VLSI POWER MANAGEMENT THROUGH ULTRAFAST NANO ELECTROMECHANICAL SWITCHES

AUTHORS

Mohammed Ubaidullah, M.Tech Scholar, Vlsi Design, Mewar University, Chittorgarh

Mr.Gaurav Sharma, Assistant Professor,Mewar University, Chittorgarh

ABSTRACT

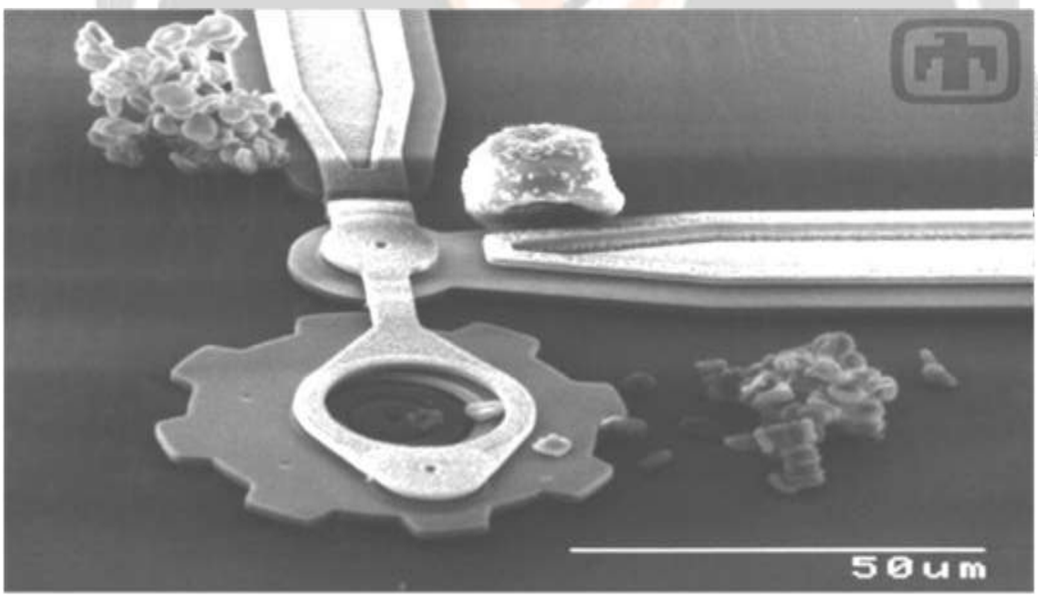
The current techniques for chip design put an emphasis on reducing the amount of power that is used. The amount of power that is lost in complementary metal oxide semiconductor (CMOS) devices has skyrocketed as their sizes have expanded dramatically. The power is being distributed over too wide of an area, which might result in the generation of more heat and thus causes an increase in temperature. According to recent reports, Intel's power viscosity has reached 1000 W/cm2 and is quickly nearing the number of 10,000 W/cm2, which is equivalent to the radiation that is emitted from the surface of the sun. Nanometer-scale CMOS provides issues to dependability due to the fact that silicon begins to melt at a temperature of 1687 degrees Kelvin. We came up with a novel armature to be used in the construction of nanoelectromechanical switches so that we could circumvent this problem. This new armature has produced results that have a leakage current of virtually nil and an operating voltage of just one volt resonating at a frequency of one gigahertz and leaving a trace on the nanoscale scale The "off" resistances of microelectromechanical system switches, often known as MEMS switches, are very high, while the "on" resistances are astonishingly low. Their switching voltages are often in the high range (between 5 and 50 V), their switching frequencies are typically in the low MHz range (1 MHz), and their leftovers are typically in the very large MHz range (numerous um2). We were able to develop and create a bias that had extremely low actuation voltages and really quick speed by using tuning chopstick figures that are amenable to typical CMOS fabrication techniques. This allowed us to design and construct a bias. The actuation voltage is reduced by a factor of 1.4 thanks to this one-of-a-kind switch figure, while the switching speed is increased by a factor of 2. The ground plane component of this system is implemented via the use of a stake ray. The ground aircraft and the main ray of the switch will travel in the same direction when the switch is switched on. Because the mass's center of gravity does not shift while the operation is taking place, the switching speed has been boosted by a factor of two as a direct result of this.These tunable chopstick nanoelectromechanical switches have the potential to be conveniently implemented in VLSI (Veritably Large Scale Integration) circuits for the purpose of effective leakage power management. This thesis will examine topics such as nanoelectromechanical system (NEMS) topologies, characteristics, leakage reduction methodologies, bias and piezo selector structure reliability for evaluating switch contact resistance and lifespan, as well as other pertinent information.

KEYWORDS- NANOMETER, SWITCHES, PIEZO-SECTOR, FABRICATION

INTRODUCTION

The proliferation of miniaturization technologies is driving the development of microelectromechanical systems (MEMS) and nanoelectromechanical systems (NES) (NEMS). The process of miniaturization has been an integral part of design ever since the 13th century, when watchmakers first experimented with ways to lower the overall size of a watch. The ever-present need to examine stuff on a tiny scale was the impetus for the creation of electron microscopes. The conflation microscope, which was initially invented in the 1600s, made it possible to see objects like bacteria that were very minute using a conventional microscope. After some time, electron microscopes were invented, and with their help, humans were able to observe objects on a molecular and even an atomic scale. The introduction of the transistor had a significant and long-lasting impact on the field of electronic manufacturing. The shrinking of the transistor is one example of a successful development. They are becoming smaller and more compact in order to reduce the amount of cumbersome devices and electrical bias. The size of a transistor in an integrated circuit manufactured today is 0.18 microns. The size of transistors is now being reduced to 10 nanometers at research facilities. The advent of the age of microdevices was marked by the miniaturization of electronic bias gauges. Because of this, new opportunities for the creation of nanodevices are becoming available presently. The phrase "perfecting the qualities paired with miniaturization" is now being used often in the world of electronic technology.

With today's technologies for Very Large-Scale Integration (VLSI) and semiconductors, the maximum bias is 32 nanometers. To put that in perspective, the thickness of a human hair is around a thousand microns. Microtechnologies and nanotechnologies are quite distinct from one another in terms of processing. In contrast to the bottom-up assembly approach used for microsystems, which is used for nanosystems, the top-down building strategy is used for the former (1). The advent of micro- and nanoelectromechanical systems has the potential to reframe the problem of microbias control. These systems integrate the mechanical elements (such as sensors, cantilevers, and pickers) and electrical circuitry (used to control the bias) required to evaluate the terrain. Patches of various sizes, including a drive gear chain and connection, pollen grains, and blood cells, are used as examples of size in Fig.1.1. Several nanoscale components are seen in Fig.1.2.



Courtesy Sandia National Laboratories, SUMMiT™ Technologies, www.sandia.gov/mstc.

Figure 1.1 Drive gear chain and linkages, with a grain of pollen (top right) and coagulated blood cells (lower right, top left) to demonstrate scale

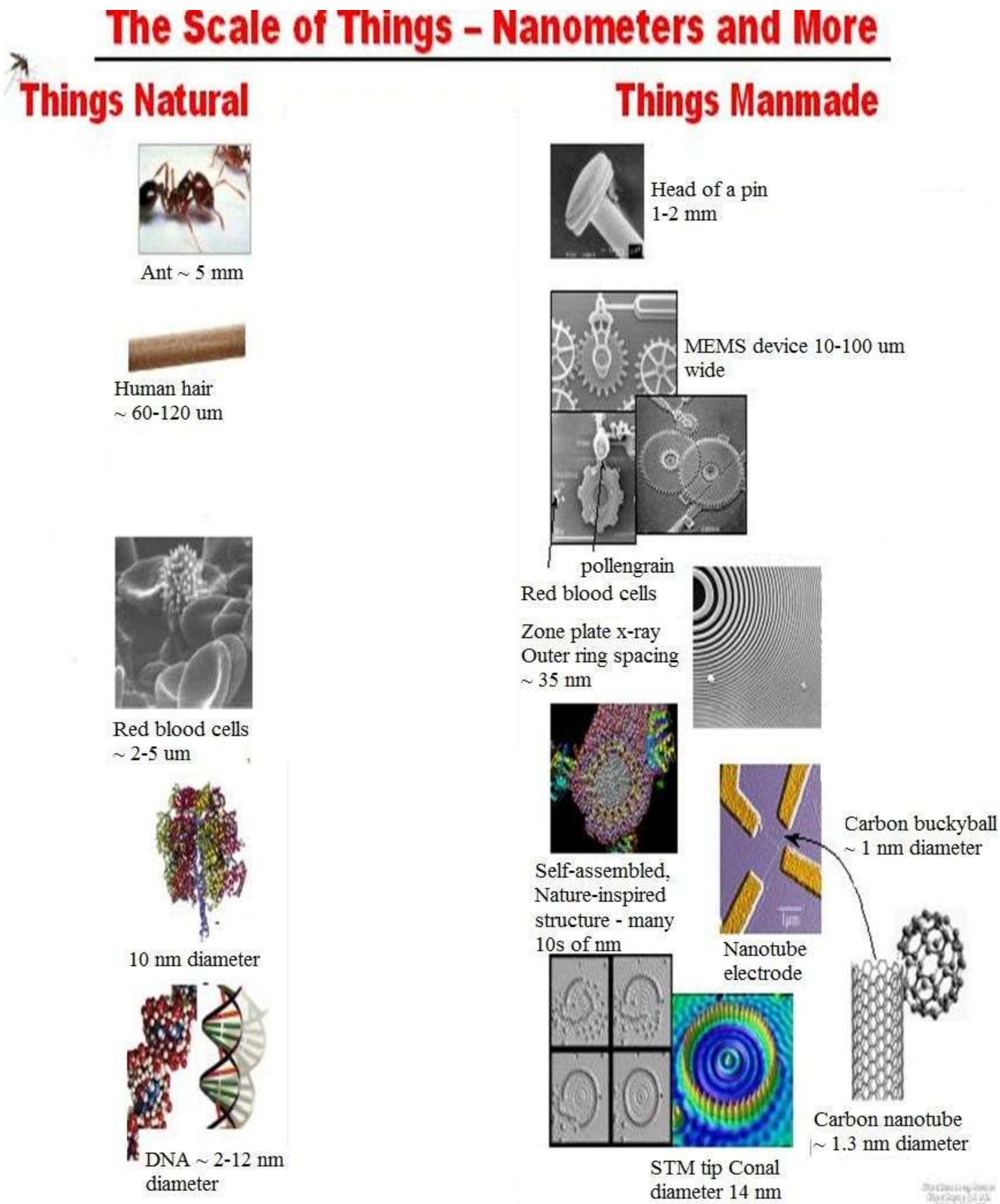


Figure1.2 The scale of things
Courtesy Office of Basic Energy Sciences, Office of Science, U.S. Department of Energy

Nanotechnology and microelectromechanical systems

Sometimes abbreviated to "MEMS," microelectromechanical systems include the integration of electronics with tiny mechanical actuators. Biases caused by the interplay of electrical and mechanical variables typically have a length on the micrometer scale. In order to produce these gadgets, batch processing methods for entangled circuits are used. In order to create a short circuit or an open circuit in a transmission line, these atomic biases are mechanically manipulated. Nobel Laureate scientist Richard Feynman is frequently cited as the forefather of contemporary MEMS and NEMS because of his inspiring lecture "There's plenitude of Room at the Bottom," given at the biannual meeting of the American Physical Society in Pasadena, California, in December 1959.

Construction of optical MEMS devices is another another field of MEMS that is progressing rapidly. Along with books on the law for bartenders and fiber optic communication cables, wide band gap accessories and ceramics are a few other examples of this prejudice. The Digital Light Processor (DLP), which is utilised in protuberance displays, is a prominent depiction of a commercially successful optic MEMS device.

The medicinal uses of microelectromechanical systems.

MEMS biases have proven to be revolutionary developments in the realm of biomedical procedures. The installation of artificial components and the dosage of medication are two examples of the sorts of operations that come under this category. There are several benefits associated with using MEMS, including its compact size, inexpensive price, straightforward surgical procedures, less required test samples, rapid opinion speed, and rapid case recuperation time. Patients with diabetes are now able to monitor their blood sugar levels and get insulin injections thanks to MEMS pumps. Various nanoelectromechanical devices and other implementations of nanotechnology are possible.

The equivalent in cadences of one nanometer is one billion. Comparatively, a human red blood cell's perimeter is around 10,000 nanometers, whereas a human hair's perimeter is roughly 100,000 nanometers. Nanotechnology is solely concerned with bias on a scale that is measured in nanometers (10-9). (10-9). Combining conventional device treatments with novel techniques such as molecular tone-assembly enables nanotechnology to generate novel bias at the nanoscale (1).

Carbon and silicon, both common in the world, occupy adjacent rows in the periodic table since they are both primary elements. Carbon's ability to form very strong and durable covalent bonds has made it an important component in nanotechnology. Its carbon chain length and thickness determine the spectrum of physical shapes it may take on. It is a gas at very short chain lengths, a liquid at intermediate chain lengths, and a plastic at large chain length.

Cylindrical carbon nanotubes are a unique kind of carbon nanostructure. Carbon nanotubes come in a wide range of colors and shapes, from single- to multi- to nano-bubble sizes. The directional stiffness and stresses of carbon nanotube bundles are characteristic of this material. Discoveries like nano tweezers, memory bias, supersensitive detectors, and adjustable oscillators are only a few instances of the rainbow of colors that may be unlocked.

The Impact of MEMS and NEMS Technologies

Important advances are being made in our daily lives because to both MEMS and NEMS (micro and nanoelectromechanical systems). Employment prospects in hitherto untapped industries, such as environment and electronics, are expanding as a direct consequence of these cutting-edge technological advances. In addition to the methods employed in semiconductor manufacturing, special techniques are needed to create microelectromechanical systems (MEMS) and nanoelectromechanical systems (NEMS). More opportunities have opened up in industries like manufacturing and education as a result of this. The microelectromechanical system (MEMS) and nanoelectromechanical system (NEMS) technologies have recently been used to developing areas including natural and photonic operations. Both government agencies and academic institutions are investing in research in these areas to spur the development of ground-breaking new goods. Due to their reduced mass, increased durability, and increased efficiency, they are financially beneficial.

But because carbon-grounded NEMS may cause cancer, it's important to look at NEMS technology thoroughly and

accurately. It's possible that the powerful essence included in NEMS might impair the body's delicate systems. Because of this, more expenditures in high-tech research are necessary to uncover the challenges provided by nanotechnology.
The development of semiconductors in electronics at the turn of the century heralded a new era. Furthermore, MEMS and NEMS technologies have the promise of ushering in yet another revolution. The amount of research done in these fields has skyrocketed in recent years.
Microelectromechanical systems (MEMS) and nanoelectromechanical systems (NEMS) are attracting the attention of more and more research institutions, which may be taken as an indication of the rapidity with which these technologies are progressing (NEMS). More than forty of these kinds of establishments may be found in the United States alone, and hundreds more can be found in other countries. Furthermore, there are around a thousand patents provided. There are several fields that might benefit from these developments, including aerospace, IT, auto, military, healthcare, and telecommunications. Developing and perfecting these sorts of technology requires a great deal of time and energy, not to mention engineering and imagination.
The packaging and the items' reliability are among the greatest obstacles. Accurate computational models are required for MEMS and NEMS design, testing, and prediction. If we want to make the most of the possibilities offered by the nanoscale future, we need to do things like increase the reliability with which NEMS bias is generated.

Types of Switches and Their Comparison

The first structural element of any electrical circuit should be a switch, as this is how the circuit is regulated. You may think of it as a regular contact that closes or opens a circuit. This is due to the fact that it may either make the circuit or break it. The switch is judged to be closed when the two halves of the contact come into touch with one another. What this means is that after the contact has been formed, electricity may flow freely through the switch. The "contact" is made up of these two elements. When there is no connection between the parts of the switch, we say that it is in the open position. Since the switch's circuit has been severed, no electricity can flow through it. The switch was broken, which caused this. Miniaturization also allowed for the development of switches with an extremely reduced number of contacts.

The size, design, and production of switches have all come a long way as a result of technological scaling. These advances have been made feasible via smaller components. These breakthroughs have been made. Mechanical switches are frequently enormous and unwieldy in size, as their functioning needs the employment of some form of mechanical action, and their working speed is often fairly slow. The speed of switches that make use of electromechanical technology may be boosted to a larger degree. For the same reason that electrostatic forces cause switching, they also cause this phenomenon. Smaller and more precise switches have been created as technology has progressed, with some already functioning at the microscale and nanoscale. By reducing the magnitude of the bias, the algorithm's calculation speed and accuracy were both enhanced. The amount of electricity utilized at the micro and nano levels was raised regardless of the degree of the bias. Colorful nanoelectromechanical switches are feasible to develop. The bottoms of some of them are made from carbon nanotubes. When implemented in memory and sensing switches, they reduce cell and bit line leakages. We present a novel switch with tunable chopstick geometry and nanoscale functionality.

CONTACT MATERIALS FOR NEMS

Plating by Contact.

The most critical step in manufacturing electrical switches is the contact plating procedure, which must be followed by sealing. The plating of the wimp switch determines its contact quality.

The Tools and Materials Needed for Contact Plating
Most traditional weak switches employ a ground subcaste made of gold plating on 52- amalgamation. Rhodium or ruthenium may be used to cover the ground subcaste in certain applications

Releasing a Plate

Typically, gold plating is applied over a lower quality metal. Two separate types of gold plating outcomes exist: pure gold and cyanic. One of the most common forms is made of pure gold. In many contexts, gold plating necessitates a prior process of gold striking. It's likely that gold striking will be required while attempting to produce secureadhesion. In cases when another process, such as gold plating, may offer the required adherence and other properties, gold striking might be skipped.

Caution's worth as a substitute for gold has increased in recent years. Much less mass is needed to obtain the same plating consistency with precaution as with gold plating due to precaution's much greater viscosity (about 60 times that of gold) (around 40 times less). Plus, the price of safety measures is about equal to one-third of the price of gold. For ground plating, this means cost savings substantially. Its high melting point and hardness, which is double that of gold, contribute to its performance-based profitability.

Rhodium plating is a kind of electroplating.

Rhodium is now used mostly as a part of electrical switch contacts. Rhodium has a high melting point and is very strong and resistant to sticking, bruising, and erosion. Similar to diamond in hardness is the precious metal rhodium. Determine how much rhodium really costs. After balancing the cost and practicality, ruthenium emerges as a more appealing option for rhodium.

Upgrade Your Tungsten Dinnerware to 2.2.5

As a result, rhodium and ruthenium have a substantially lower melting point than tungsten. Tungsten's effectiveness as a switch contact material is not unexpected in light of this. Plating is made using chemical vapor deposition (CVD). The plating's resistance to abrasion and adhesion is two of its finest attributes. Since this plating oxidizes in the presence of oxygen, it has a high contact resistance right off the bat, which is a serious defect. Aesthetic surgery is the next best thing after treating cardiovascular disease.

Criteria for Material Selection

There are different criteria to be considered while opting the accoutrements for making nanoelectromechanical switches. These criteria include melting points, resistivity and Young's modulus. The following numbers2.1 and2.2 and corresponding Tables2.1 and2.2 demonstrate the factors of colorful accoutrements suitable for making switches. The conditions suitable for making switches would be low melting point, high resistivity and high Young's modulus.

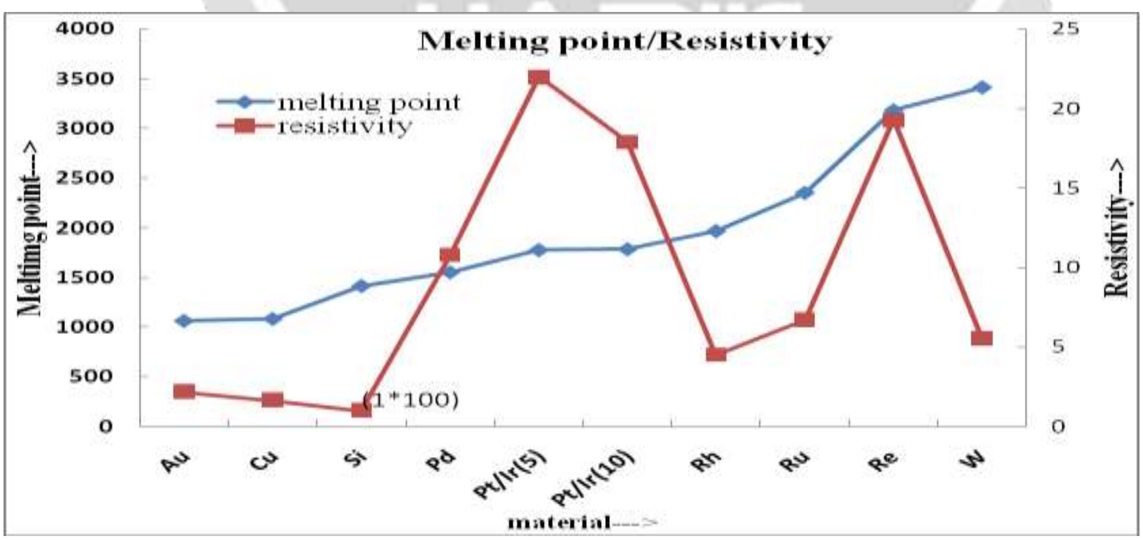


Figure2.2Melting point and young's modulus of various materials

Table2.2Melting point and Young's Modulus of various materials

Material	Melting point©	Young's Modulus (kN/mm2)
gold	1063	80
copper	1083	115
silicon(n-type)	1414	150
palladium	1552	117
platinum/iridium alloy(5)	1775	190
platinum/iridium alloy(10)	1783	220
rhodium	1966	386
ruthenium	2350	430
rhenium	3180	480
tungsten	3410	360

Based on all these factors, we are making switches with tungsten. The material's low contact resistance and high melting point are the major selling factors for its usage in practical applications because of these properties. The choice of material for a switch has a significant impact on the switch's ability to exhibit the desirable attributes that are sought for, such as low leakage power, high reliability, or rapid switching.

Tuning Fork NEMS Switch

This tuning fork shape emerged as a consequence of attempts to both lower switching voltage and increase switching speed. It features a low "ON" resistance, a rapid switching speed (1-5 ns), and a low switching voltage (1-3 V).

The tuning fork that is seen in Figure 3.3 is able to operate at high frequencies because the frequency of its second resonant mode is much higher (2f0). Because switching speeds are increasing, the only thing that is slowing down the switch is the "mechanical" response of the moving parts. This is because the RC time constant associated with charging and discharging the metallic interconnect transmission lines (which are providing the RF signal to the switch) is extremely small. The mean free pathways of air molecules in one atmosphere at ambient temperature are one um, hence the damping induced by air molecules is considerably reduced by the device's gap, which is just one nm wide. Because the mass center does not shift during the vibration of the two vertical cantilever beams in the second resonant mode of the tuning fork form, higher speeds may be attained. Figure 3.5 shows a scanning electron micrograp h taken of a tuning fork NEMS switch that is operational.

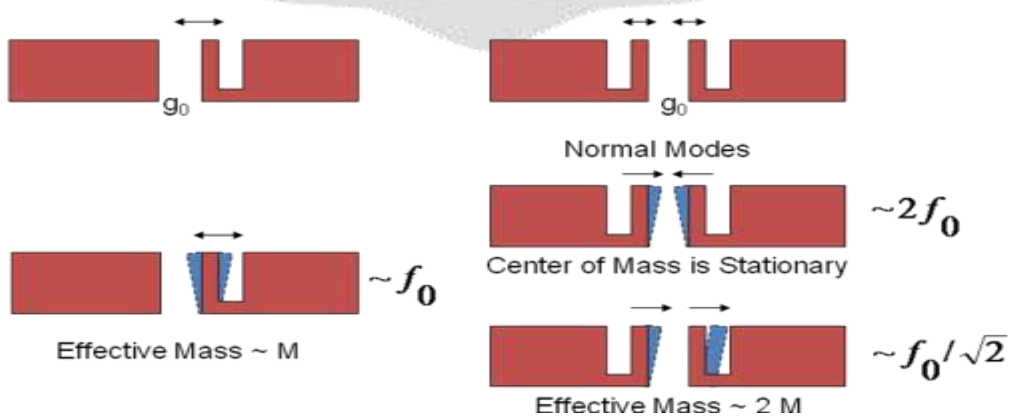


Figure3.3 Frequency advantages of tuning fork geometry

Switching Characteristics

As a means of studying the characteristics of nano-electromechanical switches' switching, a very basic circuit is used . This is well shown in Fig.3.16. This circuit consists of a palpitation creator unit (PGU) and an ordinary resistor. The PGU's output serves as an input to the circuit, while the output is connected across the resistor. In order to see the switching features, one must connect the palpitation input and the affair to a high-tech digital phosphor oscilloscope.

The input palpitation width is varied between 0.5 V and 4 V to investigate the precise switching of the device. At lower voltages, the results suggested that a parasitic capacitance was switched (05V). Since this was the outcome, this explanation seemed reasonable. The switching was very slow when these voltages were used. The switching times improved practically instantly as the voltage was increased. The higher voltage caused a quick transition. Simply put, the values 3.17 and 3.18 describe their switching properties as ratios.

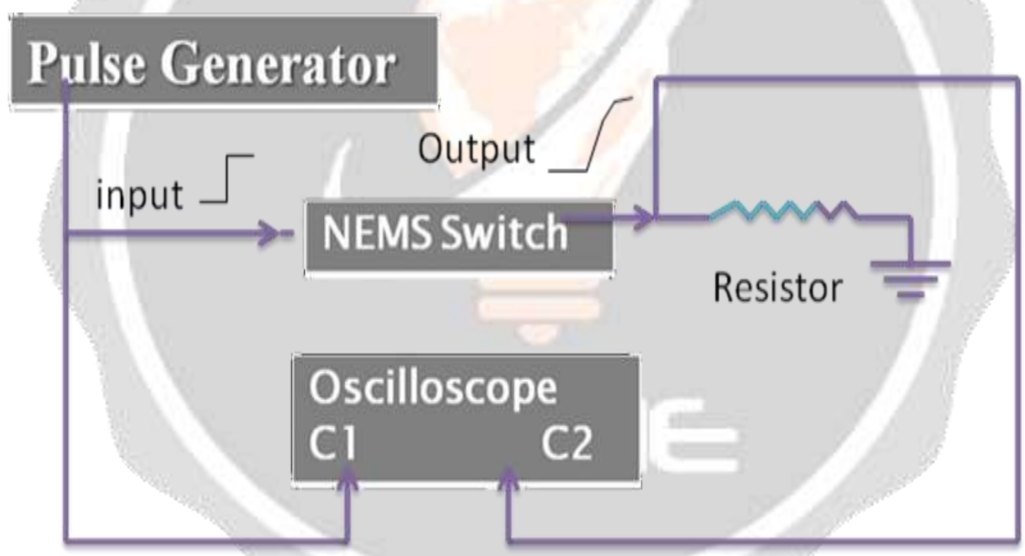


Figure3.16 Experimental set-up to measure switching characteristics

CONCLUSION

It has been shown that a unique device can be tuned to look like a chopstick, and its purportedly rapid processing rates and low actuation voltages have also been described. It has been established that gaps between silicon and the essence that are several nanometers (nm) deep may perform magnificently even when subjected to lower voltages. Simulations have been used to get estimates of both the gap and the switching voltage. According to the findings of the simulation, the rating for consistency is 13 nm. The ability to maintain consistency at 13 nanometers allowed for actuation voltages as low as 15 volts.

The leakage current that nanoelectromechanical switches generate is the primary challenge presented by these devices. There have been a lot of different attempts made to find the most visually beautiful solution for reducing leakage current, and there have been a lot of different methods. During the allotted period of time, the bias was subjected to the applications of an oxygen tube, SF6, water, and vacuum. The switching characteristics significantly decreased when the bias was treated with an oxygen tube for one minute. The treatment caused the switching characteristics to diminish.

Additionally, the influence of temperature on the switching performance was analyzed. By placing the bias in a particular piece of equipment, the temperature at which it was maintained was altered. When evaluating the switching characteristics at room temperatures, both 298 K and 409 K are employed as reference temperatures. The switching voltages became more stable as the temperature continued to rise. Continuous testing is carried out in order to check the bias over an extended period of time at high temperatures.

In order to investigate the rate at which the bias switches on and off, a laboratory apparatus that includes a palpitation generator and a resistor is used. In situations when the switching voltage is lower than the palpitation width, the switching periods will be relatively prolonged. Switching times are almost immediate if the pulse width is bigger than the actuation voltage. Gain at gigahertz frequencies may be assessed by feeding radio frequency signals into a network analyzer, which then provides an assessment of the bias.

In a flexi glass configuration, piezo electric detectors are used to determine when a switch should be triggered. Piezo selectors have an oscillating motion, which determines when the switch is open and when it is closed. It is possible to compute the contact resistances of flashy accessories like as ruthenium and tungsten by taking into consideration the space limits. The findings were utilized to do the calculation that determined the duration of the bias in a vacuum environment that was meant to replicate the circumstances that are present in space.

Research on nanoelectromechanical switches has hardly gotten off the ground up until this point. It is envisaged that NEMS bias would eventually replace the VLSI approaches that are now in use. In order for us to fulfill all of the criteria for low actuation voltages, high operating frequency, and high temperature operation, we are going to have to put in a significant amount of work. We are aware, as of this moment, that switching voltages in the neighborhood of 1

requiring a power of just 2 volts to function and boasting a frequency of many gigahertz In the future, further work will be required to generate switching behaviors that are consistent. There is a possibility that the nanoswitches will switch for an infinite amount of time; this is something that has to be researched.

It is possible to create any VLSI circuit by using just the AND, OR, and NOT gates as the sole building blocks. As a result, the design of these gates has to include nanoelectromechanical switches. Across all of our different tests, there should be no discernible shifts in the contact resistance. The switching qualities are determined by the accessories that are employed in the creation of the stake shafts. When determining which potential material will make the best required for switch construction, it is necessary to take into account the contact resistance, actuation voltages, and switching speeds of each candidate.

The major objective is to develop NEMS switches that are quicker than their typical VLSI equivalents, smaller in footprint, and more functional, all while having lower actuation voltages.

REFERENCES

[1] S.E. Lyshevski, MEMS and NEMS: Systems, Devices and Structures. Boca Raton, Florida: CRC Press, 2002, pp. 1-50.

[2] G. M. Rebeiz, RF MEMS Theory, Design, and Technology. Hoboken, NJ: John Wiley and Sons Inc, 2003, pp. 1-3.

[3] M. Gad-el-Hak, MEMS: Introduction and Fundamentals. Boca Raton, Florida: CRC Press, 2006, pp. 1-3.

[4] L. J. Hornbeck, “Digital light processing for high brightness, high-resolution applications,” in Proc. SPIE, vol. 3013, pp. 27-40, Projection Displays III, 1997.

[5] P. Rai-Choudhury Ed., Handbook of Microlithography, Micromachining, and Micro fabrication. vol. 1, Bellingham, WA: SPIE Optical Engineering Press, 1997.

[6] K. Alzoubi, D. G. Saab, and M. Tabib-Azar, "Complementary nano-electromechanical switches for ultra-low power embedded processors," Proceedings of 19th ACM Great Lakes symposium on VLSI, 2009.

[7] P. G. Slade, Electrical Contacts Principles and Applications. New York, NY: Marcel Dekker Inc, 1999.

[8] D. A. Czaplewski et al., "A nano mechanical switch for integration with CMOS logic," J. Micromech. Microeng., vol. 19 no. 08, pp.12, 2009.

[9] A. B. Kaul, E. W. Wong, L. Epp, and B. D. Hunt, "Electromechanical carbon nanotube switches for high-frequency applications," Nano Lett., vol. 6 no. 5, pp. 942–947, 2006.