it lacks an energy band gap and essentially changes all the rules for how electrons move through a graphene based device. This means that traditional constructions of electronic devices will likely not work and completely new architectures must be designed for these new electronic devices .[3]

**Nanoparticles** are of various types such as gold (colloidal gold), silver, iron, quantum dots, laser, platinum, and nanostructures. These particles form a bridge between bulk materials and atomic or molecular structures and they have large surface area. A bulk material should have constant physical properties regardless of its size, but at the nano scale size dependent properties are often observed. Thus, the properties of materials change as their size approaches the nanoscale and as the percentage of atoms at the surface of a material becomes significant. For bulk materials larger than one micrometer (or micron), the percentage of atoms at the surface is insignificant in relation to the number of atoms in the bulk of the material .

**Substrates materials:** • Silicon • Gallium Arsenide • other elemental or compound semiconductors • Metals (bulk and foils) • Glasses • Quartz • Sapphire • Ceramics • Plastics, polymers and other organics

**Additive Materials:** • Silicon (amorphous, polycrystalline, epitaxial) • Silicon compounds (oxides, nitrides, carbides, etc.) • Metals and metal compounds • Glass • Ceramics • Polymers and other organics • Biomaterials • Nanomaterials.

## IV APPLICATIONS

Ultimately, NEMS could be used across a broad range of applications. At Caltech we have used NEMS for metrology and fundamental science, detecting charges by mechanical methods and in thermal transport studies on the nano-scale .In addition, a number of NEMS applications are being pursued that might hold immense technological promise. A key application of NEMS is atomic force microscope tips. The increased sensitivity achieved by NEMS leads to smaller and more efficient sensors to detect stresses, vibrations, forces at the atomic level, and chemical signals.

### Carbon Nanotube-Based Nanoelectromechanical Systems Devices

***Nanotube nanomotor***- carbon nanotubes are used to generate a device for linear or rotational motion is a nanotube nanomotor.The weak Vander Waals interlayer interaction in Multiwalled NTs together with the rigid structure and theoretically predicted low resistance to rotational motion prompted to construct the first electrical motor using CNTs as the rotational element. Their NEMS actuator was constructed using electron beam lithography starting from arc-discharge grown MWNTs deposited on an electrically conductive substrate covered with 1 mm of SiO2. The actuator components—rotor plate, stator electrodes, and anchor leads were patterned using e-beam lithography followed by the deposition of Cr/Au metallic layers. HF etching was employed to remove roughly 500 nm of SiO2 and thus suspend the whole structure, providing clearance for the rotor.

***Nanotube-based switches* -** The first Nanotube-based switch was made in crossbar geometry. It consists of suspended CNTs that act as bistable switches. Bistability in this device arises from the interplay of the elastic energy in the bent nanotube and the Vander Waals attraction between tubes forming the crossbar junction. The device can be switched by applying voltages between nanotubes that result in electrostatic forces. Once in the ON state, the device can be _read‗ using a small bias voltage and _reset‗ using a larger voltage to produce repulsive electrostatic forces.

***Oscillators* –** due to low mass, nanoscale physical dimensions and Young‗s modulus in the TPa range, CNTs are used in for electromechanical oscillators, with operating frequencies that could be in the GHz range. Furthermore, nanotubes can act as transistors and provide an electrical read-out of their motion. Their chemical inertness should avoid problems associated with roughness and defects, which in lithographically prepared NEMS invariably lead to high mechanical dissipation.

***Nonvolatile Random Access Memory* -** The device is a suspended Single Walled NT crossbar array for both I/O and switchable, bistable device elements with well-defined OFF and ON states. This crossbar consists of a set of parallel SWNTs or nanowires (lower) on a substrate composed of a conducting layer (e.g., highly doped silicon [dark gray]) that terminates in a thin dielectric layer (e.g., SiO2 [light gray]) and a set of perpendicular SWNTs (upper) that are suspended on a periodic array of inorganic or organic supports. Each nanotube is contacted by a metal electrode. Each cross-point in this structure corresponds to a device element with a SWNT suspended above a perpendicular nanoscale wire. Because the nanotube junction resistance depends exponentially on the separation gap, the separated upper-to-lower nanotube junction resistance will be orders of magnitude higher than that of the contact junction. Therefore, two states—OFF and ON—are well defined. For a device element, these two states can be read easily by measuring the resistance of the junction and, moreover, can be switched between OFF and ON states by applying voltage pulses to nanotubes at corresponding electrodes to produce attractive or repulsive electrostatic forces.

***Nanotweezers* -** There are two types of carbon nanotube–based nanotweezers. Both nanotweezers employ MWNTs as tweezers‗ arms that are actuated by electrostatic forces. The applications of these nanotweezers include the manipulation of nanostructures and two-tip STM or atomic force microscope (AFM) probes.

***Nanorelay device*** -A multiwalled nanotube was positioned on top of the source, gate, and drain electrodes with polymeric polymethylmethacrylate (PMMA) as sacrificial layer using AC-electrophoresis techniques. Then, a top electrode was placed over the nanotube at the source to ensure good contact. The underlying PMMA layer was then carefully removed to produce a nanotube suspended over the gate and drain electrodes. The potential applications of nanorelays include memory elements, pulse generators, signal amplifiers, and logic devices.

***Feedback-Controlled Nanocantilevers* -** A feedback-controlled MWNT can be used as a cantilever. A bottom electrode, a resistor, and a power supply are parts of the device circuit. When the applied voltage is less than pull-in voltage, the electrostatic force is balanced by the elastic force from the deflection of the nanotube cantilever. The nanotube cantilever remains in the ― "upper" equilibrium position. When the applied voltage exceeds a pull-in voltage, the electrostatic force becomes larger than the elastic force and the nanotube accelerates toward the bottom electrode. The potential applications of the device include ultrasonic wave detection for monitoring the health of materials and structures, gap sensing, NEMS switches, memory elements, and logic devices.

### Nanowire-Based Nanoelectromechanical Systems Devices

***Nanowires*,** like carbon nanotubes, are high-aspect-ratio, one-dimensional nanostructures. The materials of nanowires include silicon, gold, silver, platinum, germanium, zinc oxide, and so on. Besides their size, the advantages offered by nanowires when employed in NEMS are their electronic properties, which can be controlled in a predictable manner during synthesis. This has not been achieved yet for carbon nanotubes. In contrast to carbon nanotubes, nanowires do not exhibit the same degree of flexibility, which may be a factor concerning device fabrication and reliability.

***Resonators***- Synthesized platinum nanowires were deposited on a Si substrate capped by a 300-nmthick layer of thermally grown silicon dioxide and prepatterned with Au alignment marks. The location of the deposited wires was mapped, by means of optical microscopy, using their strong light-scattering properties. Metallic leads (5nm Cr, 50 nm Au) to individual wires were subsequently patterned by electron-beam lithography, evaporation, and lift-off. Finally, the SiO2 was removed by wet etching (HF) to form suspended nanowire structures. The nonlinear response of the beam displays notable hysteresis and bistability in the amplitude-frequency space when the frequency sweeps upward and downward. This particular behavior shows that the device can be used as mechanical memory elements

***Nanoelectromechanical Programmable Read-Only Memory***

The germanium nanowires was synthesized directly onto a macroscopic gold wire (diameter = 025mm). The working principle of NEMPROM is similar to that of NRAM since both of them employ Vander Waals energy to achieve the bistability behavior, although the usage of germanium may provide better control of size and electrical behaviors of the device than that of carbon nanotube .

**Other applications:**

***Bioinspiration*****:** NEMS technology when comparable to biology provides a limited number of base materials with a wide range of functional and structural properties. The complexity of the approach (in biology as well as in engineering) increases with decreasing number of base materials. Biomimetics, means mimicking biology or nature. It is derived from a Greek word ―biomimesis Other words used include bionics, biomimicry and biognosis. Biomimetics involves taking ideas from nature and implementing them in an application, i.e., technology transfer from biology to engineering .

***Diatoms*** are single celled organisms that have moving parts in relative motion on the nanoscale. They are high-potential biological systems that can inspire emerging NEMS technologies.

***Biotechnology* -** NEMS technology is enabling new discoveries in science and engineering such as the Polymerase Chain Reaction (PCR) nano systems for DNA amplification and identification, nano machined Scanning Tunneling Nano-scopes (STMs), biochips for detection of hazardous chemical and biological agents, and nano systems for high-throughput drug screening and selection..

***Accelerometers***-NEMS accelerometers are quickly replacing conventional accelerometers for crash air-bag deployment systems in automobiles. The conventional approach uses several bulky accelerometers made of discrete components mounted in the front of the car with separate electronics near the air-bag.

***Nano nozzles***- nano nozzles direct the ink in inkjet printers. They are also used to create miniature robots (nano-robots) as well as nano-tweezers, and are used in video projection chips with a million moveable mirrors.

***NEMS in Wireless***-Discrete passives such as RF-switches, varicaps, high-Q resonators and filters have been identified as components that can be replaced by RF-NEMS counterparts. Current technology and process limitations will prevent placement of all passive components with on-chip NEMS components. But placing even some components on-chip offers significant space and cost savings, allowing smaller form factors, benefiting cell phones for example, or added functionality such as Internet connectivity

***NEMS in Optical Networks*** -An important new application for NEMS devices is in fiber optic networks. At the nanons level, NEMS-based switches route light from one fiber to another. Such an approach enables a truly photonic (completely light-based) network of voice and data traffic, since switching no longer requires conversion of light signals into digital electronic signals and then back to optical. Additional applications include active sources, tunable filters, variable optical attenuators, and gain equalization and dispersion compensation devices.

NEMS have been rigorously tested in harsh environments for defense and aerospace where they are used as navigational gyroscopes, sensors for border control and environmental monitoring, and munitions guidance. In medicine they are commonly used in disposable blood pressure transducers and weighing scales .

## V. DESIGN ASPECTS

**Design, modeling and simulation aspects:** In many applications there is a need to design high-performance intelligent NEMS to accomplish the following functions:

• Programming and self-testing; • Collection, compiling, and processing information • Multivariable embedded high-density array coordinated control; • Calculation and decision making with outcomes prediction; • Actuation and control.[5]

The design of NEMS requires a thorough understanding of the mechanics of the devices themselves and the interactions between the devices and the external forces/fields. With the critical dimension shrinking from micron to nanometer scale, new physics emerges so that the theory typically applied to MicroElectroMechanicalSystems (MEMS) does not immediately translated to NEMS. For example, Vander Waals forces from atomic interactions play an important role in NEMS, while they can be generally neglected in MEMS. The behavior of materials at nanometer scale begins to be atomistic rather than continuous, giving rise to anomalous and often nonlinear effects , for example, • The roles of surfaces and defects become more dominant. • The devices become more compliant than continuum models predict. • Molecular interactions and quantum effects become key issues to the point that thermal fluctuation could make a major difference in the operation of NEMS . The ability to design the reliable MEMS/NEMS devices demands new simulation capabilities due to the length and time scaling effects at nanoscale. Combination of classical micro forces phenomena with quantum fields and molecular considerations become key issues to the point that thermal fluctuation influences the NEMS operation. Furthermore, the roles of surface and defects become more dominant. Finally, the behavior of materials at nanometer scale begins to be atomistic rather than continuous. Taken together, it gives rise to anomalous and often nonlinear effects, i.e., nanomechanics (Casimir effect, Vander Waals, charges quantization), nano-optics (charge transfer), electrostatic-fluidics effects (dielectrophoresis, electro-welting, electroosmosis), nanomagnetics (paramagnetism), and so on. The challenge now faced by NEMS designers is to bridge the different scales to a more general framework, which has been called as ***multiscale modeling***. Conceptually, two categories of multiscale simulations can be used: both sequential and concurrent.

***(i) Sequential multiscale simulations*** - The sequential methodology attempts to piece together a hierarchy of computational approaches in which large-scales models use the coarse-grained representations from more detailed smaller-scale models. The simulations are running independently of each other and a complete separation of both length and time scales are achieved ***(ii) Concurrent multiscale simulations*** - The concurrent multiscale approach attempts to link methods appropriate at each scale together in a combined model, where the different scales of the system are considered concurrently and communicate with a hand-shake procedure. The literature contains numerous methods of concurrent coupling; (i) the combined finite element atomistic method (FEAt), (ii) the material point method (MPM), (iii) the local quasicontinuum method (QC), (iv) the bridging scale method, (v) the atomic scale finite element method (AFEM), and (vi) coarse grained molecular dynamics (CGMD) .Molecular dynamics simulations are commonly used to investigate size-dependence of the elastic properties of the nano-scale silicon cantilevers. Continuum mechanics modeling can still be used on nanoscale structures considering the dependence of elastic constants on dimensional scaling. Various electrostatic models namely: the classical conductor model, the semi classical model, and the quantum-mechanical model, are being used for electrostatic analysis of NEMS at various length scales. The design methodology facilitates, under restricted conditions, the insertion of quantum corrections to nano-scale device models, during simulation. Molecular dynamics (MD) and quantum mechanics (QM) coupled to virtual reality (VR) techniques are used for the prototyping of biological NEMS. The operator can design and characterize through molecular dynamics simulation, the behavior of bio-nanorobotic components and structures through 3-D visualization To solve analysis, prediction, classification, modeling, and optimization problems, neural networks or genetic algorithms can be efficiently used. Neural networks and generic algorithms have evolved to the mature concepts which allow the designer to perform reliable analysis, design, and optimization. [1,2]

**Control of NEMS**

The Design of Closed-Loop Nanoelectromechanical Systems is generally made using the Lyapunou Stability theory and Hamilton-Jacobi theory. In case of intelligent control of NEMS, Hierarchical distributed closed-loop systems must be designed for large scale multi-node NEMS in order to perform a number of complex functions and tasks in dynamic and uncertain environments. In particular, the goal is the synthesis of control algorithms and architectures which maximize performance and efficiency minimizing system complexity through: 1.Intelligence, learning, evolution, and organization, 2.Adaptive decision making, 3.Coordination and autonomy of multi-node NEMS through tasks and functions generation, organization and decomposition, 4.Performance analysis with outcomes prediction and assessment, 5. Real-time diagnostics, health monitoring, and estimation, 6.Real-time adaptation and reconfiguration, 7.Fault tolerance and robustness. [1]

## VI. PACKAGING ASPECTS

The packaging of NEMS devices and systems is more challenging than Integrated Circuit (IC) packaging due to the diversity of NEMS devices and the requirement that many of these devices be in contact with their environment. Currently almost all NEMS development efforts must develop a new and specialized package for each new device. Approaches which allow designers to select from a catalog of existing standardized packages for a new NEMS device without compromising performance would be beneficial. Packaging engineers have an opportunity to make this impact a reality by developing low-cost, high-performance and high-reliability packaging solutions. Hybrid approach is used in packaging nano-scale devices. This hybrid approach takes advantage of chemical methods for making the nano-scale device and uses solid-state micro fabrication for providing a platform for assembling the device and interfacing to larger-scale components. The first packaging step is for the transition from nano to micro. In this step, the nano-scale device should be positioned onto a micro fabricated platform. This step is necessary since most nano-scale devices are too small and sensitive to be interfaced directly to a macro-sized package. The second packaging step is for the transition from micro to macro. This involves packaging the micro fabricated platform and providing the proper connections to the macro-levels. NEMS devices enable us to measure very small forces. They are also strongly affected by any undesirable small forces associated with packaging .

Self-assembly is a highly parallel method and does not require one-by-one manipulation of components. In a self-assembly scheme, the nano-scale components are designed and produced in such a fashion that they self-assemble in the correct position on the micro fabricated platform spontaneously. Surface chemistry can be used to ― "program" such a self-assembly process . [2,3]

## VII. ENVIRONMENTAL IMPACTS

***Impact of Miniaturization*:**

• Potential Positive Impacts : 1. Reduction of disease.2. Job opportunities in new fields. 3. Low-cost energy. 4. Cost reductions with improved efficiencies.5. Improved product and building materials. 6. Transportation improvements

• Potential Negative Impacts : 1. Material toxicity 2. Non-biodegradable materials. 3. Unanticipated consequences. 4. Job losses due to increased manufacturing efficiencies. [4]

The effects of NEMS on our environment are not currently well established. Carbon based NEMS may be more toxic than conventional systems. Some of the NEMS may contain heavy metals and may be small enough to avoid detection by the body‘s immune system, causing damage against which there is no defense. The NEMS constituent materials may be extremely toxic to living organisms potentially hindering DNA mechanics and protein synthesis. They may also be non-biodegradable which would result in chronic toxicity. Nanomaterials may be inadvertently introduced into the environment and make their way into the food chain. Self replicating nano robots may cause serious problems. It is important to invest more time and money to research the potential dangers of nanotechnology.

## VIII. CONCLUSION

Various aspects such as manufacturing, materials, applications, design, modeling, control, packaging, and environmental with respect to Nanoelectromechanical systems has been reviewed in this paper through different literature resources. We can conclude that as an emerging field in nanotechnology, NEMS serve various purposes though research is still going on.

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