Quest Journals
Journal of Research in Mechanical Engineering
Volume 6 ~ Issue 1 (2020) pp: 49-55
ISSN(Online) : 2321-8185
www.questjournals.org

Research Paper

Considerations on Nanotechnology in Industrial Applications

Osman Yazicioglu[1] Oguz Borat[2]
[1](*Industrial Engineering Department Istanbul Commerce University Turkey)*
Corresponding Author: Osman Yazicioglu[1]

ABSTRACT: *The pursuit of the microscopic origins of friction, lubrication, adhesion, and wear is an important activity called tribology. Automotive frictional losses come from engine, transmission system, tires, air and braking. The possible saving for frictional losses in UK were estimated to about 1% of GNP.*
Nanotechnology is a multi-disciplinary engineering field, which draws from and benefits areas such as materials science and medicine. Nanotechnology is revolutionizing everything from smartphones to cancer treatment.
Nanotechnology seeks to learn new things that can change the face of science, technology, and the environment on a molecule level. They test for pollutants, find powders to enrich the medicines, and study the smallest fragments of DNA. They can even manipulate cells, and chemicals from within the body.
Nanotechnology take advanced supplies and materials and turn them into something new and exciting ones. They may try to make a once heavy invention work better while weighing less, making the object far more efficient. They may also make new and improved ways of watching out and improving the environment by doing innovative ways to test for contaminants in the air.
Nanotechnology that work with nanoelectronics will make smaller, more efficient chips and even smaller parts.
Atomic force microscopy is a new technology and the wide range of its applications is rapidly growing in research and development. It is a versatile and useful technique to study engineering processes at the nanoscale level. STM can be applied only conductor materials but AFM can be applied to all materials.
KEYWORDS: *Nano Technology, Atomic Force Microscopy, Micro Technology,*

R*eceived 16 November, 2020;* ***A****ccepted 02 December, 2020 © The author(s) 2020.*
P*ublished with open access at* ***www.questjournals.org***

I. INTRODUCTION

Nanotechnology is a functional engineering system on a molecular scale. Nanotechnology is the study of the controlling the matter on an atom and molecular scale. Generally, nanotechnology deals with structures sized between 1-100 nanometers in at least one dimension, and involve modifying or developing materials within that size. It makes the material lighter, stronger, faster, smaller and more durable. For the first time in the 1980s, Drexler coined the term nanotechnology. The atomic diameter is 0.1-0.5 nm. A molecule consisting of thirty atoms has a diameter of 1 nm [1].

Nanotechnology has potential applications in many sectors of the world economy, including consumer products, health care, transportation, energy, agriculture, coatings, computers, clothing, cosmetics, sports equipment and medical devices. Nanotechnology also has the potential to improve the environment, both through direct applications of nanomaterials to detect, prevent, and remove pollutants, as well as indirectly by using nanotechnology to design cleaner industrial processes and create environmentally responsible products. However, there are still unanswered questions about the impacts of nanomaterials and nanoproducts on human health and the environment, and the scientists have the obligation to ensure that potential risks are adequately understood to protect human health and the environment. It is hoped that scientists will identify potential risks and produce solutions, aiming to protect human health and the environment.

It is certain that developments in microscope technology have a great contribution to the development of nano technology. The atomic force microscopy (AFM) technique has a number of advantages over other competing techniques such as surface force apparatus:

(1) The use of colloid probes and planar surfaces allow measurements to be made with many types of conductive and nonconductive materials.
(2) The small area of contact between probe and planar surface minimizes problems with contamination.

(3) The AFM allows quantification of the morphology of the surfaces under study using the same instrument.

AFM can significantly impact to most fabrication and manufacturing processes at molecular and nanoscale levels due to its tremendous surface microscopic capabilities including 3D topography of nanoparticles fabrication, metrology, thin film mechanical and physical property characterization [2].

The characterization of aluminum oxide nanoparticles filled S – glass fiber composites were done using universal testing equipment properties of aluminum oxide S –Glass fiber reinforced composites. The results are indicated with increase in weight of nano aluminum oxide improves the mechanical properties [3].

A theory developed that provides a possible explanation for the event recorded in AFM work in terms of the development of negative liquid about a growing cavitation bubble. This cavitation results from of a sufficiently large tensile stress within the liquid film, due to the bounding surfaces the colloid sphere and the plane surface [4].

Triboelectric nano generators can actively function as self-powered sensors and actuators to detect, monitor, interact and respond to the ambient changes induced by environment or human. These triboelectric devices can be key components to achieve sustainable functional systems [5].

Due to reduced distance between adjacent wires in nano scale technology, the effect of crosstalk noise has brought serious reliability challenges. Two energy-efficient current-mode Driver-Receiver designs for on-chip global interconnects based on Magnetic Tunnel Junction elements is proposed. Magnetic Tunnel Junction elements operate with ultra-low voltage bias over ideal, low impedance current mode receivers and interconnection [6].

The force spectrum technique using atomic force microscopy can be used to obtain the nano adhesive forces of the styrene-butadiene-styrene-modified bitumen samples [7].

Manufacturing is the primary industry promoting economic and social development. For the past 30 years, the global trends of preciseness and device miniaturization have promoted manufacturing to the micro and nano scale [8].

In nanotechnology, top-bottom and bottom-up processes used in manufacturing. In top-bottom manufacturing, the manufacture of integrated circuits with lithography of thin films such as silicon chip was used. In bottom-up manufacturing, the starting material may be atom, molecule or ion. Carbon nanotube manufacturing in nanotechnology, manufacturing by scanning tip technique and manufacturing by self-assembly are examples of manufacturing with nanotechnology.

The global nanotechnology market is $ 40 billion in nanomaterial and $ 10 billion in nanotools in 2017 (figure 1). In nanodevices, it is $ 1 billion. Nanotechnology market value is projected to increase to $76 billion by 2020. The global energy-related market for nanotechnologies should grow from $5.7 billion in 2018 to $10.0 billion by 2023 at a compound annual growth rate of 12.0% for the period of 2018-2023 [9, 10].

The pursuit of the microscopic origins of friction, lubrication, adhesion, and wear is an important activity called tribology. Automotive frictional losses come from engine, transmission system, tires, and braking. The possible saving for frictional losses in UK were estimated to about 1% of GNP. In USA it could be gained through proper attention to tribology would correspond about $300 billion in 2017 [11].

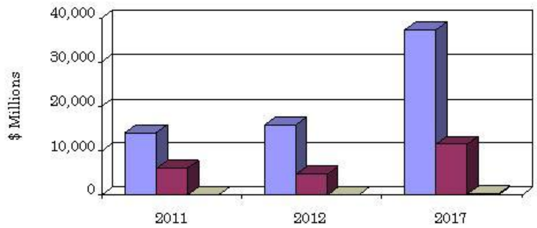
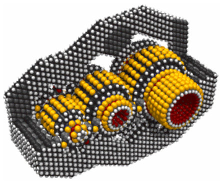


Figure 1: Global nanotechnology market [9].

With nanotechnology, K. E. Drexler modeled a gear reducer consisting of 15342 atoms (figure 2) [12]. An example gear for micro manufacturing is given in figure 3 [13].



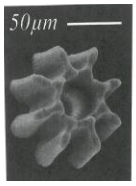


Figure 2: Nano gear reducer model. **Figure 3:** Micro gear.

Microsystem technology sizes with nanotechnology are shown in Table 1. Size of nanosystem is 1-100 nm and size of microsystem technology is 1-100 µm.

Table 1: Comparison of nanotechnology and microsystem technology.

Nano technology			**Microsystem technology**		
1 nm molecule	10 nm virus	100 nm bacteria	1 µm cell thickness	10 µm cell diameter	100 µm human hair
Electron beam microscopy	Scanning tip microscopy		Optic microcopy		
Nano manufacturing			Silicon layer technologies		

II. MICRO SENSORS

Larger entities than nanotechnology exist in the microsystem. Micro sensors are used in modern cars (Table 2).

Table 2: Application areas of microsensors.

Microsensors	**Application area**
Accelerometer	Air bag release, ABS brake, active suspension system
Angular speed sensor	Intelligent navigation system
Level sensor	Oil and gasoline level
Optic sensor	Car headlight lights control
Position sensor	Transmission, motor timing
Rang sensor	Front and rear bumper distance sensor in parking control, anti-collision
Pressure sensor	Fuel consumption optimization, oil pressure, tire pressure
Temperature sensor	Cabin air conditioner control, engine management system
Torque sensor	Drive mechanism

Microsensors are also used in medicine. These include angioplasty, tele microsurgery, artificial prostheses, implantable sensor system, drug delivery devices and artificial eye.

Microsystem is involved in technology, biotechnology and electronics. Human genetic material is packed in 46 chromosomes. Number of nodes of chromosomes different for human, animal, and plant, they have 3, 2, and 1 node, respectively. The structure of chromosomes is known as the DNA chain at the lowest level. This chain is wrapped around eight histone protein nuclei. There are about a million nucleosomes. A nucleosome is 6 nm thick and 11 nm long.

III. FIELDS OF NANO TECHNOLOGY

Research is being done to develop stronger, harder, lighter and safer materials using nanostructured materials for design. It is aimed to understand the relationship between material nanostructure and macroscopic properties and to develop new manufacturing methods. In addition, studies shown in Table 3.

Table 3: Application areas of nanotechnology

Application area
Nano electronics, optical electronics and magnetism
Advanced health and care
Nanoscale processes for environmental improvement
Efficient processes for energy conversion and storage
Reducing the size of spacecraft, autonomous decision-making
Biological threat detection with biological nanosensors
Economical and safe transport
National security.

III.I MICROSCOPES

Optical microscopes provide up to 1000 times magnification and 0.2 µm resolution. Since the wavelength of visible light is 380-700 nm, optical microscopes cannot be used to see nano bodies. If an electron microscope is used instead of an optical microscope, 10 million magnifications and a resolution of 1 nm are obtained.

The electron microscope was invented in the 1930s. Electron microscopes use an electron beam instead of light. An electron beam scans the surface of an object to obtain an image of the object. This scan is similar to a cathode ray scan on the surface of a TV screen.

The scanning probe microscope (SPM) was invented in the 1980s. The scanning-tipped microscope can make magnification 10 times that of the electron microscope. The tip tapers to the size of a single atom.

Scanning tunneling microscope (STM) and atomic force microscope (AFM) are important in nanotechnology.

III.II ATOMİC FORSE MICROSCOPES

Binning and Rohrer developed the atomic force microscope in 1980 at IBM Research - Zurich. They won the 1986 Nobel Prize. AFM was first described in the scientific literature in 1986. The first atomic force microscope was released in 1989. Atomic force microscopy is a new technology and the wide range of its applications is rapidly growing in research and development. It is a versatile and useful technique to study engineering processes at the nanoscale level. This powerful technique has been used to visualize surfaces both in air and process relevant aqueous environments [2].

To determine the surface topography with the highest possible resolution, a scanning probe such as the scanning tunneling microscope AFM is used, though these techniques are limited to small areas as <0.1 mm across.

The characterization the roughness of surfaces using some techniques may be compared as in Table 4.

Table 4: Comparison of experimental techniques.

.

Types of measurement	Resolution lateral, nm	Resolution vertical, nm	Comment
Optical microscopy	250-300	180-350	Depends on system quality
SEM	10	-	Requires vacuum limits z-height information

The choice measuring tool often depends on the length scale over which the topographical information is desired. If it is sufficient to know the finish of surface over a large area of the sample without precision of high, optical methods may be used.

If it is desirable to know the surface topography with the highest precision a scanning probe such as the scanning probe such as the scanning tunneling microscope or AFM is used. Of these two techniques, AFM is now by far the most widely used.

An AFM consists of a flexible lever and a pointed tip attached to it (used to scan the surface). In contact mode, the rover tip is hovered over the sample so that the thrust force remains constant in order nN (nano Newton) between the movable tip and the sample. If the rover end encounters a bulge, the thrust force between the rover end and the sample increases. In order to make the thrust in between constant, the rover tip moves slightly up, and thus the thrust force between the rover tip and the sample remains constant. This amount of upward movement gives the relative height of the ledge in question. If the rover end encounters an indentation, the thrust force between the rover end and the sample decreases. In order to make the thrust in between constant, the rover end moves slightly downwards and thus the thrust force between the rover end and the sample remains constant. This amount of downward movement gives the relative depth of the indentation in question. The pull-thrust forces between the rover tip and the sample are measured using piezoelectric material. Movements that occur in the vertical direction when the rover tip is hovering over the sample are measured using a laser beam sent to the opposite side of the support to which the rover tip is connected. The laser beam reflected from the support falls at different points in the detector due to the vertical movement of the support. Since the detector is sensitive to position, the violence information obtained shows the vertical movement of the support, hence the topography of the sample surface. The resolution in the vertical direction is 0.1 nm. The vertical movement of the rover tip can also be measured with the help of a spring. If the height of the rover tip is kept constant, rather than keeping the thrust force between the rover tip and the sample constant, a map of the push-pull forces between the sample and the tip is obtained. The roving ends are made of Si and Si_3N. In atomic force microscopy, horizontal resolution also increases when the sharpness of the tip increases.

A scanning tunnel microscope can only be used on conductive material surfaces, while an atomic force microscope can be used on any material surface. Atomic force microscopy responds to different types of forces depending on the application: physical contact force, mechanical force tip, non-contact van der Waals forces, capillary force, magnetic force, etc. The vertical angle of the tip is measured optically. Comparable to scanning tunnel microscope with atomic force microscope:

1. AFM takes an image with a nanometer-sized tip. STM uses a quantum tunnel to get images.
2. In AFM tip also contacts the surface or calculates with initial chemical bonding. The STM calculates the image indirectly between the tip and the sample via the quantum-grade tunnel.
3. In AFM, the tip is slightly in contact. In SMM, the end is located at a short distance from the surface.
4. For AFM, the resolution is better than STM. So AFM is more widely used in nanotechnology.
5. STM can be applied only conductor materials but AFM can be applied to all materials.
6. AFM works in liquid and gas medium but STM works only in vacuum.

On atomically smooth surfaces, AFM can yield 3-dimensional topography in a single scan. It also provides a greater level of detail. SEM does not provide effective resolution on such surfaces. In thin films, such as memory capacitors, AFM and SEM give similar results. However, while SEM does not give slope information, AFM gives height information (figure 4).

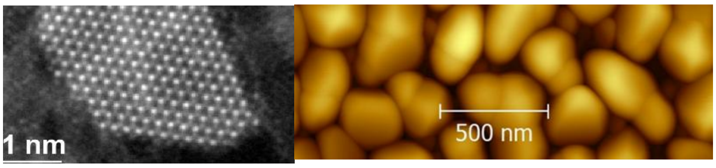


Figure 4: Image of MoS_2 particle and Zn layer.

On relatively rough surfaces, SEM excels because it also gives depth in the field.
For atomic force microscope Veeco MultiMode V brand AS-12 model, the scanning area is 10 µm x10 µm (figure 5).

Figure 5: An atomic force microscopy (Middle East Technical University, Turkey).

The sample should be placed in a diameter of up to 15 millimeters. The surface to be examined must be parallel to the placement surface and less than 8 mm. Surface examinations of thin film coatings, surface examinations of organic and inorganic materials, phase differences, differences in electrical conductivity and differences in magnetic field direction can be obtained.

In AFM, the force acting on the last few atoms of sharp tip measured as that tip moves gently over the sample surface (figure 6). This is accomplished by mounting the tip at the end of a cantilever with a known spring constant. As of 2019 many AFM designs measure deflections as small as 0.01 nm [11].

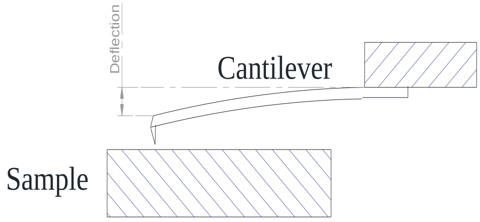


Figure 6: Schematic of the AFM

III.III ROUGHNESS PARAMETERS

AFM trace over a surface to provide a single line profile of the surface topography (figure 7).

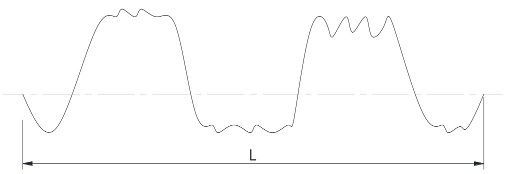


Figure 7: A single profile of surface topography [11].

By repeatedly collecting traces separated by a small distance in the orthogonal direction, in 3D representation of the topography can be obtained.
The most common surface roughness parameter is R_a, which is the arithmetic mean of roughness of the surface (Equation 1). This defines variation in z-height. Most methods for linking to surface fatigue or surface roughness use R_a or a similar measure, R_q, i.e. the root mean square of surface roughness (Equation 2). This for sinusoidal surfaces. Approximately R_q parameter for Gaussian distribution is given in Equation 3. The suitability of these two measurement parameters for use in life estimation calculations is a matter of debate, and their prevalence may be linked to their past availability in common profile gauges rather than their accuracy in classifying the surfaces. The growth of the isotropic super finishing process in the industry has served to increase the need to evaluate alternative measurements of surface roughness due to extremely different surface properties.

$$R_a=(1/L)\int_0^L /z\ / dx \qquad (1)$$

$$R_q=[(1/L)\int_0^L z^2 dx]^{0.5} \cong 1.11\ R_a \qquad (2)$$

$$R_q \cong 1.25\ R_a \qquad (3)$$

III.IV FUNDAMENTALS OF ATOMIC FORCE MICROSCOPES

Fundamentals set-up of an AFM shown in figure 8. Cantilevers are commonly either V-shaped, as shown, or a rectangular, ‘diving board’ shaped. The cantilever has at its free end a sharp tip. This tip acts as a probe of interactions. This probe is generally in the form of a squared-base pyramid or a cylindrical cone.

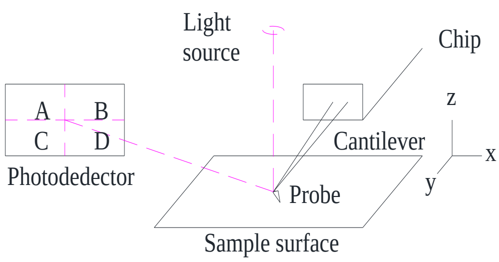


Figure 8: AFM set-up [14].

Commercially probes and cantilevers are made of silicon or silicon nitride. Upper surface of the cantilever is coated with thin reflective surface of gold or aluminum.

Either the probe is bought into and out of contact with the sample surface by the use of a piezo crystal upon which the cantilever chip or the surface itself is mounted, depending on the particular system.

Movement in this direction is referred to as the z-axis. A beam of laser light is reflected from reverse side of the cantilever onto a position-sensitive photodetector. Any deflection of the cantilever will produce a change in the position of the laser spot on the photodetector, allowing changes to the deflection to be monitored. A configuration for the photodetector is that of a quadrant photodiode divided into four parts with a horizontal and vertical divining line. The deflection signal is calculated by the difference in signal strength detected by the A+B versus C+D quadrants. Comparison of the signal strength detected by A+C versus B+D will allow detection lateral bending of the lever. Once the probe is in contact with the surface it can then be raster-scanned across the surface to build up relative height information of topographic features of the sample.

IV. CONCLUSION

It is aimed to understand the relationship between material nanostructure and macroscopic properties and to develop new manufacturing methods. In addition, studies are being carried out in the following areas: nano electronics, optical electronics and magnetism, nanoscale processes for environmental improvement efficient processes for energy conversion. Comparable to scanning tunnel microscope with atomic force microscope: AFM takes an image with a nanometer-sized tip. STM uses a quantum tunnel to get images, for AFM, the resolution is better than STM. STM can be applied only conductor materials but AFM can be applied to all materials, and AFM works in liquid and gas medium but STM works only in vacuum.

REFERENCES

[1]. Brown, T.L., H. E. LeMay, Jr., B. E. Bursten, C. J. Murphy, P. M. Woodward and M. W. Stoltzfus. Chemistry, the Central Science. 14 th Ed., 2018, Pearson Education Limited.

[2]. Hilal, N., W. R. Bowen, L. Alkhatib and O. Ogunbiyi, A Review of Atomic Force Microscopy Applied to Cell Interactions with Membranes. Chemical Engineering Research and Design, 2006. 84(A4): 282–292.

[3]. Mahesha, G. G. and Jayakrishna K. Evaluation of Mechanical Properties of Nano Filled Glass Fiber Reinforced Composites. Materials Today: Proceedings 22 (2020) 3305–3311.

[4]. Barrow, M.S., W. R. Bowen, N. Hilal, A. Al-Hussany, P. R. Williams, R. L. Williams and C. J. Wright, A Study of the Tensile Properties of Liquids in Confined Spaces Using an Atomic Force Microscope. Proceedings: Mathematical, Physical and Engineering Sciences. 2003. Vol. 459, No. 2039 p. 2885-2908.

[5]. Shi, Q., T. He and C. Lee. More than energy harvesting – Combining triboelectric nano-generator and flexible electronics technology for enabling novel micro-/nano-systems, Nano Energy, 2019. 57:851–871.

[6]. Jamshidi, V. and M. Fazeli (2019). Ultra-low power and reliable magnetic based interconnects for nano-scale technologies. Microelectronics Journal, 2019. 90:39–47.

[7]. Bo, L. C. Yujiao, L. Xianga, L. Hailian and L. Xiaomin. Effect of material composition on nano-adhesive characteristics of styrenebutadiene-styrene copolymer-modified bitumen using atomic force microscope technology. International Journal of Adhesion and Adhesives 2019. 89:168–173.

[8]. Bodnariuk, M. and R. Melentiev. Bibliometric analysis of micro-nano manufacturing technologies. Nanotechnology and Precision Engineering 2019. 2:61–70.

[9]. www.bccresearch.com/market-research/nanotechnology/nanotechnology-fuel-cell-research-review.html BCC Research, A realistic Market Assessment. 2019 Nanotechnology and Advanced Materials Research Review, 30.10.2020.

[10]. www.nanomarketwww.statista.com 12.10.2020.

[11]. Mate, C. M. and Carpick, R. W. Tribology on the small scale. 2nd Ed., 2019, Oxford University Press.

[12]. www.nanotechnologist.com K. Eric Drexler : pioneer of nanotechnology.

[13]. Groover, M. P. Fundamentals of modern manufacturing: Materials, Processes and Systems. 7th ed. 2019. Wiley.

[14]. Bowen, R. B. and N. Hilal. Introduction to AFM for improved processes and products. 2009. Elsevier BH NewYork.

Osman Yazicioglu, et. al. "Considerations on Nanotechnology in Industrial Applications." *Quest Journals Journal of Research in Mechanical Engineering.* 6, (1), (2020): pp 49-55.