Emerging Trends of Nanotechnology towards Picotechnology: Energy and Biomolecules

R. Sharma*, A. Sharma**
*Center of Nanomagnetics and Biotechnology, Florida State University, Tallahassee, FL 32310 USA, rs05h@fsu.edu
**Department of Electrical Engineering, MP A&T University, Udaipur, Rajasthan India

ABSTRACT

In nature, metal oxide particles display their existance of picomolecules in solution state at the picoscale and bioactive states in the body. We put evidence of picomolar behavior of picoscale molecules different than nanomolar behavior of particles using PICOTECHNOLOGY devices. PICOTECHNO-LOGY means picomolar measurement of picoscale molecule physical properties measured by pico-devices or picoscopes. The picoscale particles can be encapsulated more precisely within polymers and can be functionalized with protein, nucleotides, and drugs at picoscale to develop as smart intracellular targeting/ monitoring pico-carrier devices. The preparation technique and physiological conditions at picoscale decide the size and functionality of these pico-carrier devices. Their usable success rate, feasibility and potentials are yet to be proven or we donot know. The major difference between nanodevices and pico-devices is their intermolecular and intramolecular thermodynamics in medium and their molecular conformational interaction with molecular assembly in cytoarchitecture of the neurofilament, actin-myosin, microtubule proteins. In future, picoscale-carrier device can be presumed as potential spears without interacting with host signal transduction and immunoprotection. Present time, picoscopes, picoscale physical instruments are in use for monitoring purposes. In conclusion, ultrafine size of newer picotechnology products may be better suited and easy to functionalize them for design of particle based picodrug, picochemicals, pico-targeting molecules.

Keywords: Picoscale,Picotechnology, Molecules, Energy, Dimensionality

1 INTRODUCTION

Several metal solutions are known to act with high activity as their concentration in solution is decreased towards picomoles. Best examples are calcaria phos(calcium phosphate), natrum mur (sodium sulphate), ferrum ox (iron oxide), arsenica(arsenic oxide) known in Homeopathy based on the physical principle of administration of similar metal ions 'amplify' the bioreaction of same metals in physiological conditions (more than 10^8 times) in the inverse order upon decreased metal administered concentration. If picomoles of metal is administered in the body will cause high magnitude of physiological reaction activation than metal is administered in nanomoles. In keeping this view in mind, reactions requiring calcium, iron, magnesium, zinc etc cofactors in picomole concentration is becoming area of interest to understand the potentials of 'extremely low metal administration' to trigger the battery of intracellular and physiological milieu due to less known or unknown proteins and protein regulatory factors. The protein and metal cofactor interaction in biomolecules is extremely important and its picomolar range needs new technical development. We focus on role of sodium in neurofilament proteins, calcium in actin-myosin proteins and microtubule proteins. However, ultra small concentration of ions is less likely to trigger at molecular conformation level but more likely triggers thermodynamics and energy activation by increasing enthalpy and entropy.

1.1 Picodevices

In biochemical analysis and physical analysis, electrothermal atomic absorption spectrophotometry (EAAS) was studied using a Perkin-Elmer-Zeeman 3030 spectrophotometer is routine technique [1]. Other example is thyroid hormones measurement by ELISA or chemiluminescence to measure the TSH, T3 (9-26 picomoles/L) and T4 (0.60-1.5 picomoles/L). The art of measuring picomolar concentrations of nucleotide phosphates or energy molecules is age old [2]. In the electronics field, picodevices such as picomole concentration of Cl^- by picoelectrometeric titration, sodium ion monitoring device of quadrupole electron impact

mass spectrometry, picobio-inspired environmental biosensors have made advancement.

A biosensor named “Picoscope” was developed for real-time simultaneous detection of several biological agents by measuring picometer-range changes of the thickness of different biorecognition spots on the biochip surface. The Picoscope technology seems significantly increase the power of research instruments for bio-, nano- and pico-technologies.

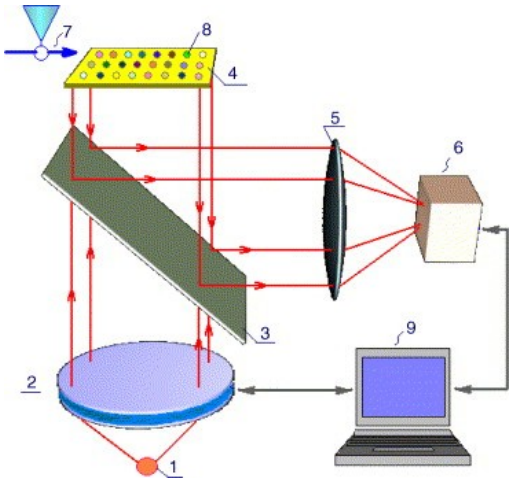

Fig. 1. Scheme of the Picoscope: 1, superluminescent laser diode; 2, scanned Fabry–Perot interferometer; 3, semi-transparent mirror; 4, glass slip; 5, optics; 6, CCD camera; 7, fluidic system; 8, recognition spots or wells; 9, computer.Source:NSTI2008Proc.Vol2p539-542.

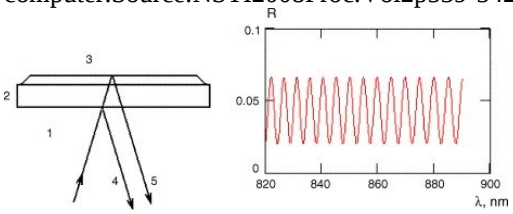

Fig. 2. (a) Scheme of the interference pattern formation: 1, air; 2, glass slip with a biomolecular layer; 3, biological solution; 4 and 5, reflected beams. (b) Reflection spectrum of a glass slip of 50 μm thick.

1.2 Pico-biochip

The Picoscope used immobilization of one antibody on the biochip surface via the biotin–streptavidin bridge. *Bacteria* by the Picoscope can be sensed by biotinilated glass slip: streptavidin, first biotinilated antibody against *bacteria*, and antigen in the form of cell suspension at the concentration of 10^7 cells/ml. The change of the antigen layer thickness averaged over the sensor's surface can be detectable. The picochip technology has tremendous advantage in picoparticles based on antibody-biotin-streptavidin-metal compounds to generate bio-response [2].

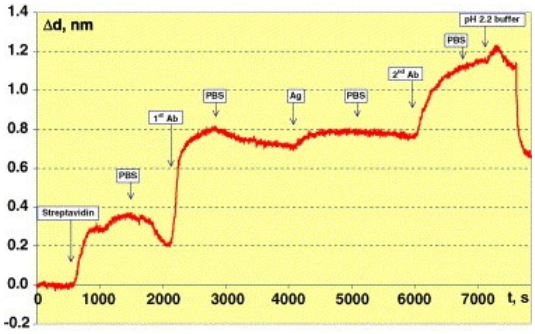

Fig. 4. Sensogram of detection of *L. monocytogenes* at concentration 10^7 cell/ml. Source:NSTI2008Proc.Vol2p539-42.

To increase the sensor's response depends on the surface density of the immobilized antibody was varied by changing the density of the biotin molecules during the biochip preparation stage and streptavidin concentration to optimize capturing the remaining cells and soluble proteins.

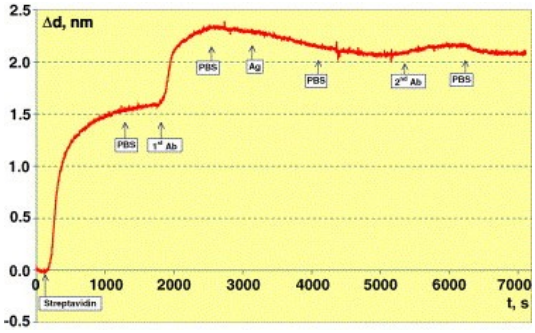

Fig. 5. Sensogram of detection of *L. monocytogenes* at concentration 10^4 cell/ml by second antibody. NSTI2008Proc.Vol2p539-542.

Surface plasmon resonance (SPR) “BIAcore 2000” and Picoscope can be useful for biosensors based on fluorescent labels. Other

attractive applications of the Picoscope based on CCD camera and multi-spot biochip are high throughput screening and multi-agent analysis of liquids, e.g. for food pathogen detection.The picochip production is in progress based on immobilization of antibodies and the biotin–streptavidin bridge such as measuring binding kinetics using the two-channel Picoscope.

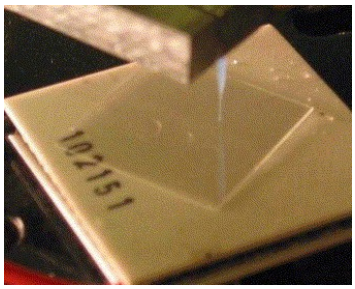

Fig. 7. Experimental setup for multi spot biochip preparation. NSTI2008Proc.Vol2p539-542.

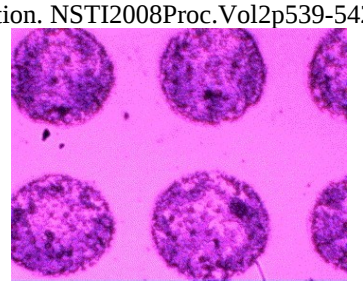

Fig. 8. Image with visualized spots of antibody on the biochip. NSTI2008Proc.Vol2p539-542.

An image of several antibody spots of 280 μm in diameter visualized by Picoscope is shown in Fig. 8. For the visualization, the sandwich assay was realized on a biochip similar to that used for *L. monocytogenes* detection. The size, shape and position of the antibody spots had the required regularity for multi-agent analysis by the Picoscope[2].

2 PICOSCOPE AS OSCILLOSCOPES

Designed specifically for the complex task of analysing high-speed electrical signals, PicoScope 9000 Sampling Oscilloscopes are ideal for many advanced applications including: signal analysis, timing analysis, testing and design of high-speed digital communication systems, network analysis, semiconductor testing, and research and development.

2.1 PICOSCOPE AS DATA LOGGER

A data logger is an electronic device that is used to record measurements over time. Pico data loggers require no power supply and simply plug into a parallel, serial or USB port on your PC.

By connecting suitable sensors, Pico data acquisition products can be used to measure temperature, pressure, relative humidity, light, resistance, current, power, speed, vibration... in fact, anything that you need to measure.

Pico data loggers are supplied complete with PicoLog — this powerful but flexible data acquisition software allows you to collect, analyze and display data. With PicoLog the data is viewable both during and after data collection, in both spreadsheet and graphical format. You can also export the data for use in other applications.

Why picoscopes are better measurement instruments?

- The low-cost, educational DrDAQ data logger is used throughout the world by both educational institutions and individuals alike
- For measuring temperature and humidity loggers such as the TC-08 thermocouple data logger and RH-02 temperature and humidity data logger offer an accurate solution to your measurement needs
- The pH Measuring Kit features Automatic Temperature Compensation, and allows you to accurately measure and record the acidity or alkalinity of a solution
- Ideal for use over large areas, the widely used EnviroMon data logging and alarm system is a network based system capable of automatically measuring and recording readings from up to forty sensors, and providing warnings when readings go out of range

2.2 PICOSCOPE IN AUTOMOTIVE DIAGNOSTICS

Pico Automotive Diagnostics Kits turn your PC into a powerful automotive diagnostic tool**.** Suitable for use with any modern vehicle, and available in both 2 and 4 channel versions, the multi-award-winning Automotive Diagnostics Kits can be used to measure and test virtually all

the electrical and electronic components and circuits in a modern vehicle.

Figure 2: Picoscope as automotice diagnostic device. Source: NSTI2008 Proc.Vol2p539-542.

2.3 Picoscope in environment monitoring

EnviroMon is a complete data logging system. It automatically measures and records temperature, humidity and other parameters and provides warnings when readings go out of range. EnviroMon is both flexible and economical: you can start off just recording a single temperature and expand to monitor up to 40 sensors spread around a site.

Figure 3: A Picosoftware records environment climate conditions.
Source: NSTI2008Proc.Vol2p539-542.

EnviroMon works on a network so that sensors can be placed 100s of metres apart. Measurements from the network can be read off the display on the logger, sent to a printer, downloaded to a PC or even displayed live on a website. Using a modem (radio, telephone or GSM) the loggers can be monitored remotely.

The system offers these important benefits:

- It carries out routine measurements automatically, leaving staff to get on with their job
- It sounds an alarm when there is a problem: if there is no alarm, no action is required
- It maintains a permanent record of measurements, so that you can prove compliance with appropriate legislation
- It provides timely warnings of equipment failure, minimising the risk of spoiled stock
- It is easy to install and use

2.4 Picoscope as temperature and humidity data logger

The Pico range of temperature and humidity data loggers offer a simple, accurate and cost-effective way to monitor and record temperature and humidity on your PC.

Figure 4: Picoscope in environment data logging
Source: NSTI, 2008 Proc.Vol2p539-542.

2.5 EnviroMon® data logging system

EnviroMon is an extremely versatile, expandable data logging and alarm system. It is ideal for real time monitoring of a wide range of parameters

such as temperature, humidity, pressure, and energy usage over large areas.

2.6 Humidi Probe®

The HumidiProbe® is a temperature and humidity data logger. The HumidiProbe® contains the sensors and data logger all in one compact probe— simply plug the unit into a USB port and accurate measurements can be taken fast and efficiently. The HumidiProbe is a self-contained humidity and temperature measuring data logger. Simply position the HumidiProbe near the source you want to measure, plug the cable into the USB port on your PC, and you're ready to measure humidity and temperature.

Monitoring temperature and humidity is very important: temperature and humidity play an important part in health, comfort and productivity. Extreme temperatures can also cause electronic equipment to age faster and mechanical equipment to breakdown. If humidity is too high it can lead to corrosion of equipment, mould growth — even printers jamming; if the humidity is too low it can lead to problems with static electricity and dehydration problems with everything from wine making to wood storage.

2.6.1 Versatile and expandable

The HumidiProbe's compact, all-in-one design allows it to be used in various locations and in a wide range of applications. Up to 4 HumidiProbes can be connected to one PC allowing you to accurately monitor the temperature and humidity in multiple locations at once, and at a low cost.

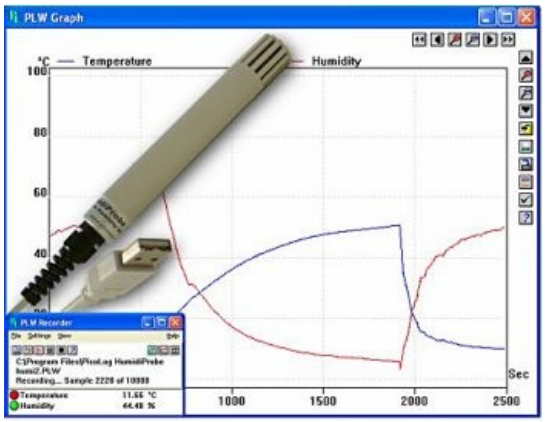

Figure 5: Picoscope in humidity and temperature monitoring.
Source:NSTI2008Proc.V.2p539-42.

2.6.2 Easy to use software

The easy to use PicoLog data acquisition software is supplied with the HumidiProbe® — this powerful, yet flexible, data acquisition software allows you to collect, manipulate, analyse, and display and export data. Software alarms can be configured for both temperature and humidity so as to provide a warning when measurements go out of a specified range. Updates to PicoLog can be downloaded for free from the Pico website.

2.6.3 An accurate and cost effective solution

If you need to measure, and record, temperature and humidity the HumidiProbe provides you with an answer that is compact, simple to use, accurate and cost effective.

3 PICOSCOPE IN MEASURING SAFETY IN ELECTROSURGERY

The electroacupuncture (EA) is used with special reference to the heart, particularly in patients with an implanted pacemaker. The newly developed model 3425 PicoScope[TM] (Pico Technology Ltd), with a four channel differential amplifier input connected to a laptop PC operating in battery mode records the simulating currects. With this recording system, two sets of experiments in which EA can be provided by a Cefar acus4[TM] stimulator. Earlier, the results were confirmed that the placement of a pair of acupuncture surgery needles for EA can be used to predict the paths taken by the stimulating currents, and thus their areas of likely influence. When the needles are placed in closely adjacent acupuncture points in a limb, there is little or no detectable spread of the currents along the limb or into the chest. These applications are extremely useful in cardiothoracic surgery [4].

4 BIOSYSTEMS

4.1 Neurofilaments

The network of neurofilaments is further visible at the subnano range of angstrom A units(100 picometers). It enhances the understanding and visualization of proteins in nerve cells containing neurofilaments. The intermediate filaments include the three neurofilament (NF) proteins (designated NF-L, NFM, and NF-H for light, medium, and heavy, respectively). Neurofilaments appear to be anchored to actin filaments and MTs by neuronal members of the plakin family, α-internexin, IF, nestin also play role.

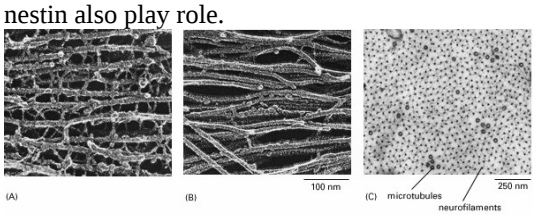

Figure 2. Electron micrographs of two types of intermediate filaments in cells of the nervous system. (A)Freeze-etch image of neurofilaments in a nerve cell axon, showing the extensive cross-linking through protein cross-bridges - an arrangement believed to provide great tensile strength in this long cell process. The cross-links are formed by the long, nonhelical extensions at the carboxyl terminus of the largest neurofilament protein. (B)Freeze-etch image of glial filaments in glial cells illustrating that these filaments are smooth and have few crossbridges. (C) Conventional electron micrograph of a cross-section of an axon showing the regular side-to-side spacing of the neurofilaments, which greatly outnumber the MTs. Source: Skoog et al. 1970 [3]

Overexpression of NF-L or NF-H in transgenic mice indicated the role of neurofilaments in the pathogenesis of motor neuron disease.

4.2 Actin

It is cytoskeletal protein 7 nm in diameter polar structure and form three dimensional networks of actin cytoskeleton.

The actin monomers bind with ATP and hydrolysis play a key role with tubulin to provide dynamic instability, which is very important for their functions. Tropomyosin, binds with actin filaments to act cooperatively in generating the movements of the cell surface, including cytokinesis, phagocytosis, and cell locomotion.

4.3 Microtubules (MTs)

MTs are the polymers play role in cell movements, intracellular transport of organelles, and the separation of chromosomes during mitosis. MTs have a cylindrical form with a diameter 25 nm. made of tubulins. Dynamic instability due toMT plus end binding proteins, also called “plus end-tracking proteins”, or +TIPs are able to “surf” the dynamic ends of MTs. EB1,EB3, APC,CLASP2,LIS1,CLIP-170, and CLIP 115 and dynactin complex. Thus when +TIPs are expressed as GFP-fusions, fluorescence is brightest at the growing tip of the MT and trails off in intensity toward the minus-end of the MT, thus forming a “comet tail.”

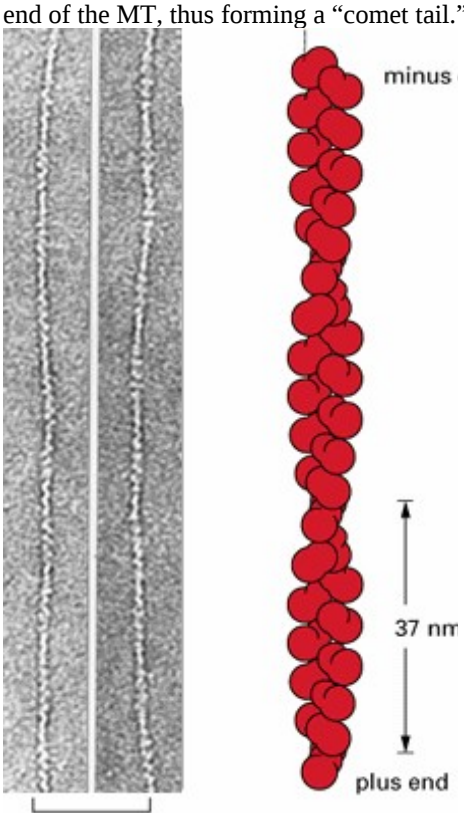

Figure 3. Actin filaments. (A) Electron micrographs of negatively stained actin filaments. (B) The helical arrangement of actin molecules in an actin filament. Source:NSTI2008 Proc., V2, p539-542.

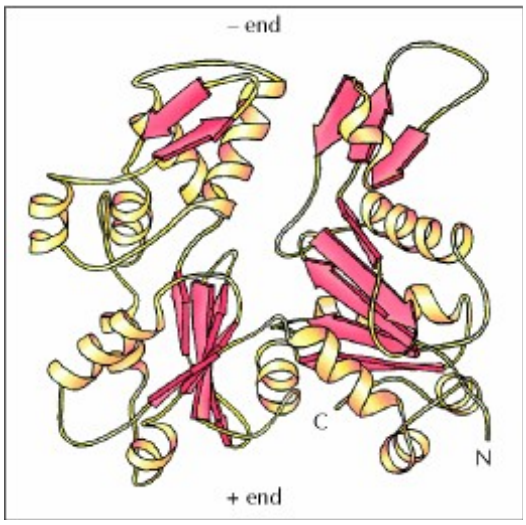

Figure 4. Assembly and structure of actin filaments (A) Actin monomers (G actin) polymerize to form actin filaments (F actin). The first step is the formation of dimers and trimers, which then grow by the addition of monomers to both ends. (B) Structure of an actin monomer.
Source: NSTI2008 Proc.V2,p539-542.

This specific association of +TIPs with MT distal ends was initially explained by treadmilling. Other factor is "delivery (or deposition) of Kinesin" driven. MTs depolymerise and GFP-TIP speculate dynamic behaviour of MTs. However, MT behaviour using specific GFP-tagged MT plus end binding proteins as markers has become very popular. Visualization of GFP-TIPs in cells by time-lapse fluorescence microscopy revealed that all fusion proteins move in a comet-like pattern and demonstrated that, at least in CHO cells, most MTs grow persistently from the cell centre towards the cell periphery [3].

4.5 Functions of +TIPs

Several categories of +TIPs, EBs, CLIPs, CLASPs regulate MT behaviour as rescue factors at the MT tip. CLASPs interact with the CLIPs. The EBs modulate the dynamic instability of MTs. The +TIPs can link the MT cytoskeleton such as CLIP-associating proteins (CLASPs), cytoplasmic dynein/dynactin complex. The first +TIP found (CLIP-170) targets dynein and dynactin to the MT ends and links dynein to MTs. MTs specifically at the leading edge of migrating cells show glycogen synthase kinase-3β (GSK-3β) inhibition to cause asymmetric distribution of CLASPs.

5 CONCLUSION

The concept of pico scale of measurement in physics, environment, biology and chemistry is highlighted with examples of metal ions, climatic conditions, and bioassemblies. The integrated monitoring using picoscope and monitoring oscilloscope for use in proteins linked with metals in supramolecular macromolecules is described with potentials of picomolar science. The temperature, humidity and electricity and their regulatory factors play a significant role in biomedical, automotive actions of biomolecules in the environment. The proteins and their regulatory metal cofactors play a significant role in structural-functional actions of biomolecules in the body. Picodevices have paved the way to determine minute amounts of metabolites, hormones, nucleotides. Picochips and pico-inspired biological applications remain further attraction in future. Overall picotechnology remains to see as most powerful computation device in data simulation in physical, biological, engineering and environmental applications.

REFERENCES

[1].Shalmi, M., Kibble, J. D., Day, J. P., Christensen, P. & Atherton, J. C. American Journal of Physiology 267, F695—701,1994..
[2].Nitkin PI, Gorshkov BG, Nitkin EP, Ksnevich TI. Sensors and Actuators B: Chemical

111-112, 11;500-504,2005.
[3].Skoog L. Eur J Biochem. 17:202-2-8, 1970.
[4] Thompson JW, Cummings M. Acupuncture in Medicine. 09 Mar, 2009