CONGRESO INTERNACIONAL DE NANOTECNOLOGIA

NANOTEC 2005

A INCORPORAÇAO DA NANOTECNOLOGIA NOS PROCESSOS DE FIAÇAO DE FIBRAS NATURAIS,ARTIFICIAIS E SINTÉTICAS

INCORPORATION OF NANOTECHNOLOGY IN SPINNING OF NATURAL, ARTIFICIAL AND SYNTHETIC FIBRES

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INTRODUCTION

Nanotechnology is the science and technology at the atomic and molecular level. It opens the opportunity for a new range of materials.

Nanotechnology is predicted to be the technology of the 21st century.

Nanotechnology is not an industry in itself. It is a series of enabling technologies that can improve end-products and services in many mainstream industries.

Nanotechnologies and nanosciences represent a new multi-disciplinary and interactive approach to material science and engineering.

Textile industry needs new fibres with special functionalities. Fibre based product design for performance should be the future of nano-fibre and nanostructures.

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The word “Nano” comes from the Greek word “Nanos” meaning dwarf.

This prefix is used in metric system to mean one billionth. A nanometer (nm) is thus one billionth of a meter.

A nanometer is so small that if one meter were extended from New York to Los Angeles, each nanometer would still only be the size of an aspirin.

Albert Franks defined nanotechnology as that area of science and technology where dimensions and tolerances in the range of 0.1 nm to 100 nm play a critical role.

The creation of modern information technology was made possible by systematically reducing the size of devices on a chip, thereby increasing the processing ability of a single chip.

It is essential to study nanofibre phenomena offering new options that in the long term can lead to many industrial applications.

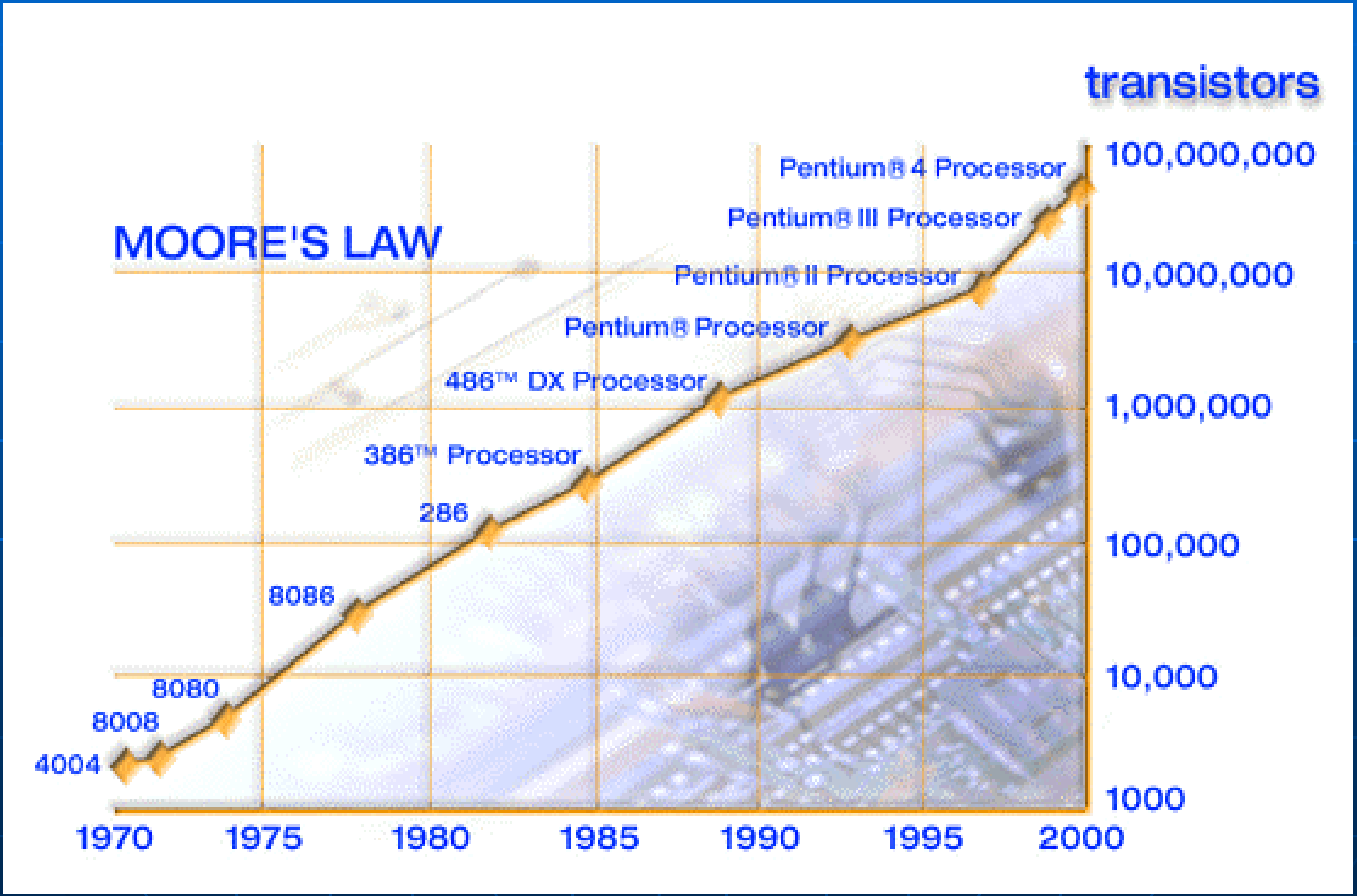
“Moore´s Law”

Gordon Moore made his famous observation in 1965 just four years after the first planar integrated circuit was discovered.

The press called it “Moore´s Law” and the name has ever since struck.

Moore observed an exponential growth in the number of transistors per integrated circuit and predicted that this trend would continue.

MOORE'S LAW



transistors
MOORE'S LAW
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10,000,000
1,000,000
100,000
10,000
1000
Pentium® 4 Processor
Pentium® III Processor
Pentium® II Processor
Pentium® Processor
486™ DX Processor
386™ Processor
286
8086
8080
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4004
1970
1975
1980
1985
1990
1995
2000

UPDATE ON NANOTECHNOLOGY IN TEXTILES

First innovations in textiles will come in fibre manufacture. Textile manufacturing process will become short and a completely new concept of clothing will emerge.

In prehistoric times humans wore clothes to protect themselves against adverse climatic conditions; today we wear clothes for fashion. In future we will wear clothes to obtain health and personal benefits.

The incorporation of nano-particles and nano-capsules in textiles opens an entirely new field.

Singled walled carbon nanotubes (SWCNT) are finding new applications to improve conventional based fibres.

Future research fields are: Electro-spinning; conductive and thermal fibres; anti-bacterial, anti-odour, anti-stain, anti-radiation fibres; Wrinkle resistant, oil and water repellence; UV protection; moisture management character; filters for aerosol particles; healthy bed clothing etc.

BRIEF HISTORY OF FIBRE SPINNING

Wet Spinning: The oldest method of spinning a fibre.

Melt Spinning: The simplest method of obtaining a fibre.

Melt Blowing: Heated air jets are used to attenuate molten polymer streams into fibres.

Dry Spinning: A chemical solution mixed with a solvent, is forced through a spinneret into warm air.

Molecular spinneret: A revolutionary development in fibre spinning is yet to come. This invention will reduce the actual giant plants to the size of one room together with a substantial reduction in energy consumption and manufacturing costs.

Electros-pinning: In 1934 Formhals patented a process wherein electrostatic force was used for the production of polymer filaments. When used to spin fibres, the process is known as electro-spinning.

Co-electro-spinning: Carbon nanotubes can be mixed with conductive and nonconductive polymers to form spinning dopes for co-electro-spinning. With high level of electrical conductivity and mechanical properties, the nano-composite fibrile concept can be exploited.

Coagulation spinning technique: US Patent 6 682 677 describes a coagulation spinning technique that can produce fibres, ribbons and yarns of carbon nanotubes. The technique eliminates any core-sheath effects due to carbonaceous contaminants, eradicates dimensional instabilities and results in improved mechanical properties.

THE ELECTRO-SPINNING PROCESS

Conventional fibre spinning techniques use mechanical forces to produce fibres by extruding polymer fluids and subsequent drawing of the resultant filaments.

The electro-spinning processes uses ecetrostatic forces to drive fibre formation.

This process produces fibres having nanoscale diameters ranging between 1 to 5 nm.

The process is very versatile: a wide range of polymer liquids can be spun using only small amounts of polymer.

First investigations focused on the structure and morphology of electro-spun fibres.

A quantitative process understanding is a must to benefit from the full potential of these new wonder fibres.

WHAT IS ELECTRO-SPINNING?

A high voltage is used to create an electrically charged jet of polymer solution or melt.

One electrode is placed into the spinning solution and the other is attached to the collecting surface.

Electric field is subjected to the end of a capillary tube that contains the polymer fluid.

On increasing the intensity of the electric field, the hemispherical surface of the fluid at the tip of the capillary tube elongates to form a conical shape known as the Taylor cone.

A critical value is attained when the repulsive electrostatic force overcomes the surface tension and a charged jet of fluid is ejected to from the tip of the Taylor cone.

The discharge polymer solution jet undergoes a whipping process. Charged polymer fibres randomly laid are collected on a grounded metal screen.

A metering pump is needed to generate a constant pressure and flow of the fluid.

SCHEMATIC DIAGRAM OF ELECTROSPINNING PROCESS

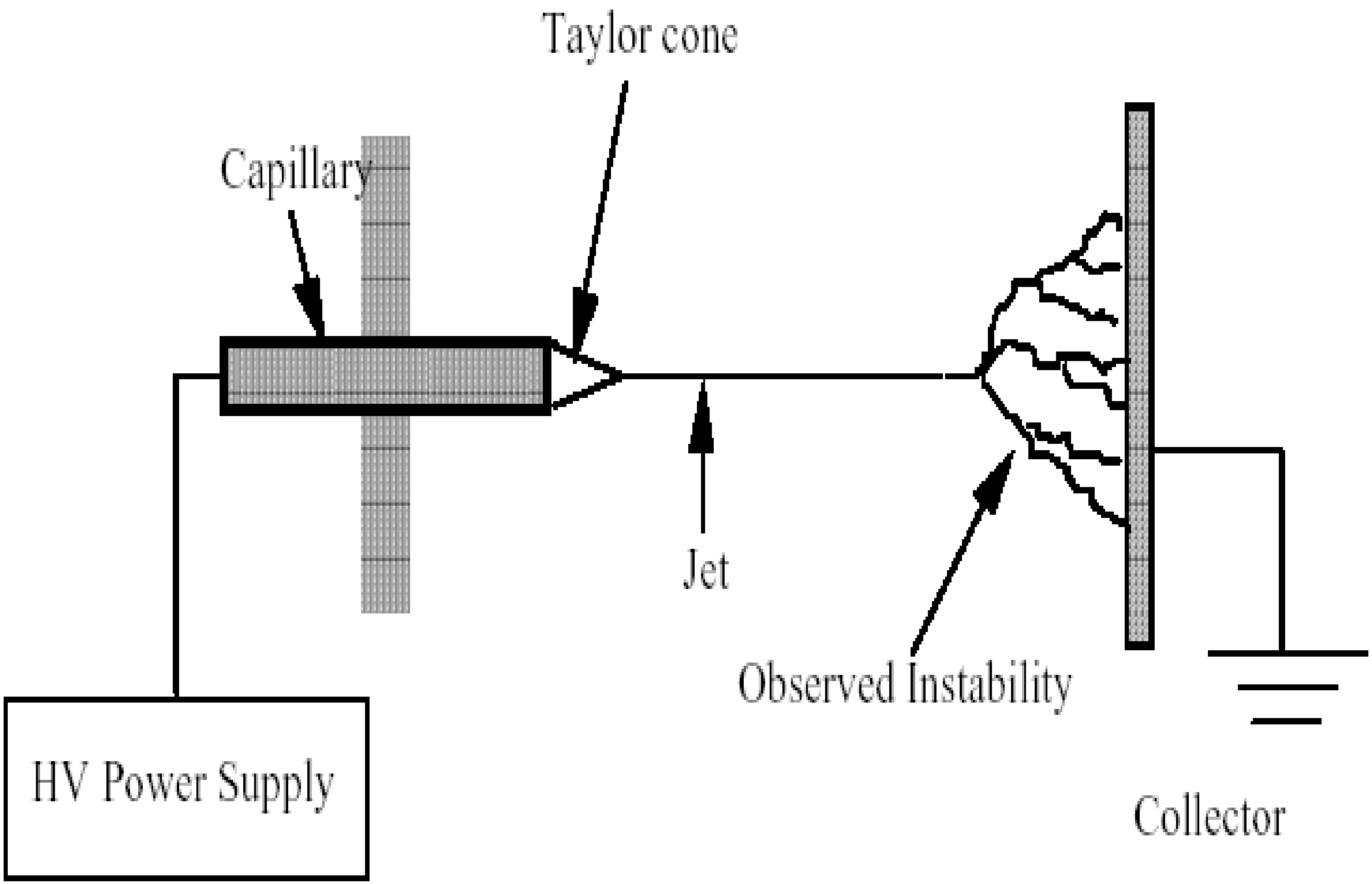
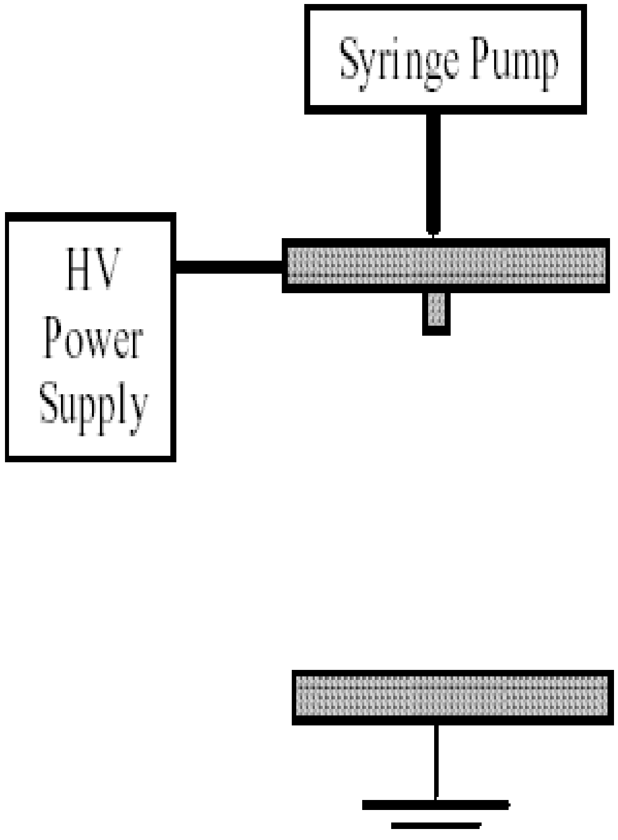


Figure 1 Prototypical electrospinner (point-plate configuration)

SCHEMATIC DIAGRAM OF ELECTROSPINNING PROCESS



gure 2 Electrostatic fiber spinner with parallel-plate geometry.

SCHEMATIC DIAGRAM OF ELECTROSPINNING PROCESS

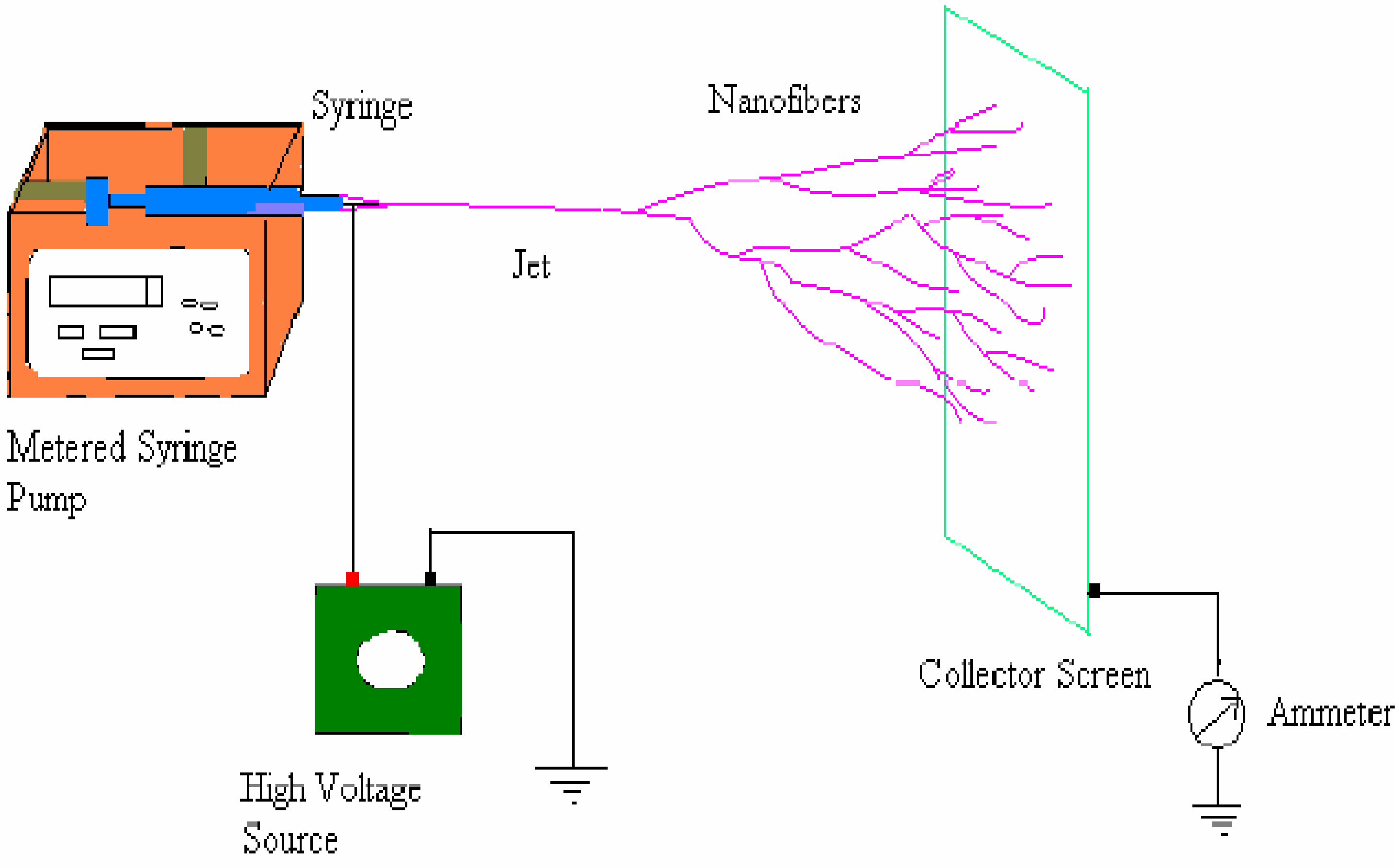


Figure 1 **Schematic of Electrospinning Process**

SCHEMATIC DIAGRAM OF ELECTROSPINNING PROCESS

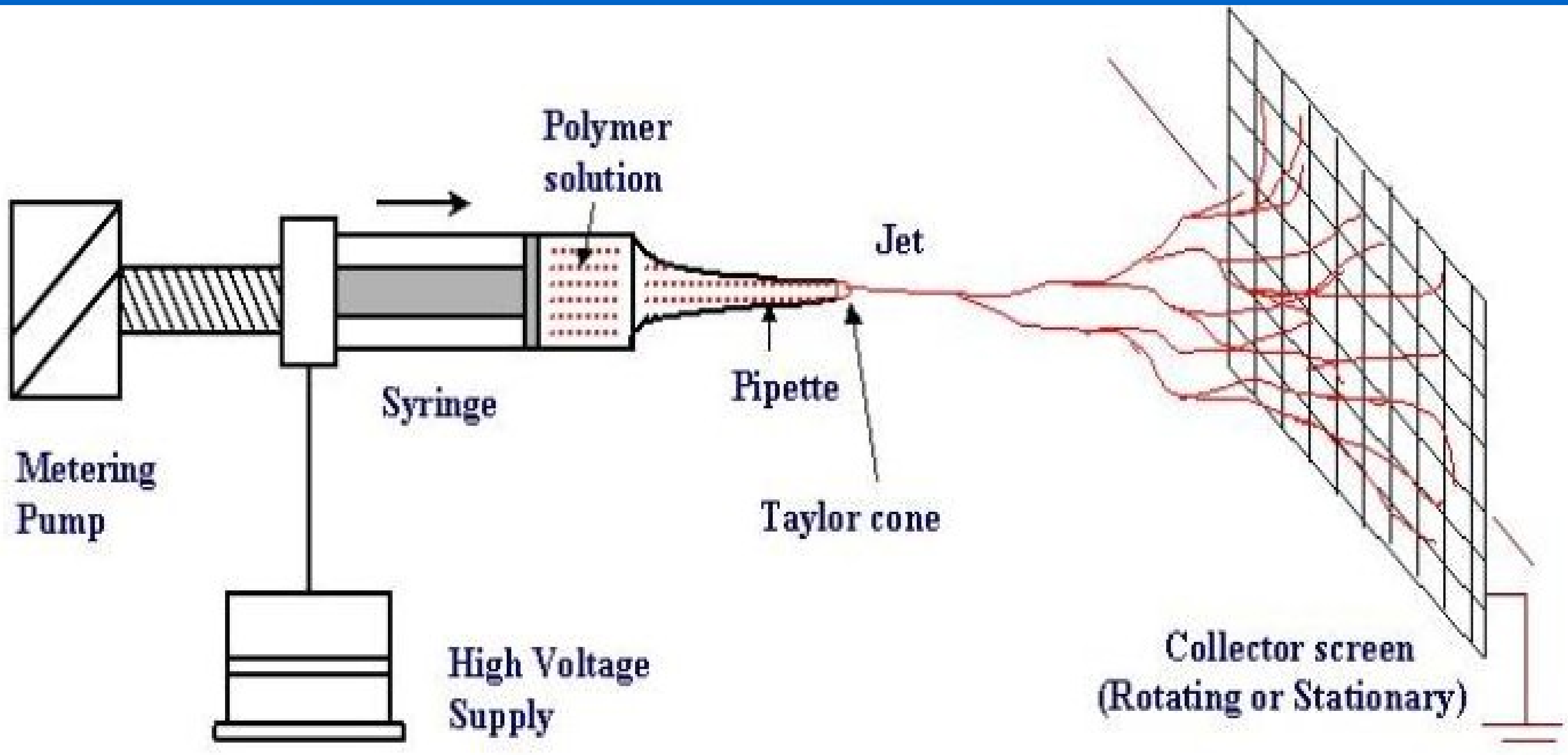
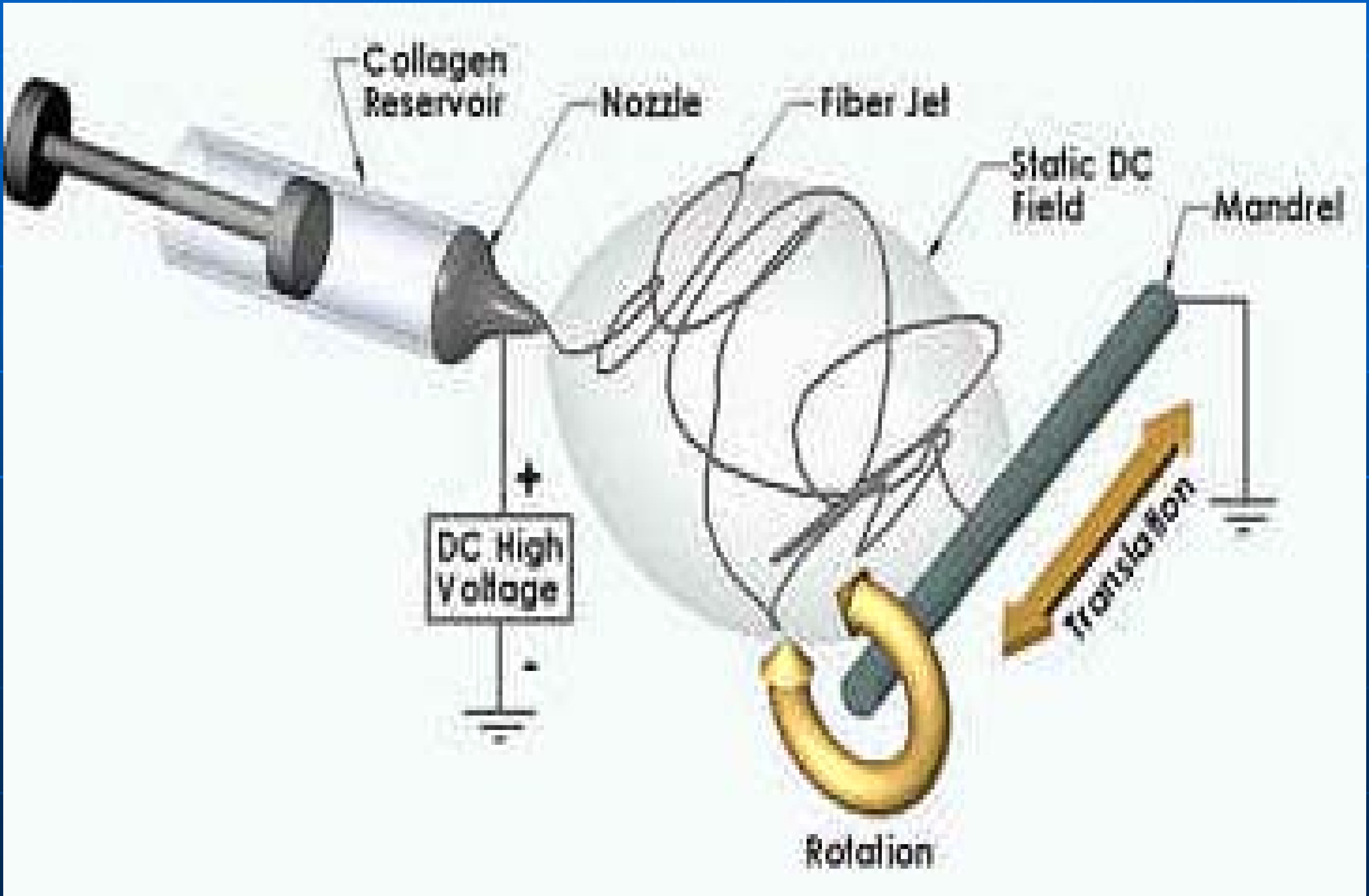


Figure 1. Schematic of the Electrospinning setup.

SCHEMATIC DIAGRAM OF ELECTROSPINNING PROCESS



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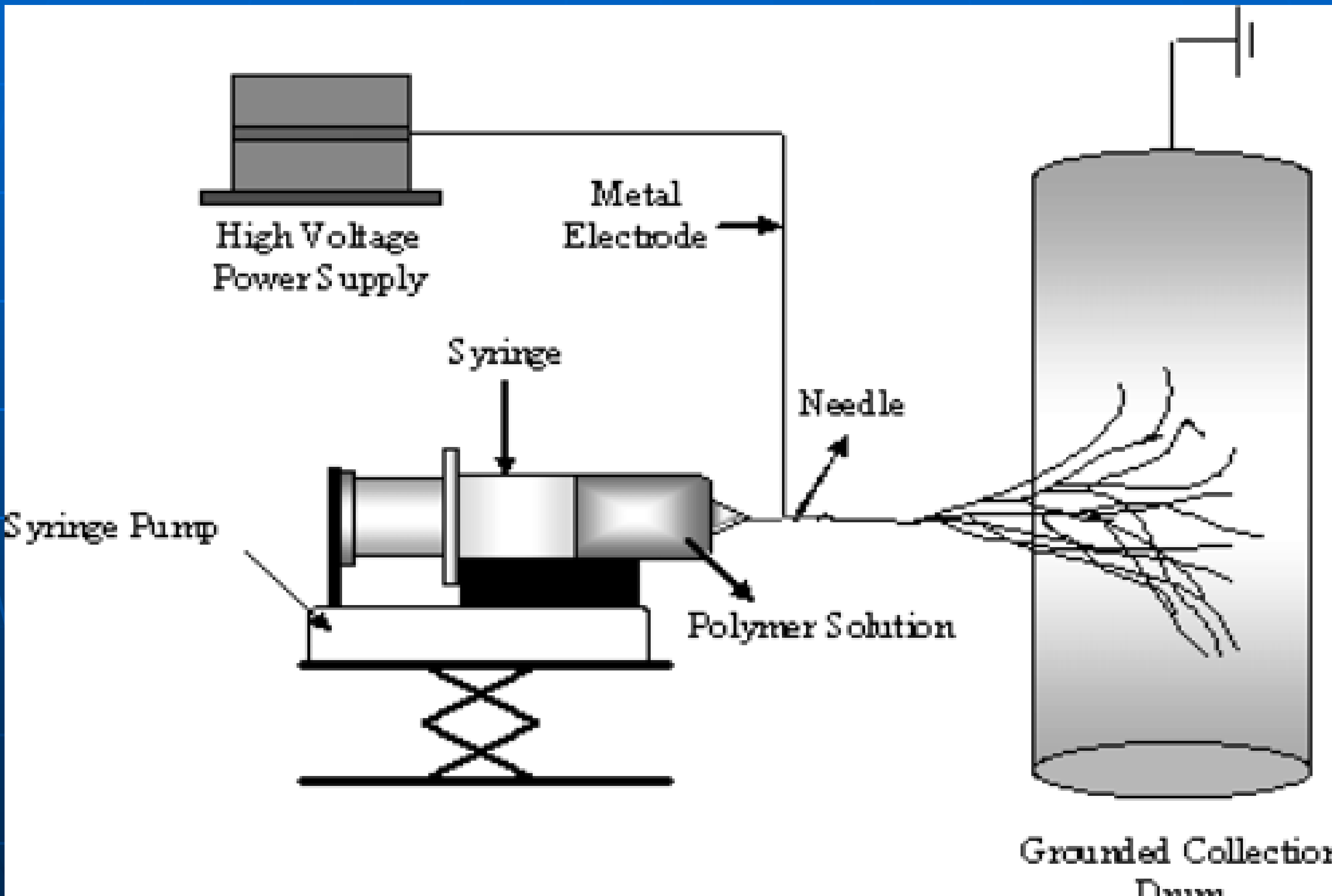

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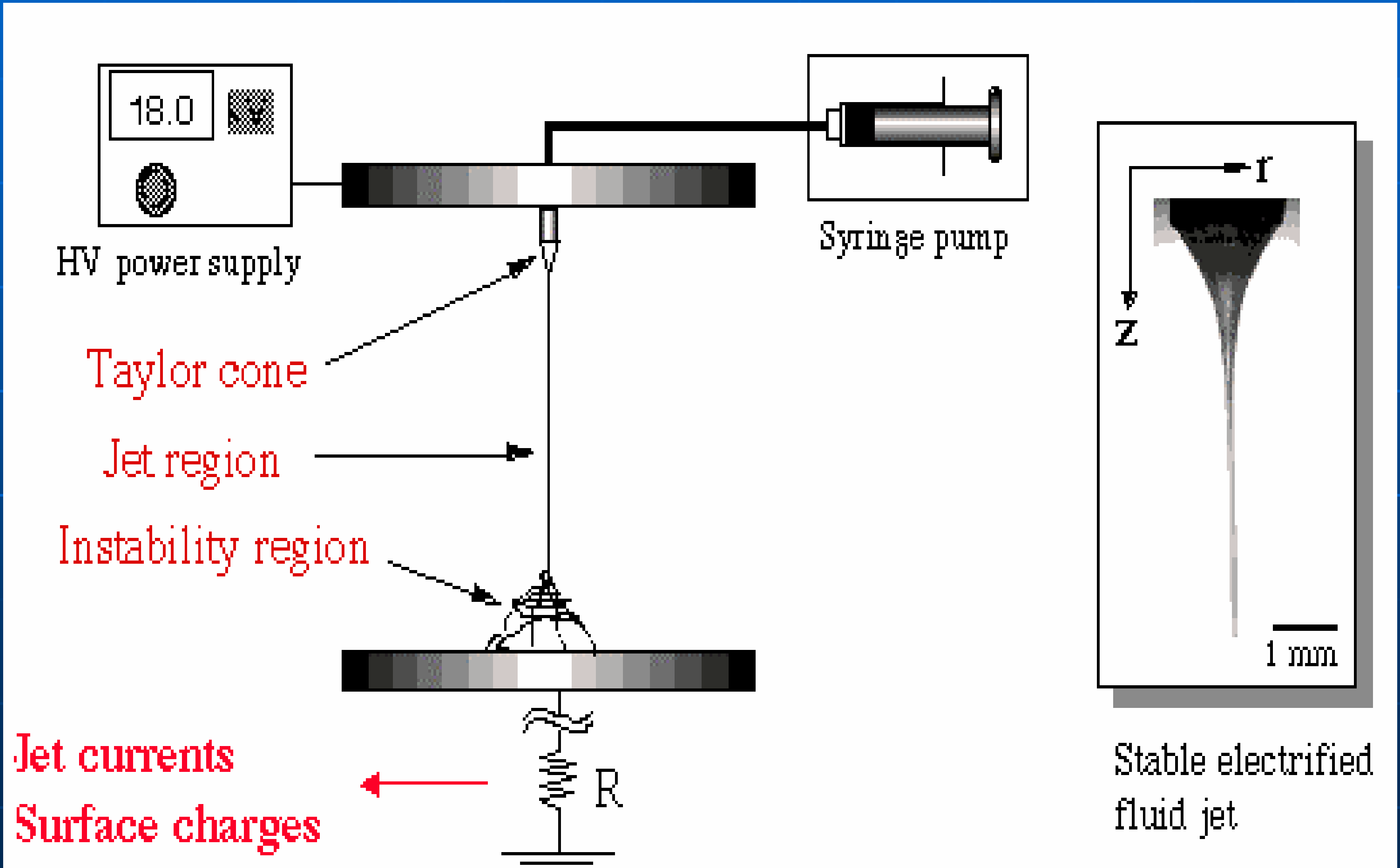

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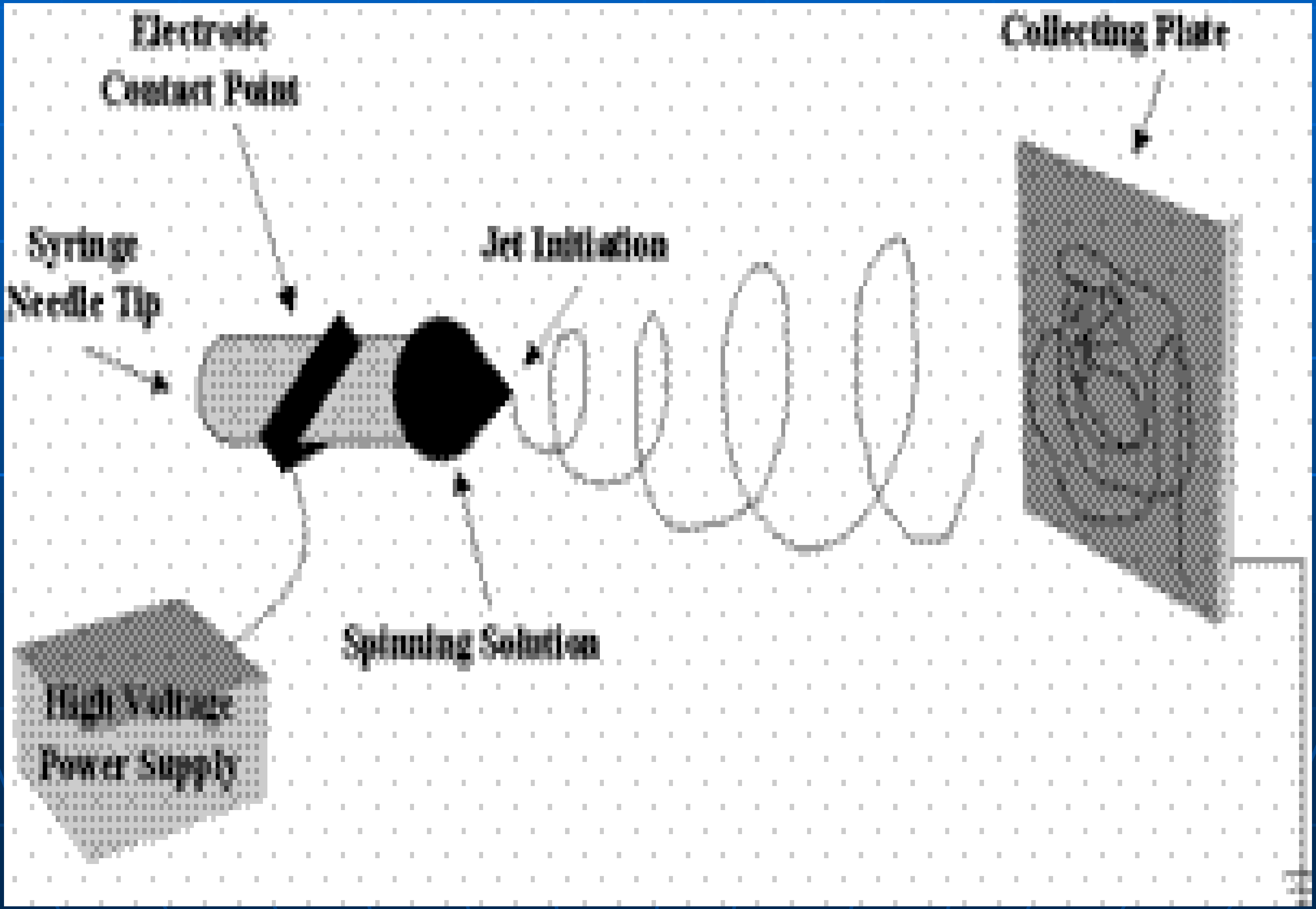


ELECTRO-SPINNING PROCESS VARIABLES

Process variables can be divided into two groups:

System parameters:

- Molecular weight of the polymer and its distribution.
- Polymer viscosity, conductivity and surface tension.

Process parameters:

- electrical potential
- flow rate and concentration
- distance between the capillary and collecting screen.
- motion of the target screen

Ambient parameters:

- temperature, humidity and air velocity

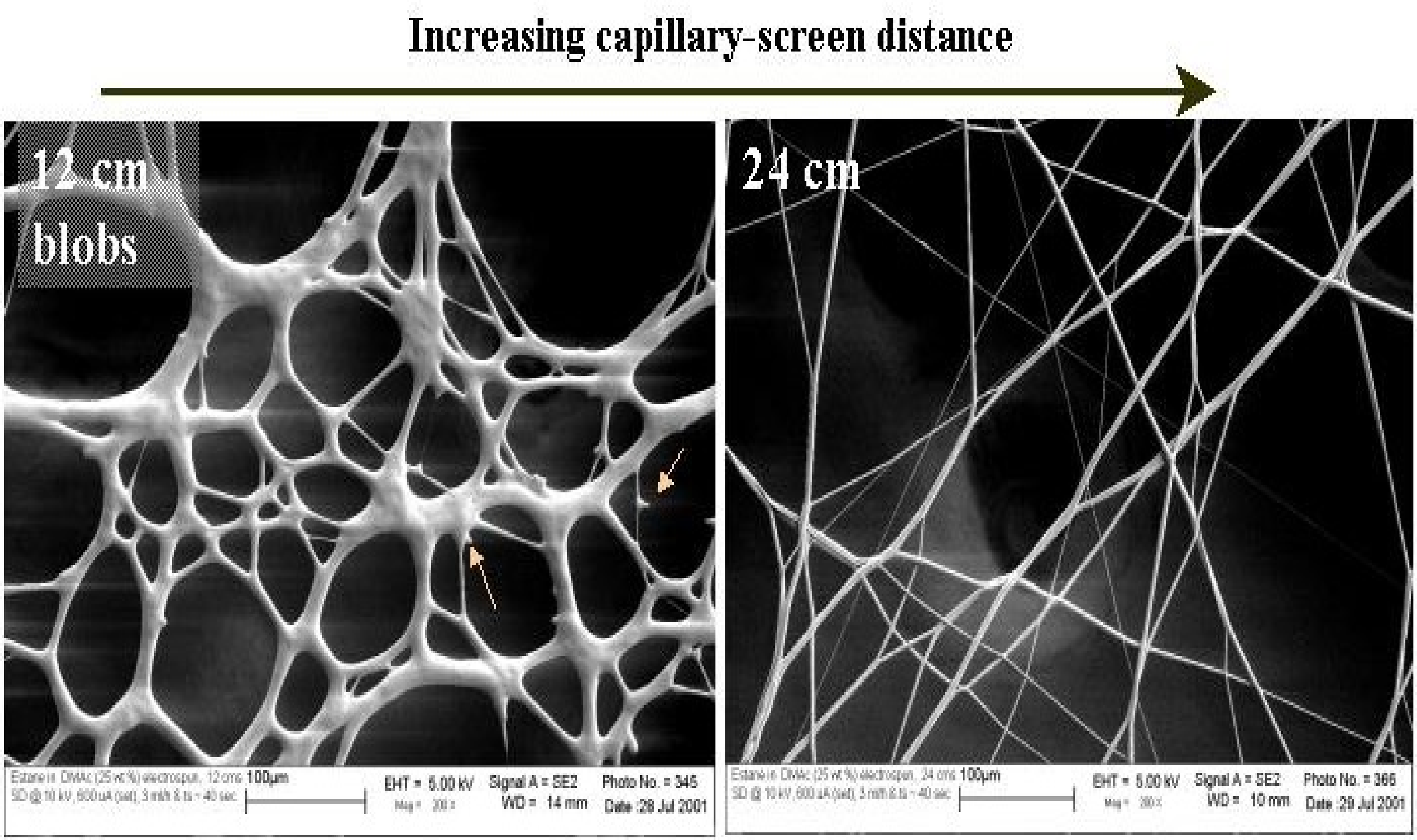


Figure 4. Effect of increasing capillary-screen distance on 25-wt % Estane® 5750 electrospun at 10 kV & 3ml/h. The Average diameter range is 5 μm – 905 nm. A broad distribution of fiber diameters was obtained.

Source: http://www.che.vt.edu/wilkes/electrospinning

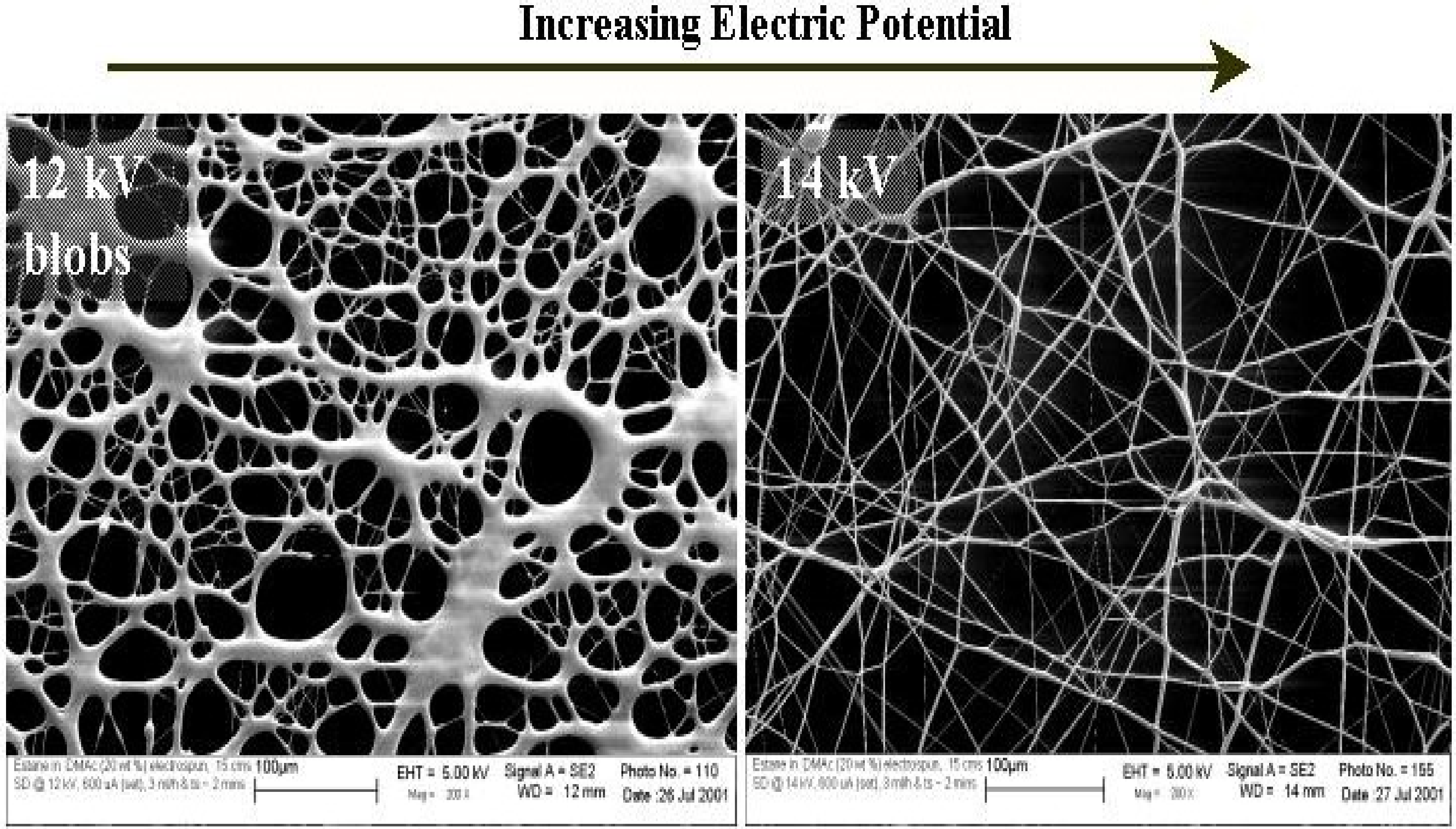


Figure 5. Effect of increasing electric potential on 20-wt % Estane® 5750 electrospun at 3ml/h & 15 cm capillary-screen distance. Fiber diameter decreases with increasing voltage

Source:http://www.che.vt.edu.Wilkes/electrospinning

POLYMER SOLUTIONS FOR ELECTRO-SPINNING

VARIOUS POLYMER SOLUTIONS WERE USED BY DIFFERENT RESEARCHERS

Dissolving cellulose cotton and biodegradable renewable in an adequate solvent.

Kit and Jagannathan, university of Tennessee, developed a polymer blend to electro-spin nylon and polyethylene terepthalate.

Fujihara used two different polycaprolactone (PCL) solutions with a mixture solvent of chloroform and methanol to spin nanofibre.

Heidi Schrender and Gibson applied voltages between 5 and 30 kV to overcome surface tension forces. Fibres were collected as an interconnected web of small filaments.

Timothy Grafe and Kristine Graham used electro spinning process for making nanofibre and nonwoven nanofibre webs from synthetic fibre forming polymer.

Incorporation of electro-spun nanofibre into functional structures was studied by Kristine Graham et al. They came to the conclusion that Aerosol barrier permeability modelling and testing confirmed advantages of nanofibre.

Dan Li and Younan Xia, University of Washington, have demonstrated that long, hollow nanofibre having circular cross-sections can be directly manufactured by electro-spinning two immiscible liquids through a coaxial, two capillary spinneret. These hollow nanofibre could be obtained as uniaxialy aligned arrays, having lengths up to several centimeters by modifying the collector.

Polycarbonate nanofibre were produced by electro-spinning by Kattamuri and Sung of the University of Massachusetts. They used the following optimum conditions: 16% 0f polycarbonate flowing at 0.01m/minvith a voltage of 30kV, distance of 25 cm, temperature 28°C and ambient humidity 32%.

Composite materials made from reinforcements having nanofibre provide superior structural properties. Potential applications of nanofibre are:

Applications in Life Science

Tissue Engineering Scaffolding

Filter media and textile technology

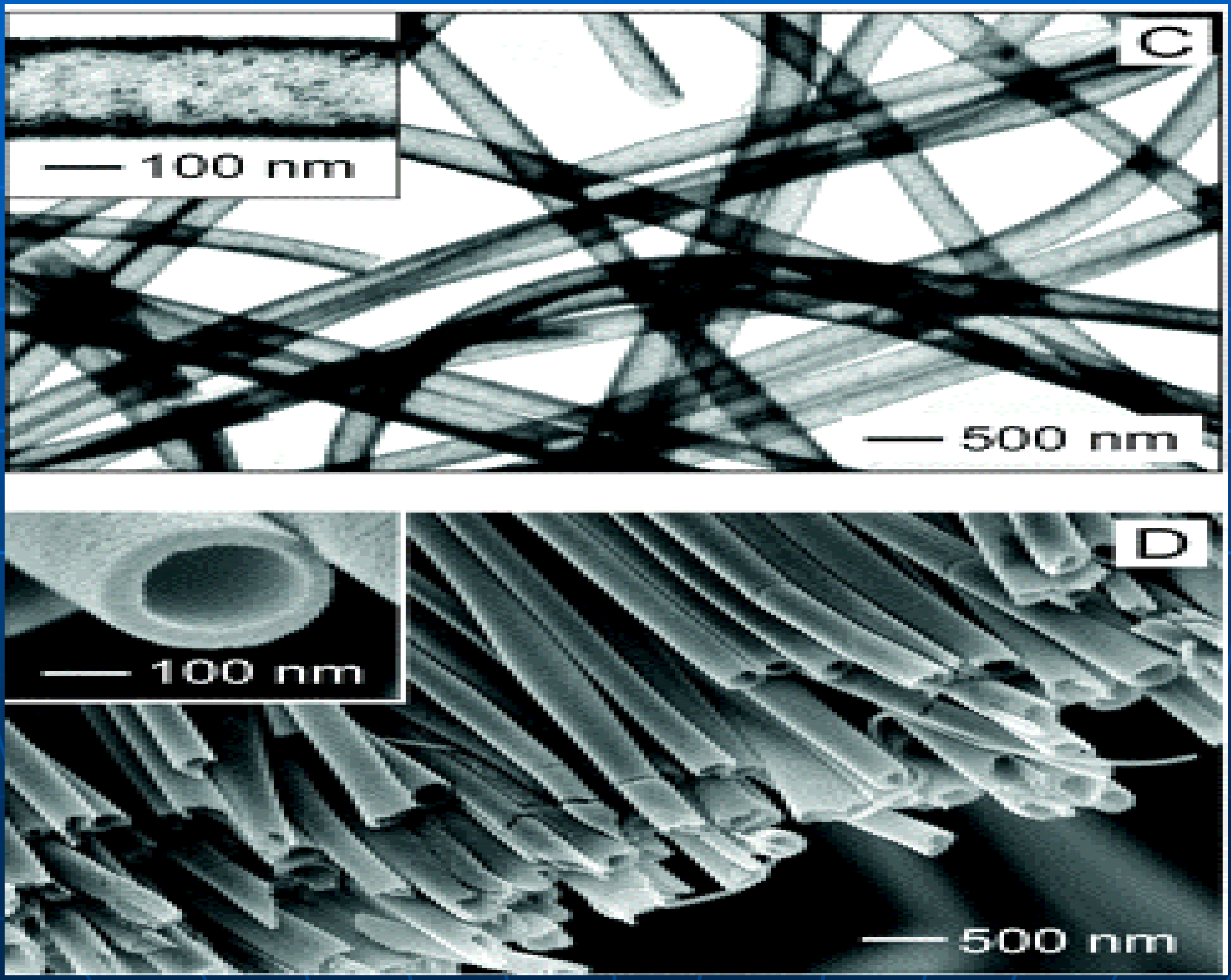
Cosmetic skin

Military protective clothing

Nano sensors

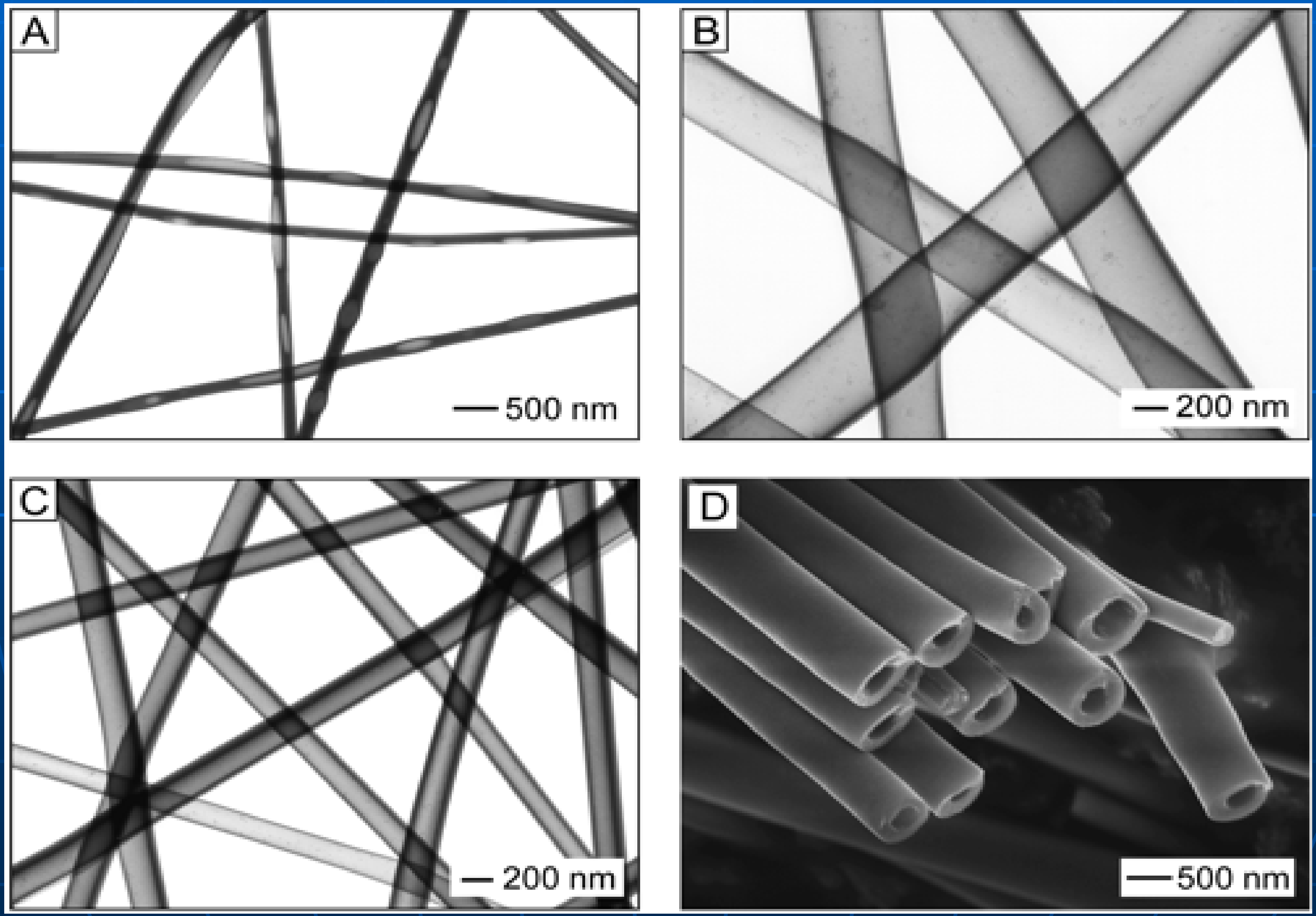
Fabrication of composite hollow nanofibre by electro-spinning

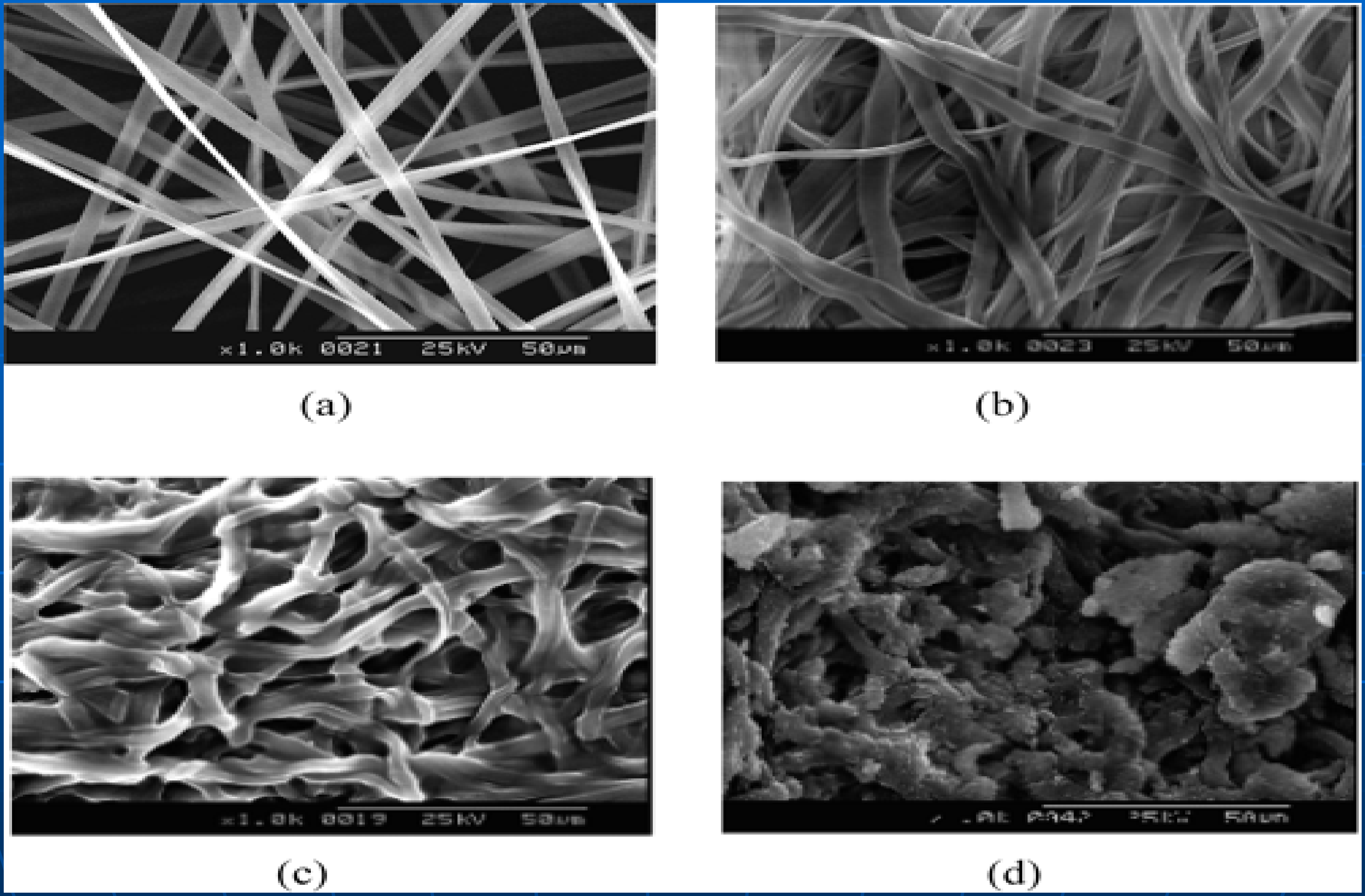
source: Dan Li and Younan Xia. Univ. Of Washington



Fabrication of composite hollow nanofibre by electro-spinning

source: Dan Li and Younan; univ. Of Washington





TEM images of TiO2/pvp hollow fibres manufactured by electro-spinning varying injection rate and voltages. Source:Dan Li and Younan Xia.Univ. Of Washington, Seattle

CARBON NANOTUBES PROPERTIES

Carbon nanotube is very unique as it has extraordinary mechanical properties:

CNT is a tubular form of carbon having diameter as small as 1 nm. Its length varies from few nm to microns.

CNT is configurationally equivalent to a two dimensional grapheme sheet rolled into a tube.

CNT has extraordinary mechanical properties:

-Young´s modulus over 1 Tera Pascal, as stiff as diamond and tensile strength more than 200GPa.

CNT can be metallic or semi-conducting, depending on chirality.

Electrical conductivity: six times higher than copper.

Carbon nanotubes are the building blocks of nanotechnology.

Thermal conductivity better than all except pure diamond.

CNT come in varieties of forms: long, short, single walled, multi walled, open, closed, and having different spiral structures.

CNT Manufacture:

Fist step; formation of grapheme sheet material.

Second step: Grapheme sheet are fed in a continuous manner to cutter rollers.

Third step: newly formed edges are joined within the cutter rollers. Two edges are forced toward each other and a tube is formed by a self assembly process.

- Dramatic developments in the textile materials field over the next 10 to 20 years is about to come because of the single walled carbon nanotubes.

- Satish Kumar from Georgia Tech's School has developed a technique to produce composite fibres containing up to 10% carbon nanotubes.

- Breaking up of bundles of nanotubes into individual ones, the quantity of tubes required to improve the properties of fibres could be reduced from 10% to as little as 0.1% by weight. This will help make use of nanotubes feasible for commercial products.

- By including individual nanotubes in composite fibres, the orientation of polymer chains can be improved, reducing the amount of fibre entanglement and increasing the crystalline rate.

Having a very tough temperature resistant material with a density less than one, seems a dream today, but the day we can do this, it will conceptually change how fibres are made.

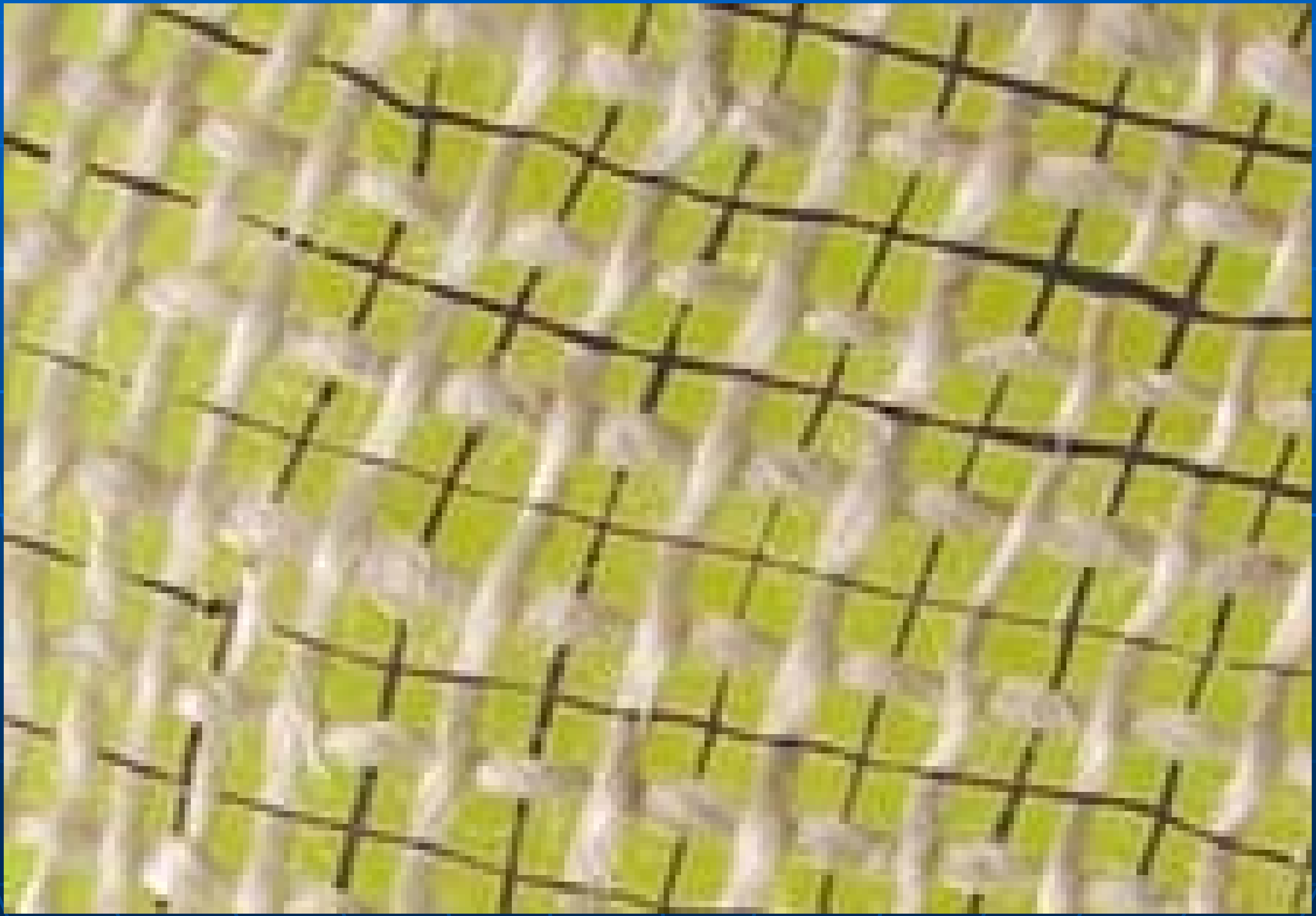
Nanotube composite fibres will induce electronic capabilities to garments: cellular phone and computing capabilities to be woven into a fabric.

Composite carbon nanotube fibres will revolutionize the textile industry which will be completely different from what we have today.

Humans will have to select clothes according to circumstances and situations and the concept of fashion will probably disappear and the concept of survival will take over.

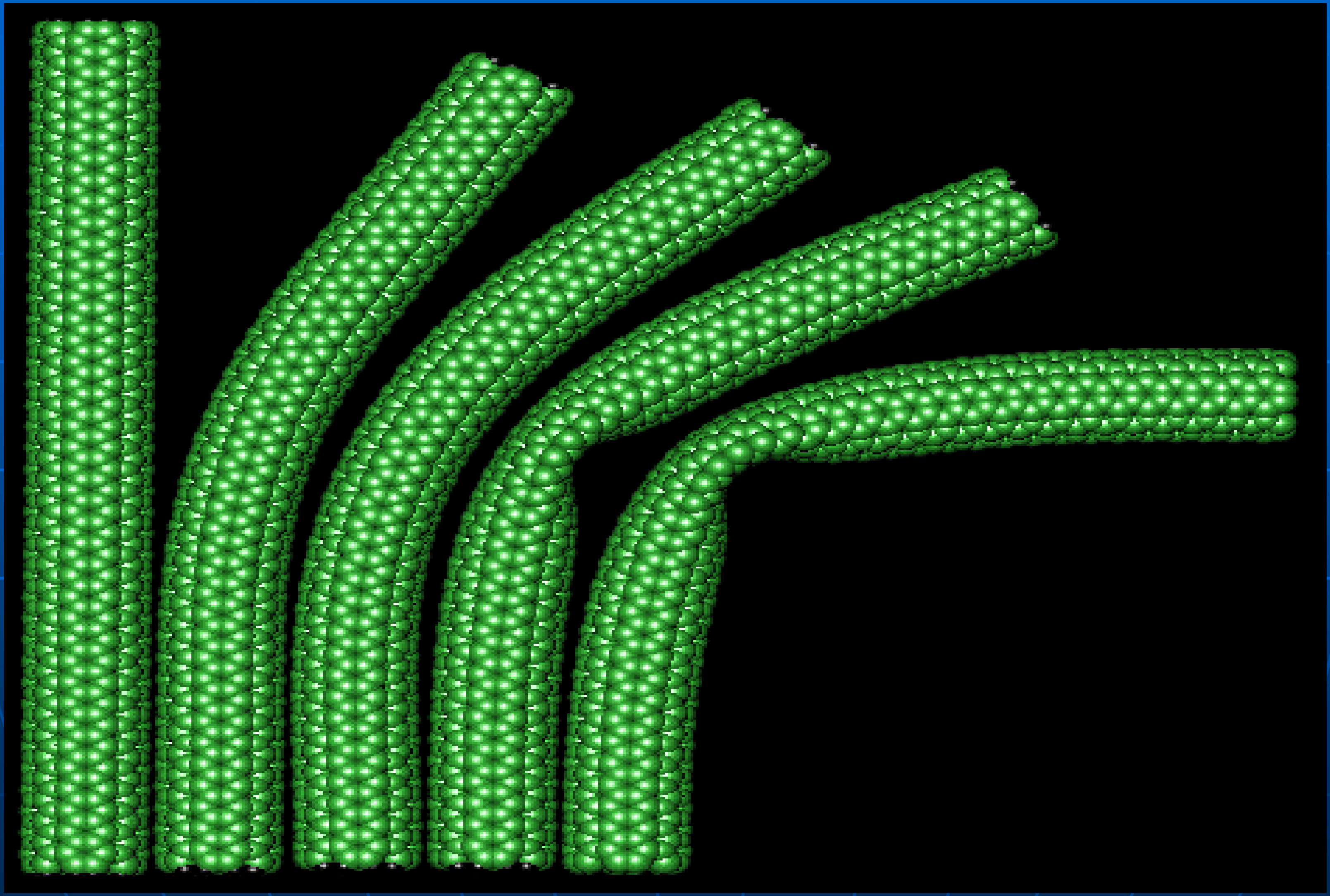
Lucy Dune from Cornell University has developed “Smart” jacket that warms up, lights up at night and even monitors heart rate.

Fabric containing nanotube yarns for thermal conductivity. Source: The Nanotech inst. Univ if Texas at Dallas Richardson.



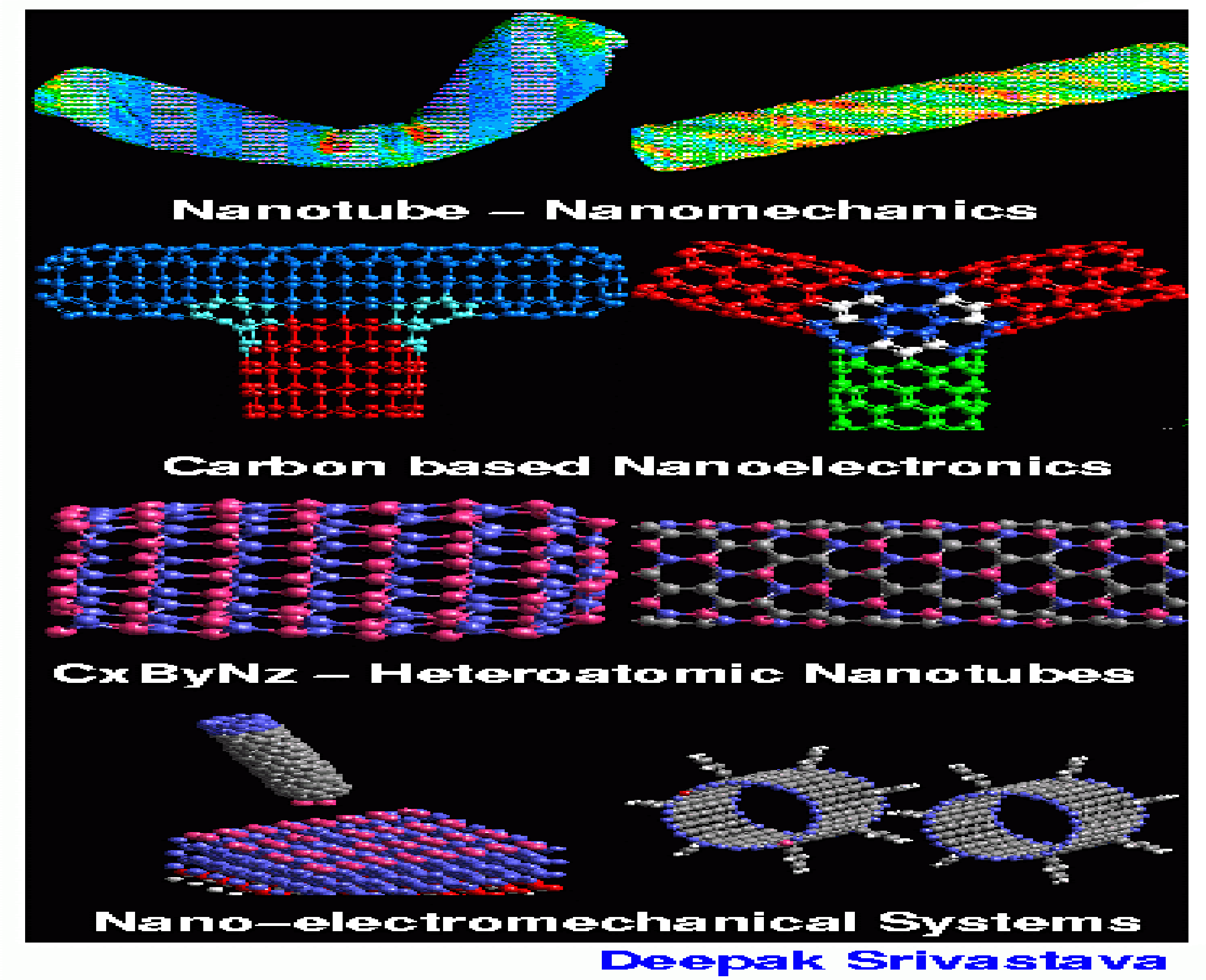
Fabric containing two carbon nanotube yarns supercapacitors woven in ortogonal direction: Source, The nanotech Inst. Univ. Of texas at Dallas

Computer models of carbon nanotubes

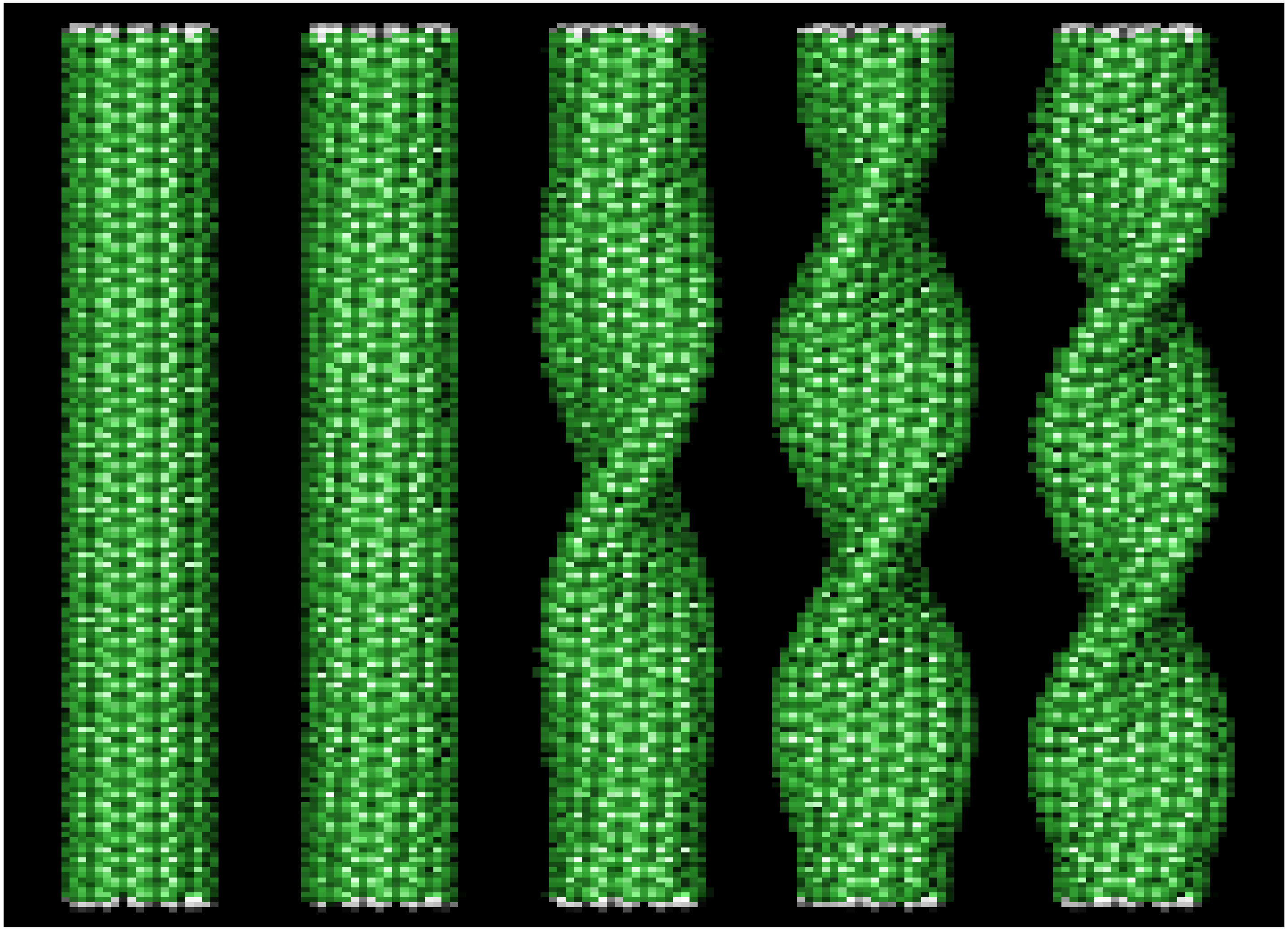


C0mputer models of Carbon nanotubes

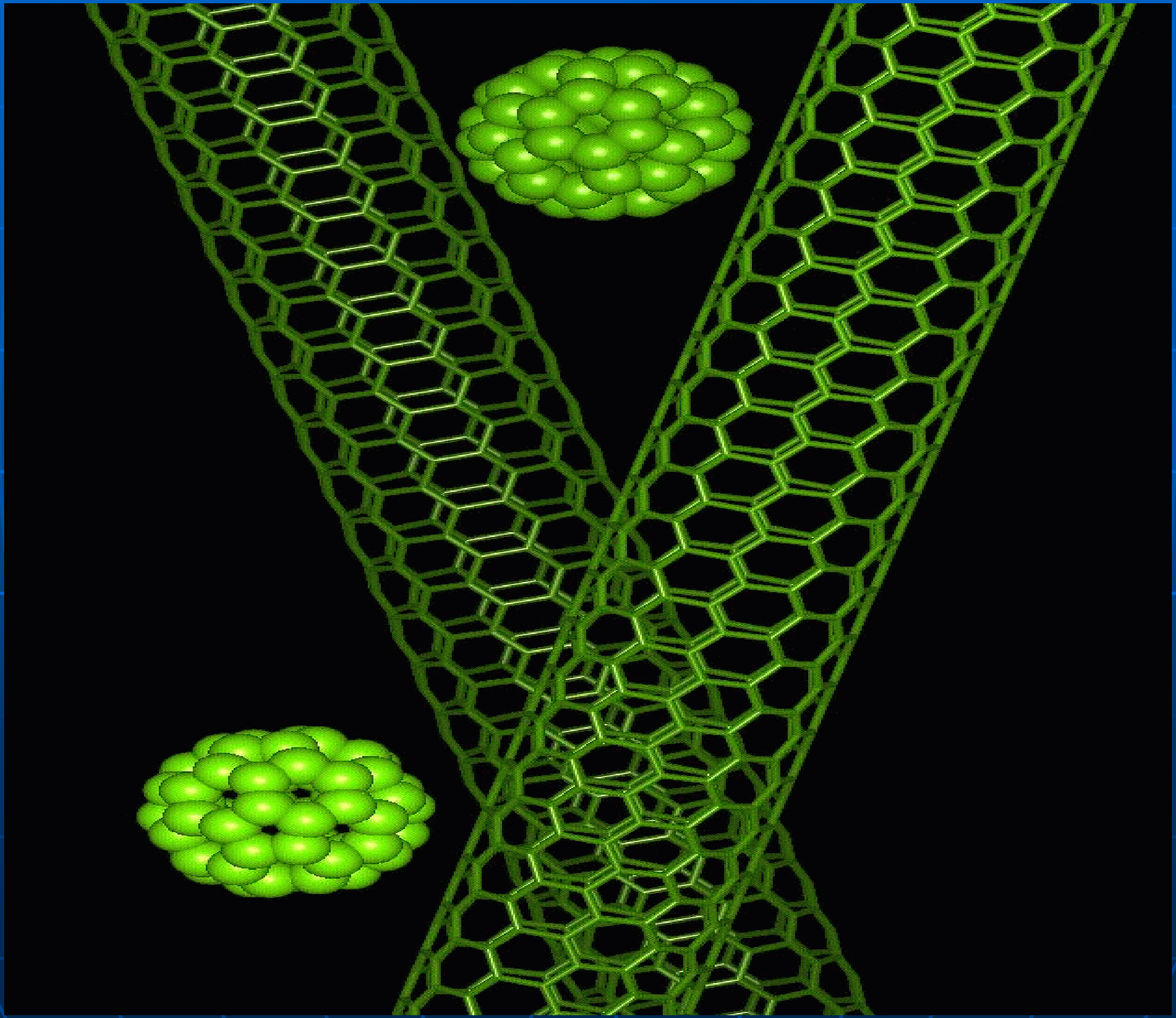
NANO IMAGE



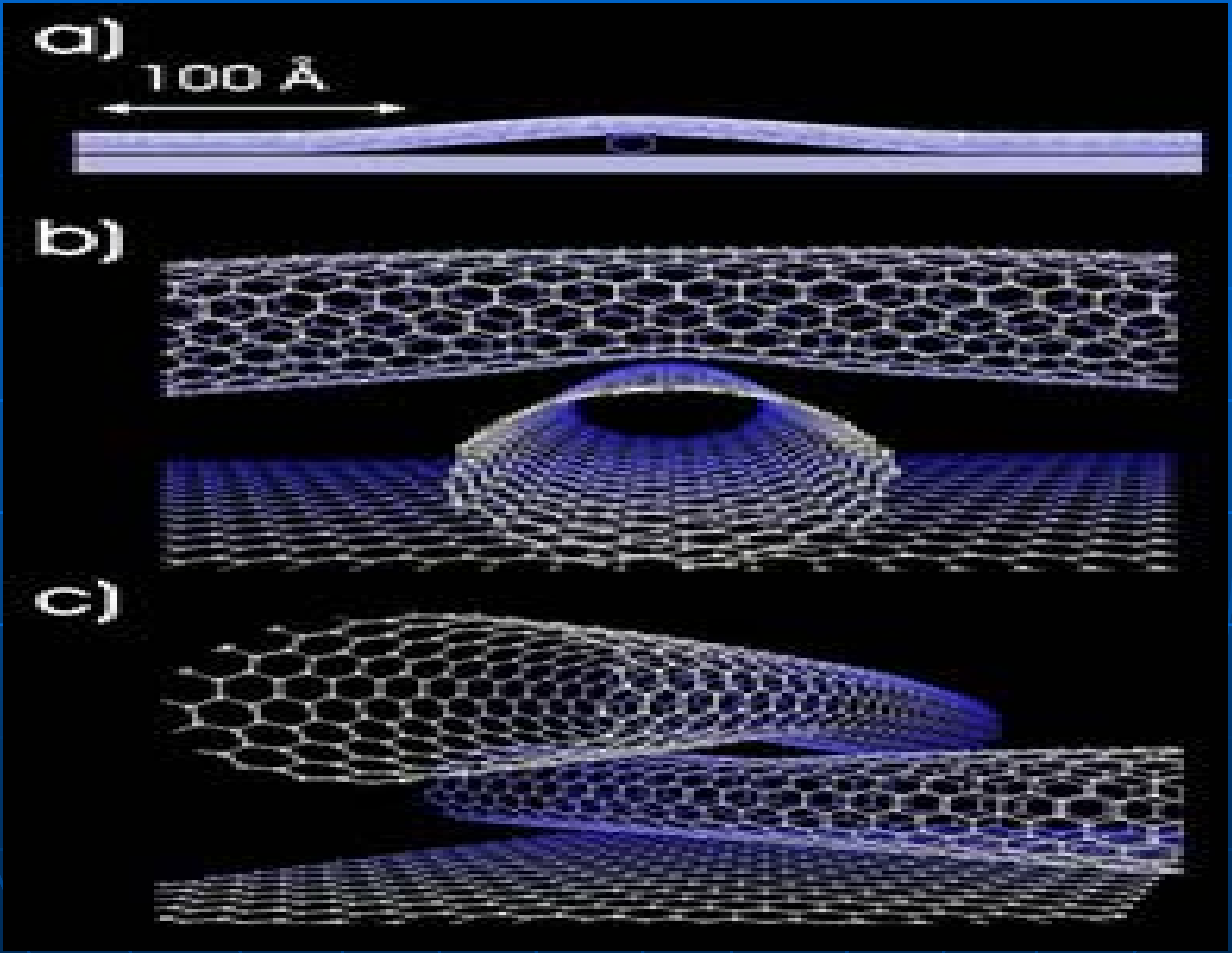
NANO IMAGE: Twisted Nanotubes



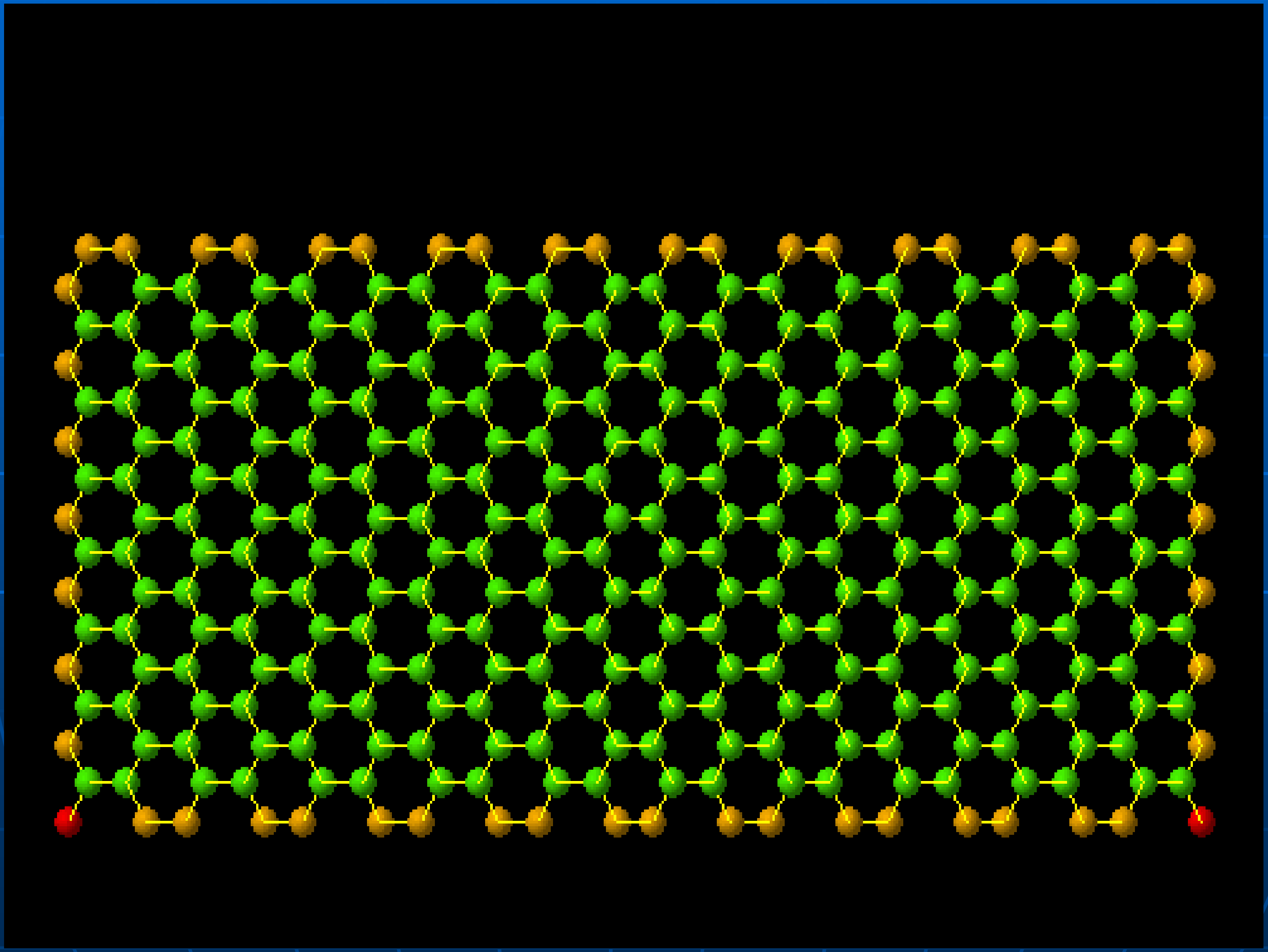
Single walled carbon nanotubes with micro-capsules



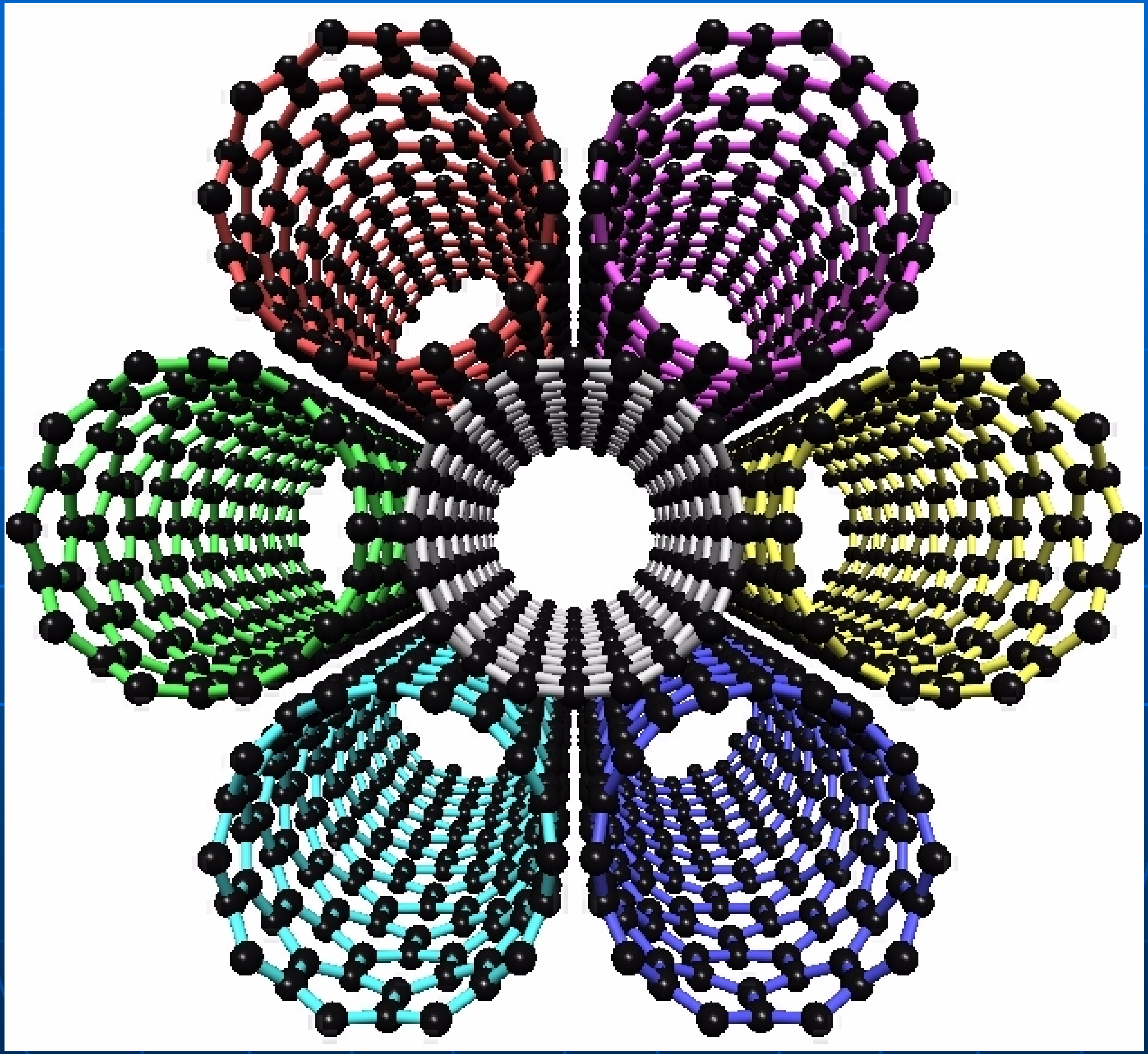
Computer models of Single walled carbon nanotubes



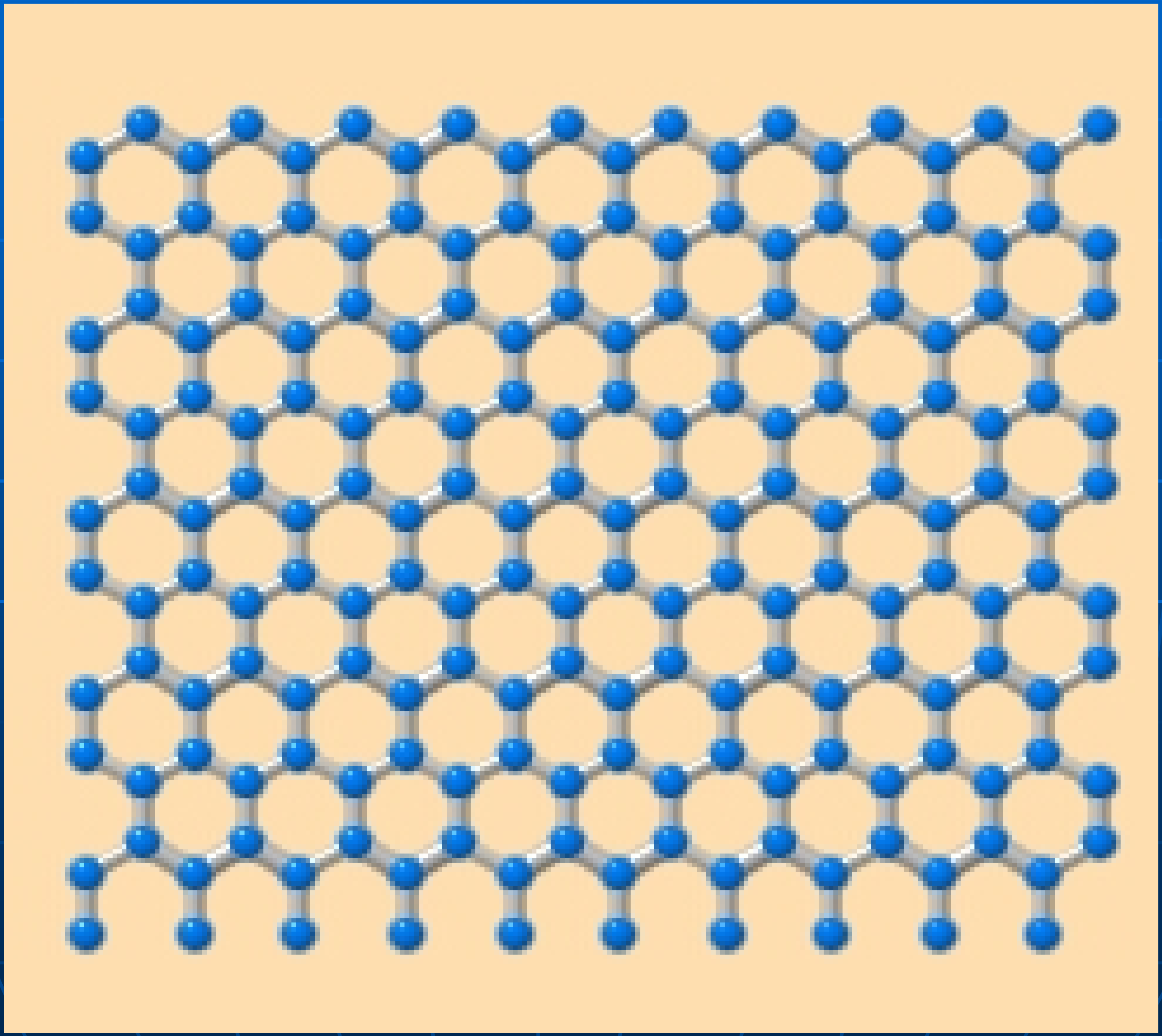
Graphene sheet rolled into a carbon nanotube



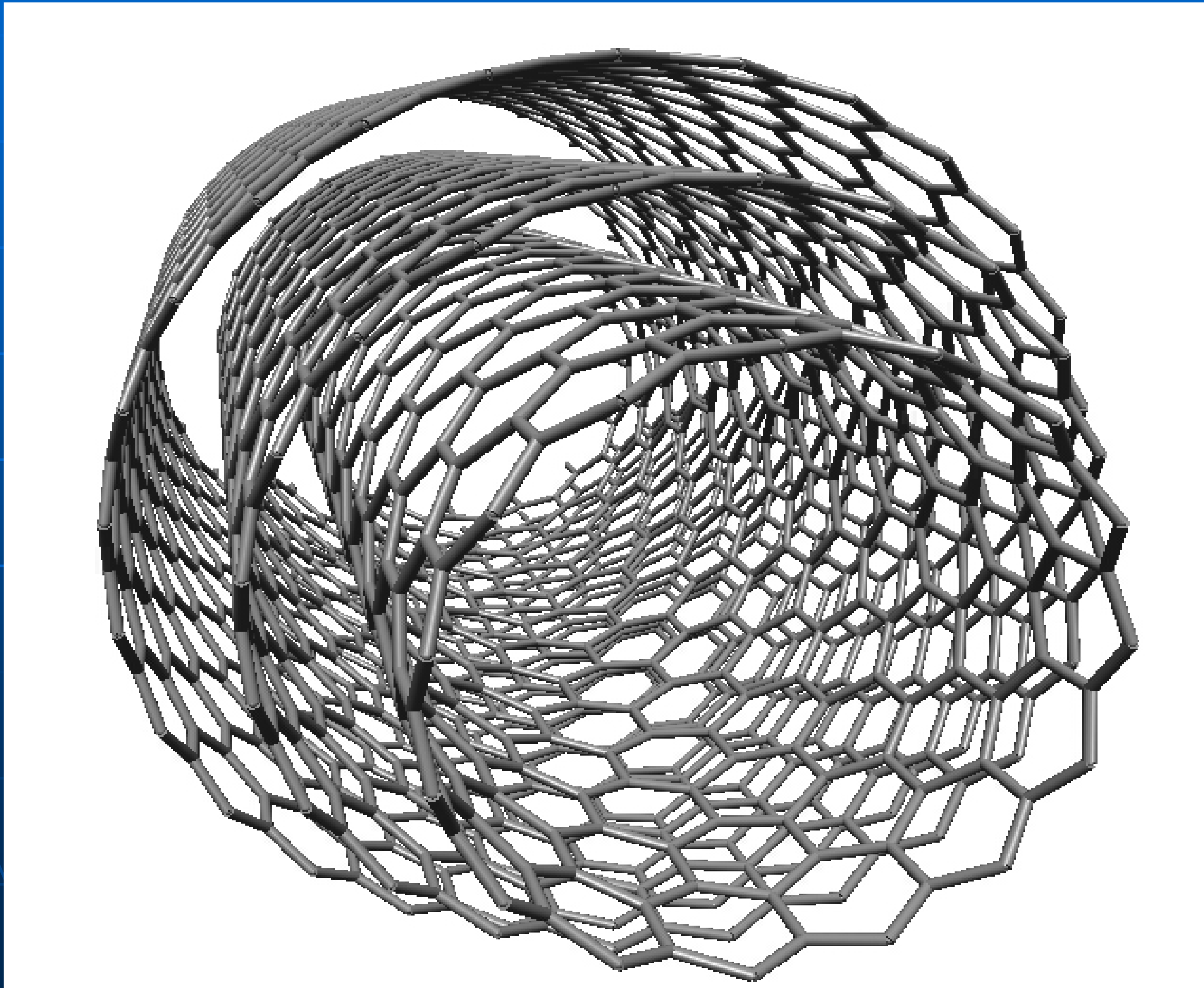
COMPUTER MODEL OF NANOTUBE BUNDLES



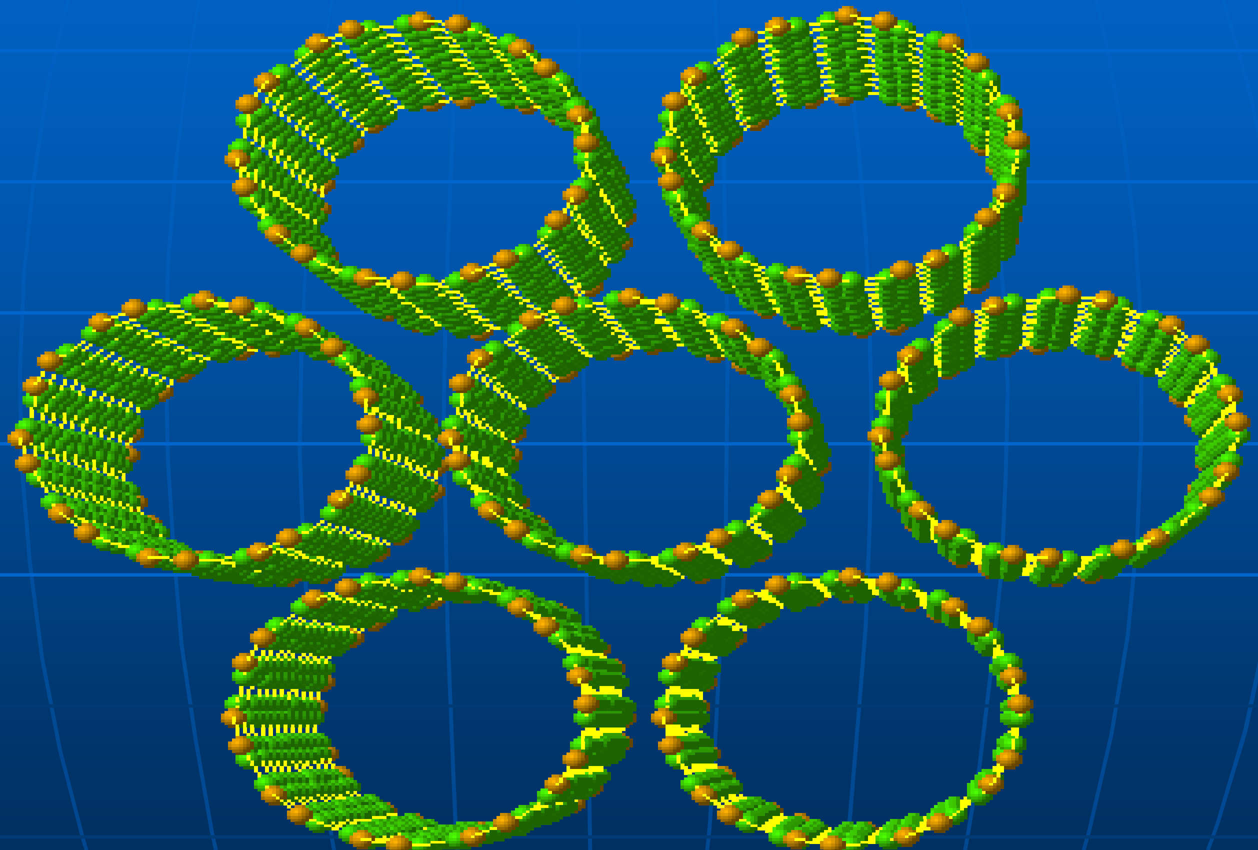
COMPUTER MODEL OF GRAPHENE LAMINATE



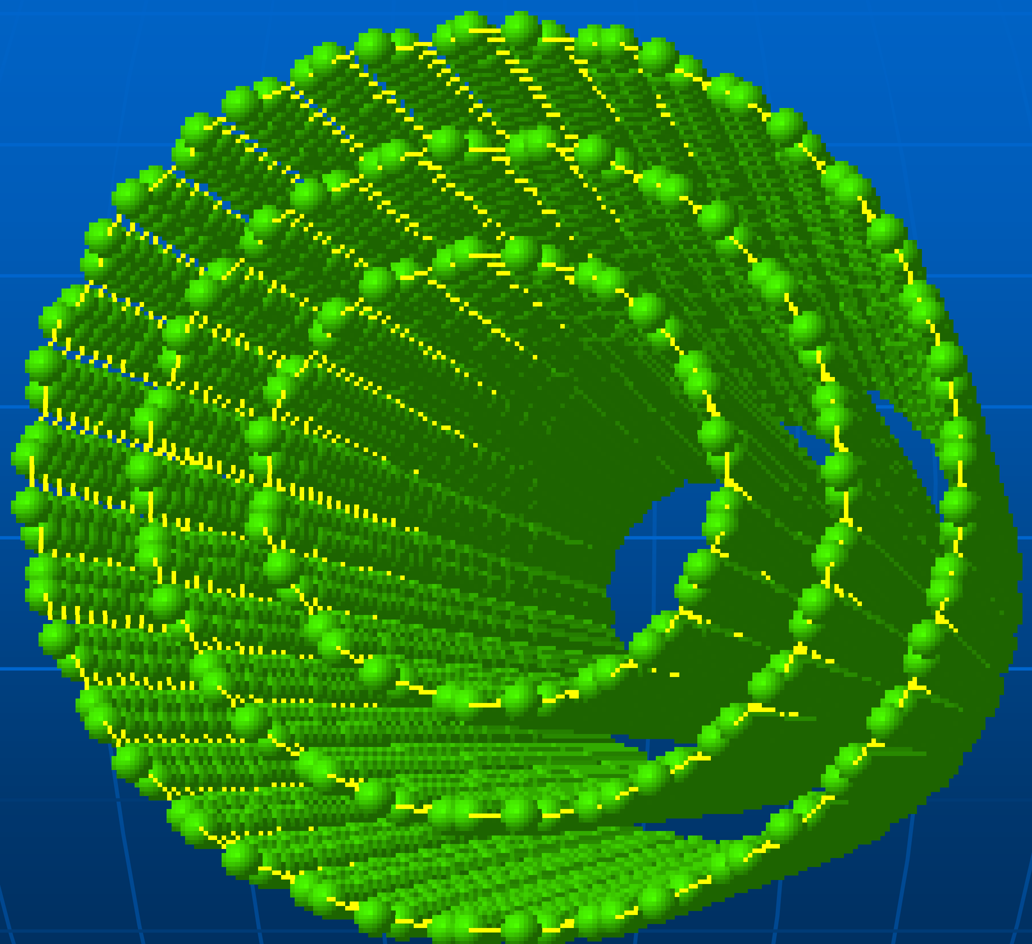
COMPUTER MODEL OF CARBON NANOTUBE



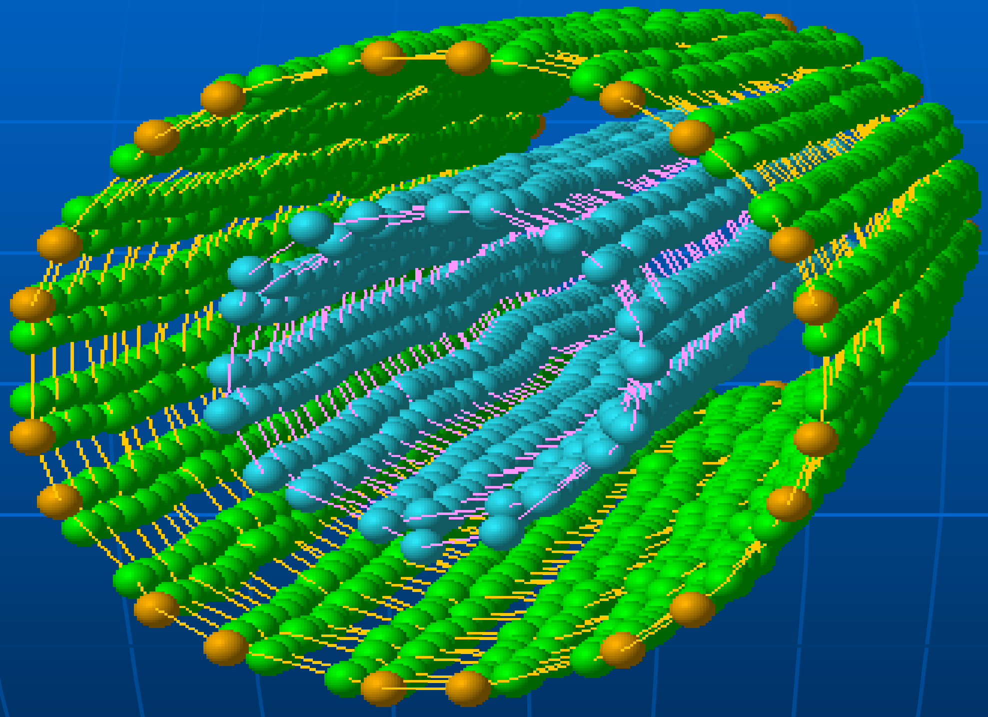
Carbon nanotube bundles



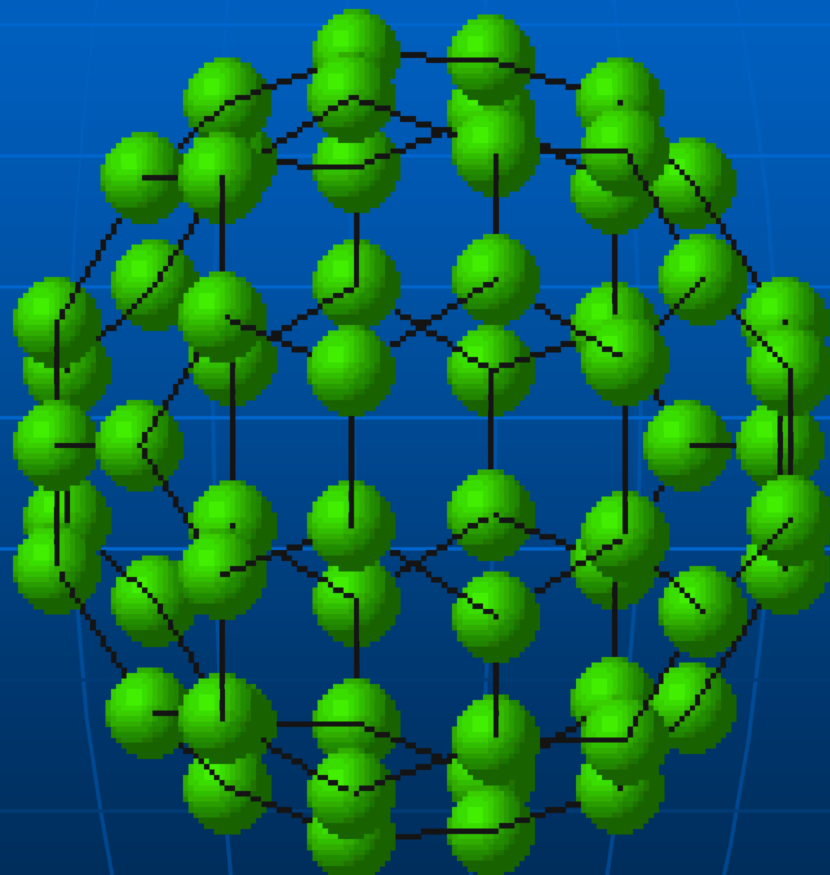
Computer model of Multi walled carbon nanotubes



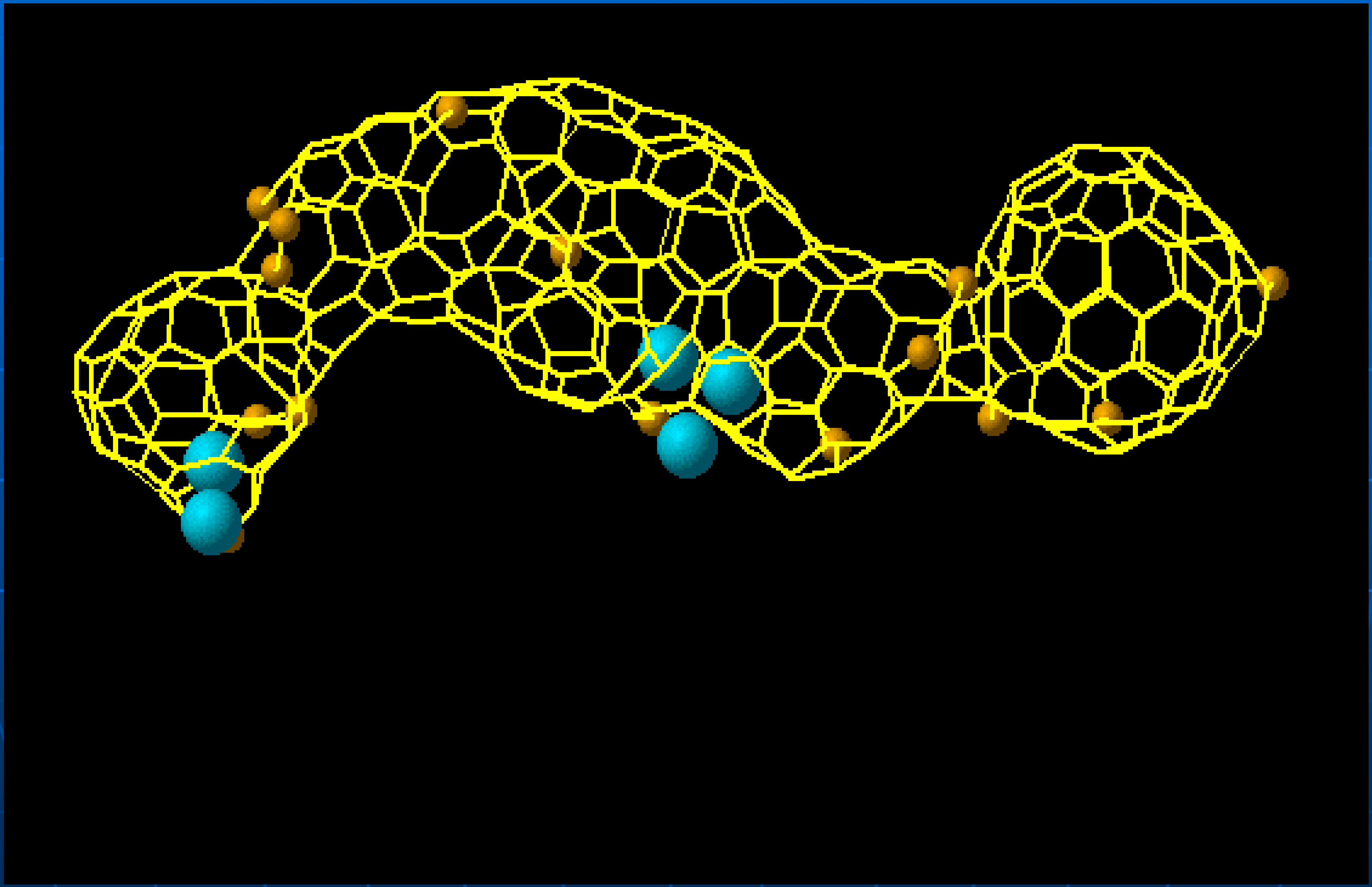
Computer model of carbon nanotube



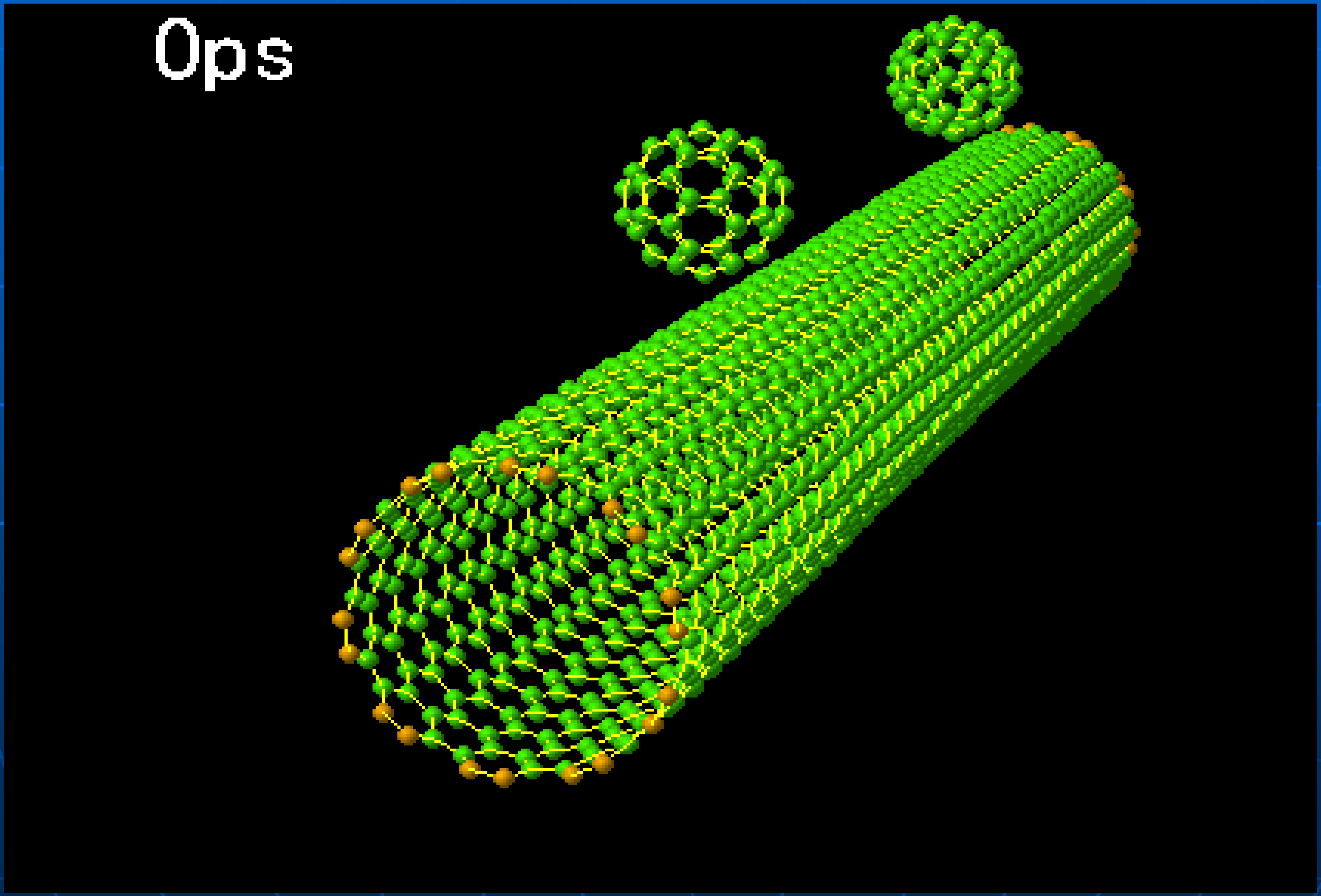
C 60 carbon molecule employed in the manufacture of nanotube



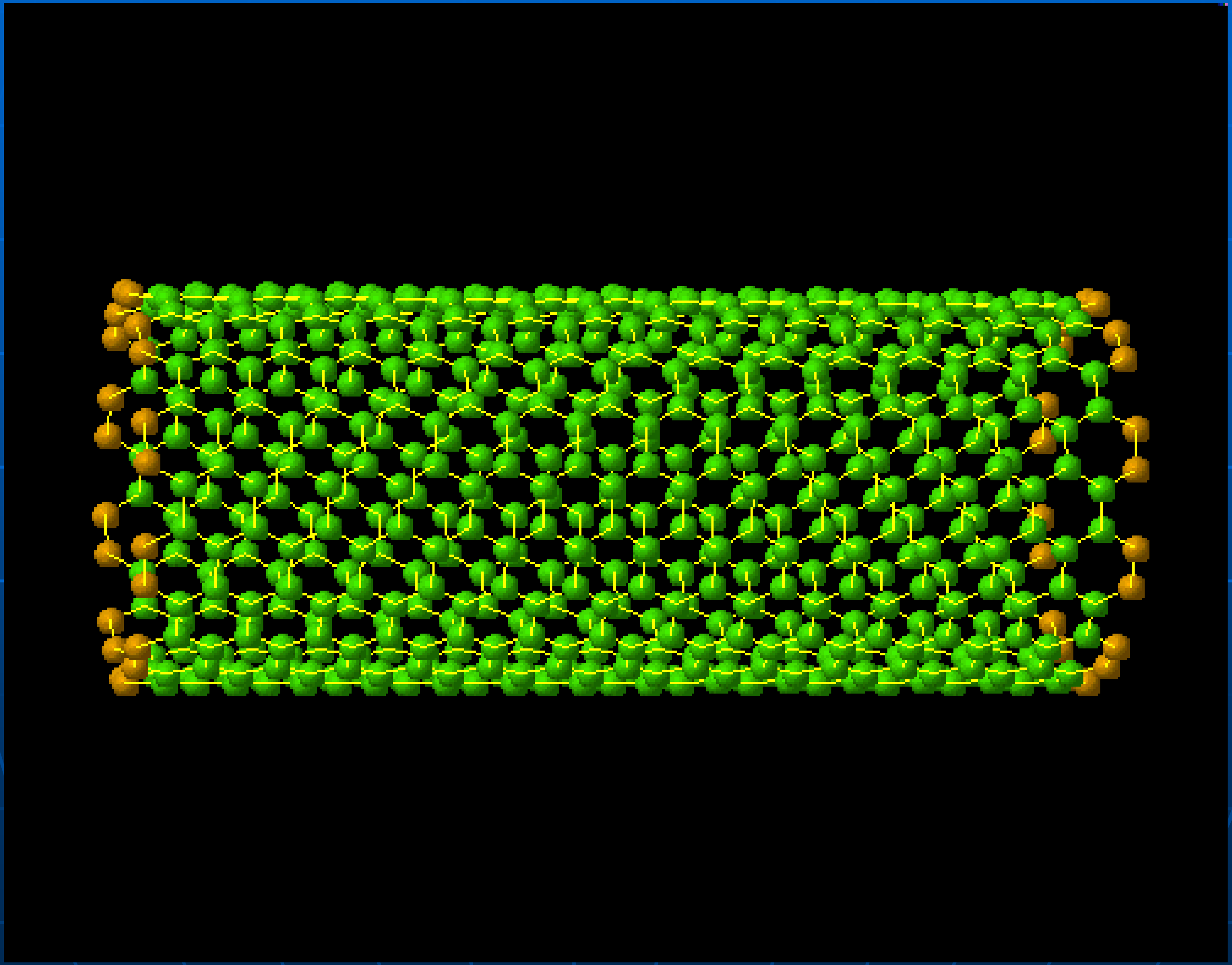
Computer model of spiral structure of carbon nanotube



Computer model of Carbon nanotube and micro-capsules



COMPUTER MODEL OF CARBON NANOTUBE



FIBRE DEVELOPMENTS

Sterling fibres: A leading manufacturer of acrylic fibres , produces an anti-microbial fibre whose end uses include; socks, sweaters. Under-wears, gloves, hats and active wear. The actual amount of fibre needed depends strongly efficacy desired and the fabric construction.

Triclorosan: This is an anti-microbial agent which is actually incorporated into the structure of the acrylic fibre during spinning. The fibre holds the anti-microbial, like a felt tip pen holds ink, and provides a reservoir to continuously replenish the surface for long lasting anti-microbial properties.

Unifil: Has developed AMY (Anti Microbial Yarn) to prevent foul odours and help consumers protect against micro-organisms that can cause fabric discolouration and apparel corrosion.

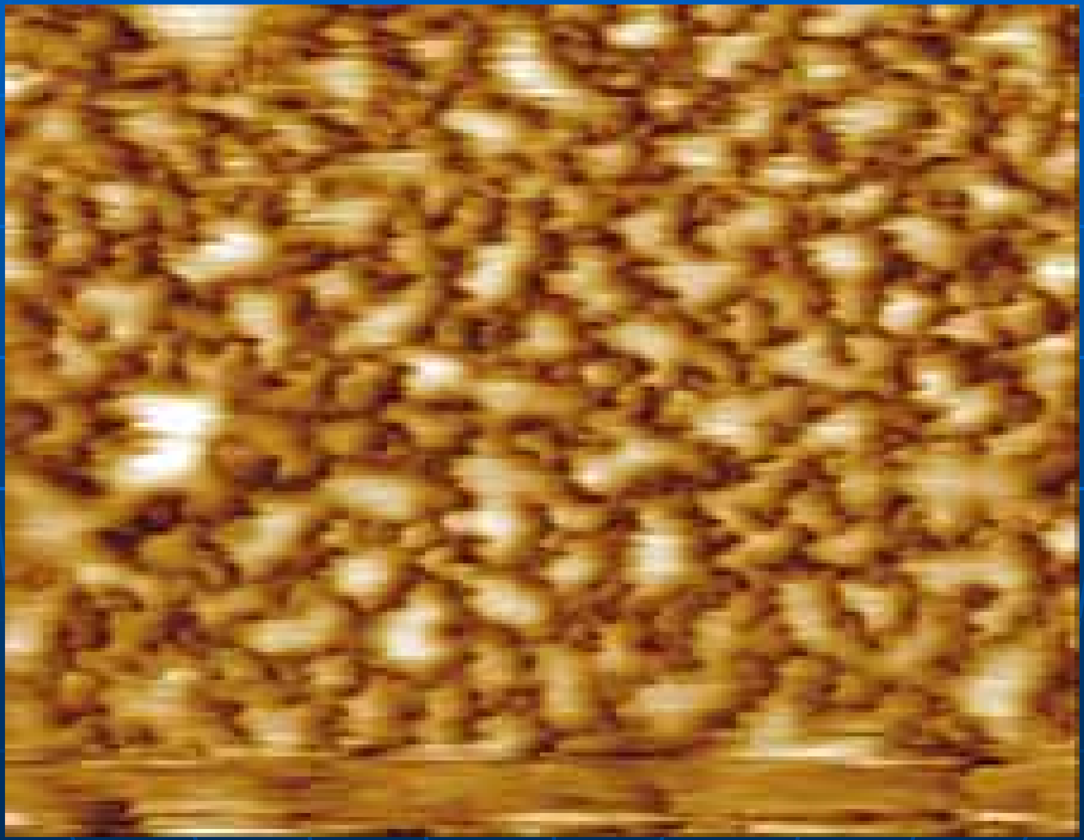
FIBRE DEVELOPMENTS

KoSa produces anti-microbial polyester yarn which contains a silver ceramics additive that protects the yarn from growth of bacteria, mould and fungi in or on the yarn surface. It can be used in fashion apparel applications, uniforms and work-wear, automotive interriors and marine fabrics.

Nylstar is marketing Skinlife, an anti-microbial version of Meryl polyamide 6.6 fibre for garments that come in contact with the skin. Meryl Skinlife is unique in that it is bacteria-static agent which is induced into the yarn matrix making it a permanent feature in any garment.

Swim-wear innovations: The DuPont Aqua Wear includes new ideas in fabrics incorporating novel treatments and finishes resulting in benefits of comfort, freedom and movement, protection, shape retention and quick drying.

SWIMWEAR FABRIC SURFACE COVERED WITH NANOBUBLES



FIBRE DEVELOPMENTS

INVISTA. Produces ANTRON nylon 6.6 “stain resiat” fibre.

It improves the long term appearance retention of carpets.

Possible applications: Healthcare; Corporate education and hospitality segments where stains such as coffee, fruit juice, soft drinks, wine, cough syrup and chloraseptic are common.

ANTRON is an environmentally friendly product

RHODIA: Produces Anti-allergen acrylic product for healthcare.

Nanofibre for neural/orthopaedic implants: Diagnostic neural probes and prosthetic devices from carbon nanofibre based components might be technically and practically feasable.

How can we use nanotech to add value added properties to different kinds of natural and manmade textiles without changing the look or feel of the fabric?

The technology works like this: a cotton fibre is almost a round cylinder. On a nano-scale, it is the size of a tree trunk. Now imagine grafting lots of little hairs on to the trunk until it creates a peach fuzz effect.

This can be done on textile fibres using nano-whiskers which are built atom by atom.

The whiskers have to be the right shape. Once applied to the fabric, the whiskers have to land on the surface and stick with blades pointing up.

The fuzz is permanent and creates a cushion of air around the fibres. It is undetectable, except when seen under a high-power microscope.

Smart clothes: These shield consumers from odour through the use of various **anti-microbial fibres and yarns,** are taking hold in the sector of active wear, intimate apparel, swim-wear, socks, career wear, uniforms etc.

Duro Industries from Massachusetts markets **anti-microbial fibres** for end uses like climbing, hiking, snow boarding, skiing and a variety of outdoor activities. Duro's fabrics also have UV protection and moisture management protection properties.

Super-light weight range of cellulose-wrapped acrylic fibres: The density of acrylic fibres is between 1.17 and 1.40, 24% as light as 1.54 cotton.

The biggest disadvantages of acrylics are found in their lack of water absorbency, high electro-static properties as well as somewhat unnatural tepid and waxy look and feel.

Cotton, when in the form of sweaters, is heavy and not a practical material and becomes even heavier when wet and is extremely slow in releasing moisture.

Nano-touch will simultaneously eliminate the undesired characteristics of both cotton and acrylic, breaking fresh ground for super light-weight variations of cellulose fibres.

Nanostandards: ASTM International; at the 2004 planning meeting, it was agreed that whilst the research into the properties, synthesis and applications of nanostructures is growing at an exponential rate, there is no common language to describe the chemical compositions and physical forms of these new materials.

This lack of common language hampers the technical and public communication when materials containing nano-materials enter the market place.

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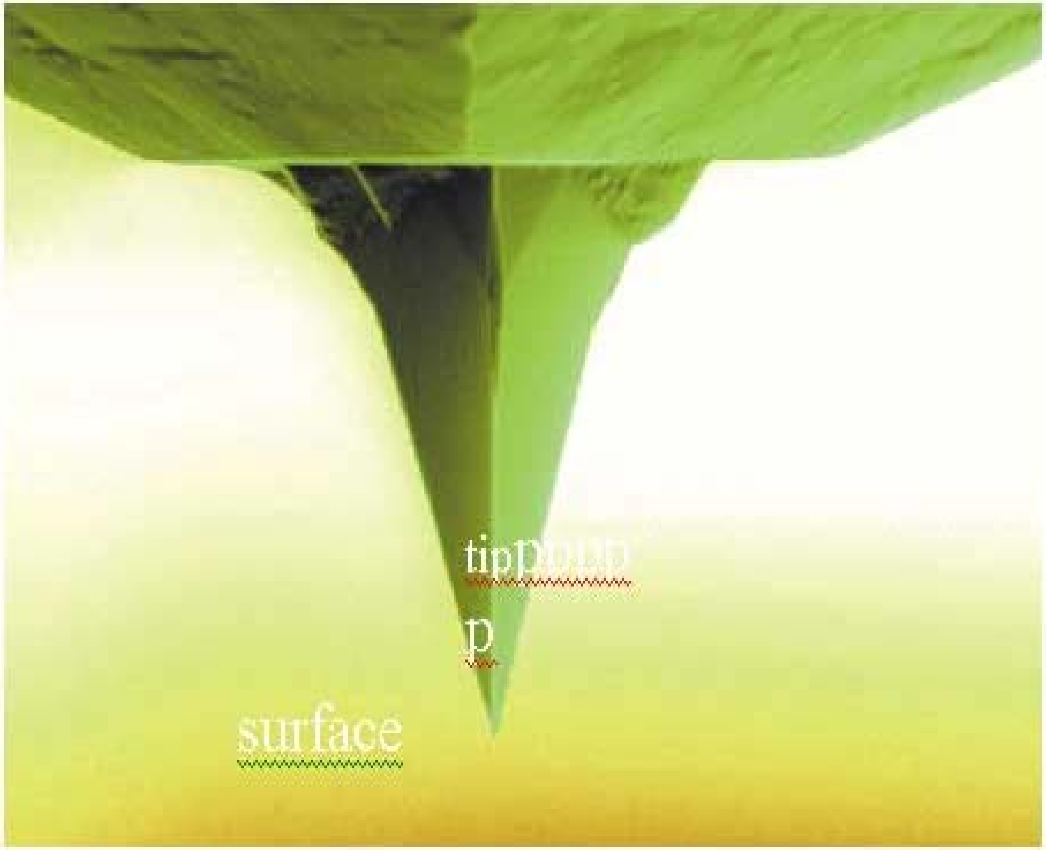
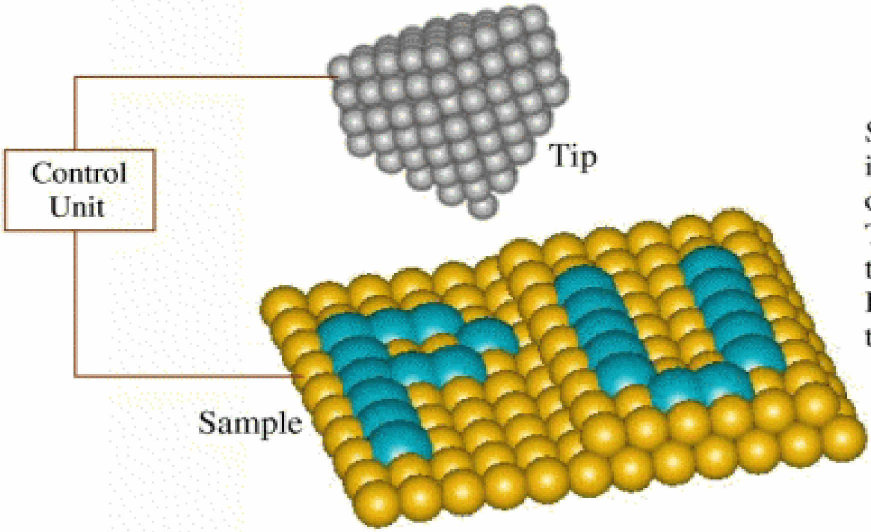
NANO IMAGE

An atomic force microscope (AFM) tip made of Si

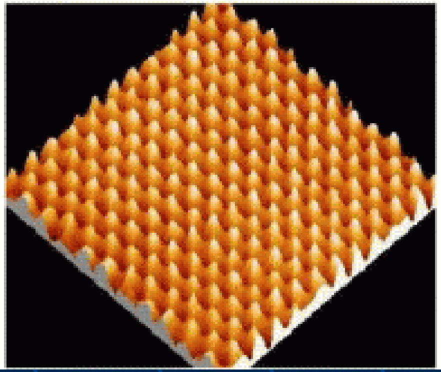


NANO IMAGE

Scanning Tunneling Microscopy



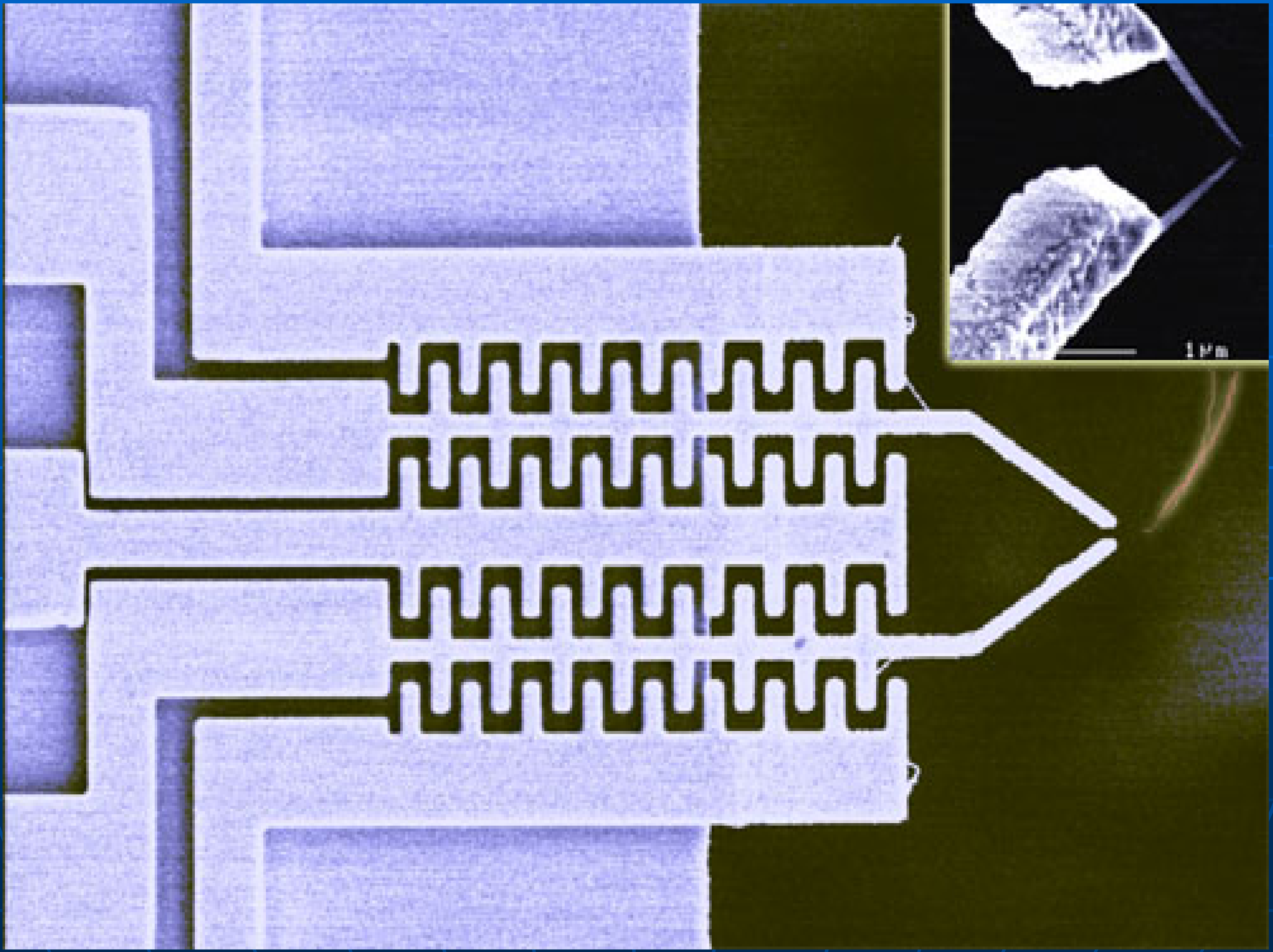
Scanning Tunneling Microscopy (STM) is a process that is used to study the properties of surfaces at the atomic level.
The STM scans an atomically sharp tip over a surface, typically at a distance of a few angstroms or nanometers.
It uses the quantum mechanical tunneling current to determine the distance between the tip and the surface.



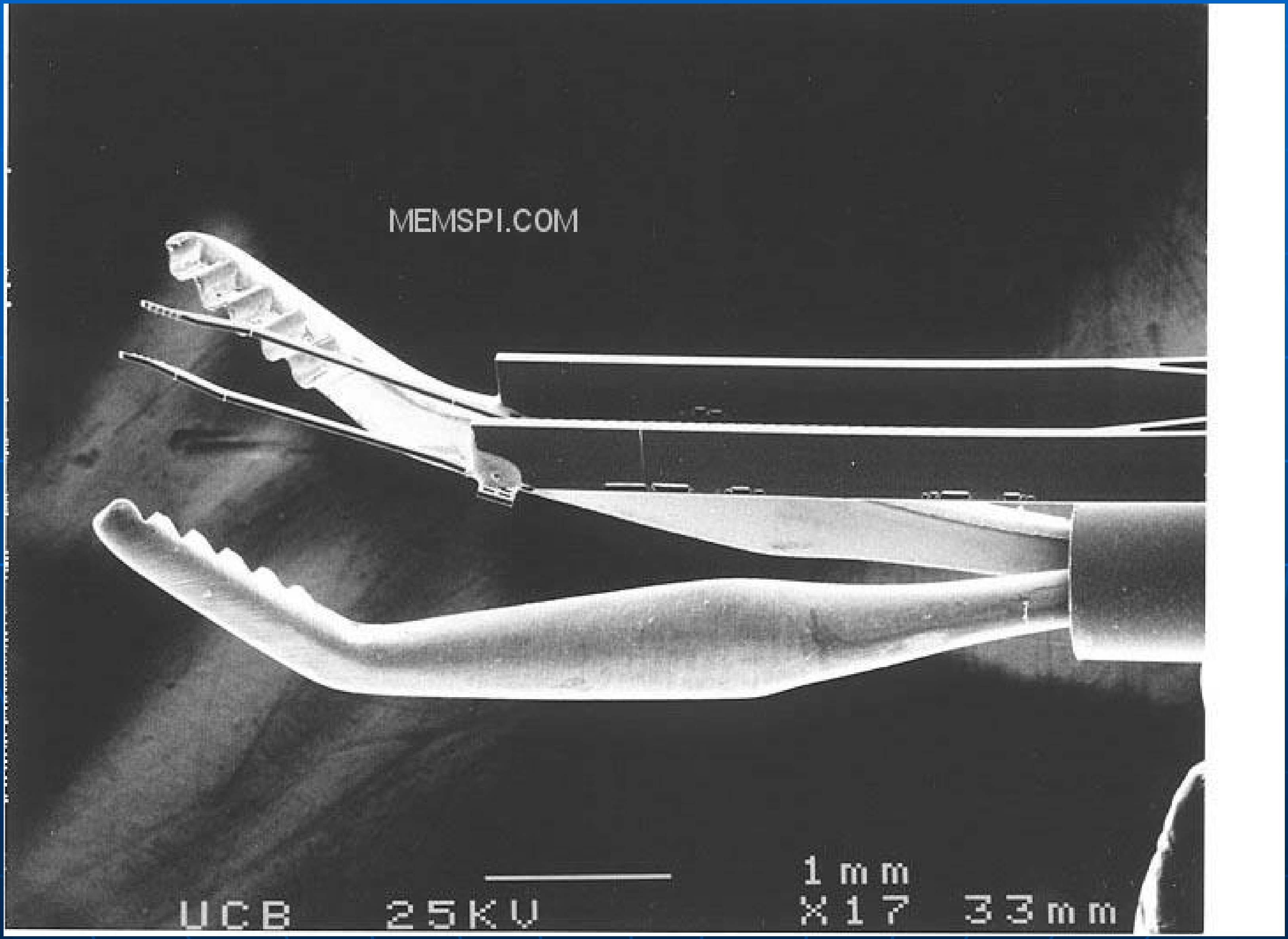
Atomic image of
Highly Oriented Pyrolytic Graphite (HOPG)

In this image, every other carbon atom appears from the real honeycomb structure of HOPG.
The resulting image is a hexagonal closed-packed pattern due to a particular symmetry of the wave functions at the Fermi surface near the $\overline{K}$ points in the surface Brillouin zone.

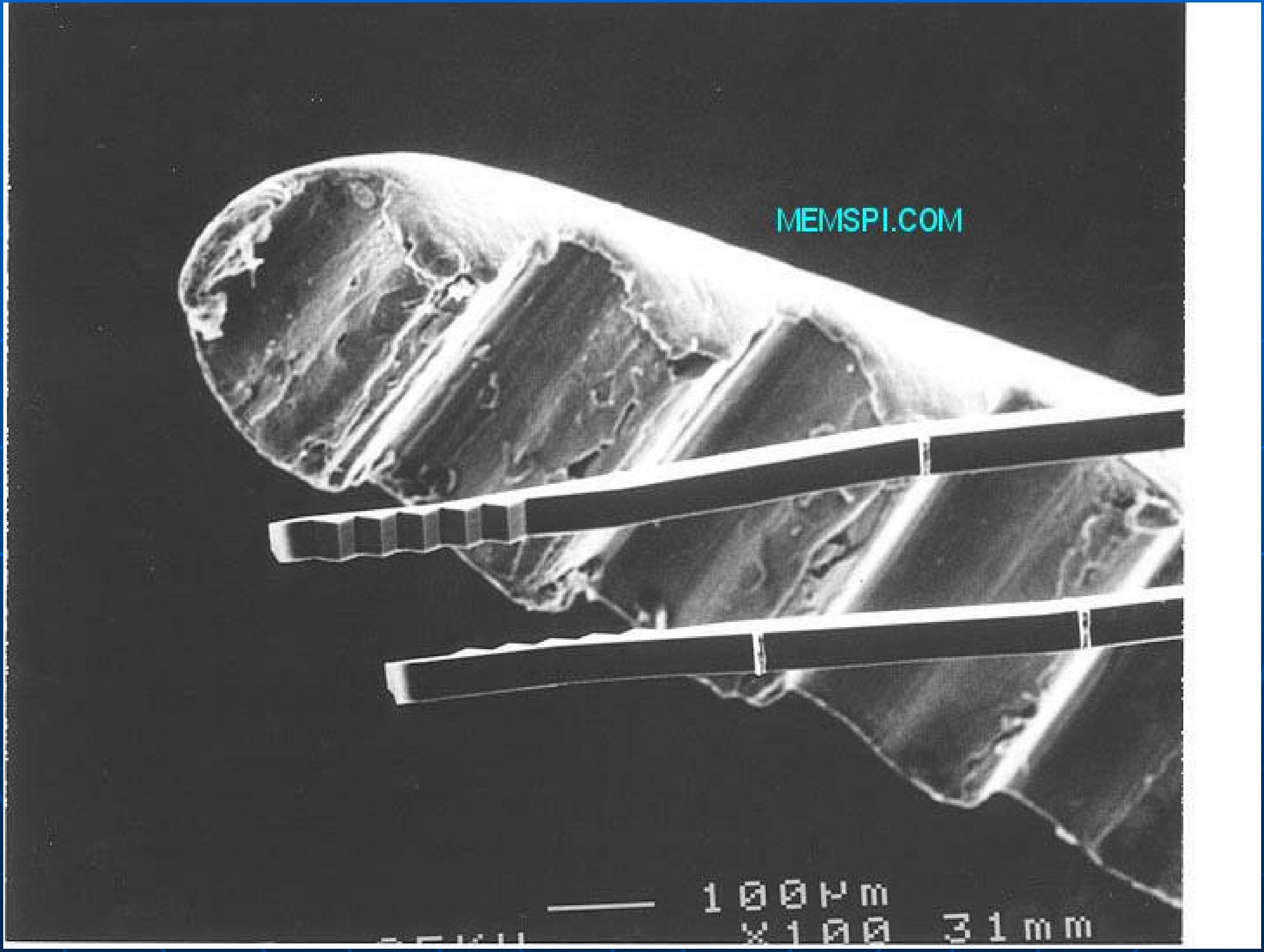
NANOTWEEZERS



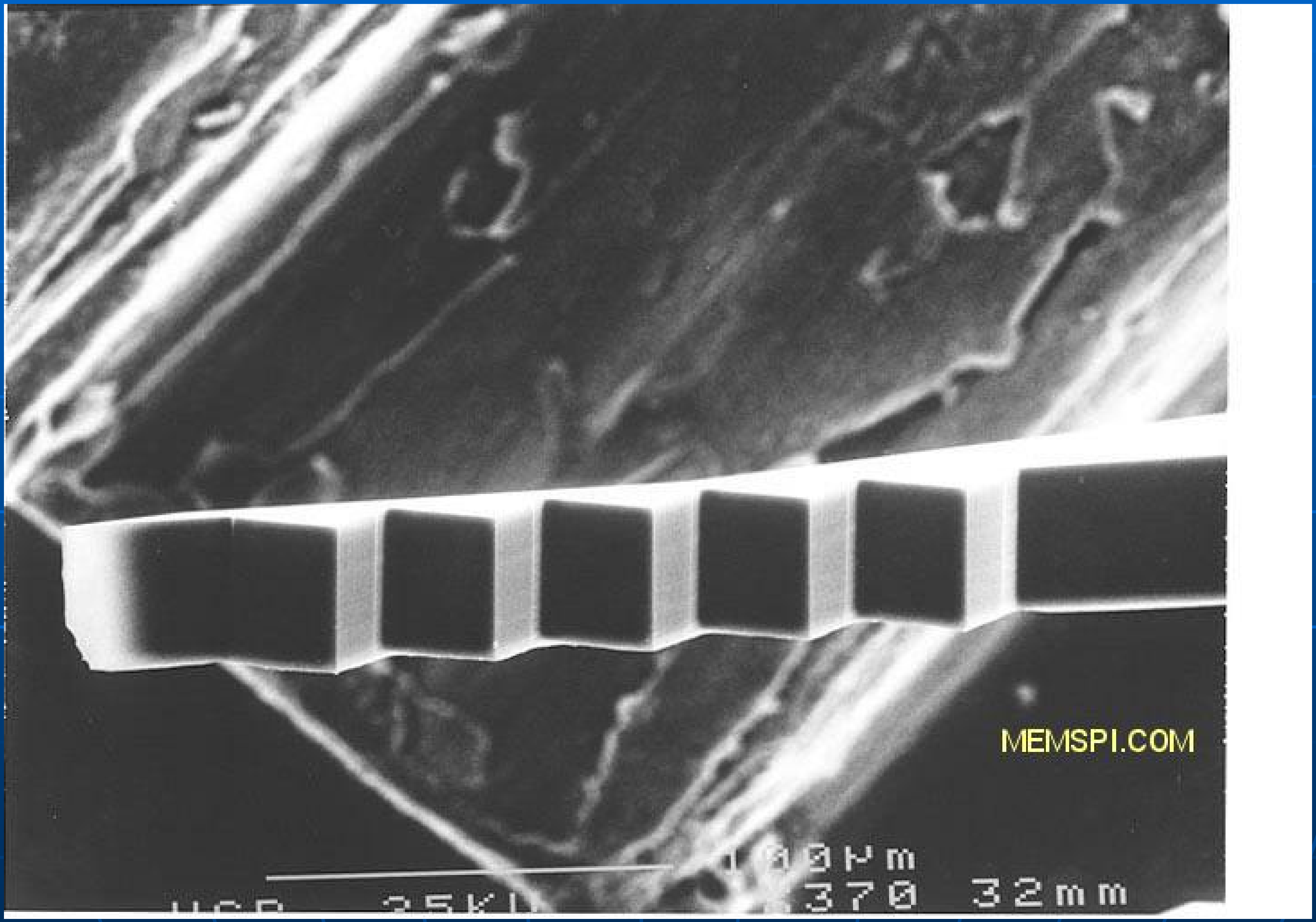
Nano tweezer as compared to classical tweezer



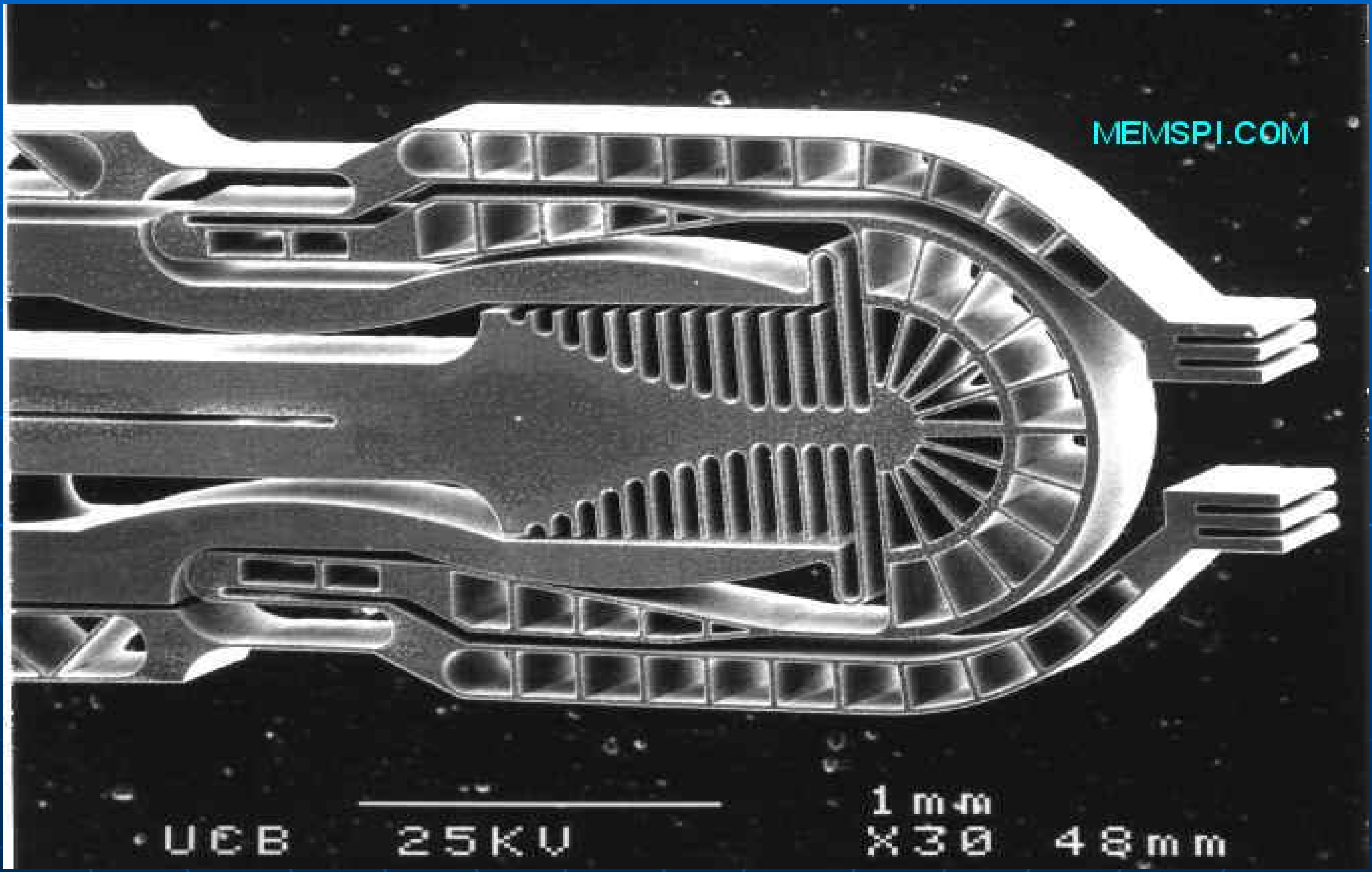
Nanotweezer as compared to Classical tweezer



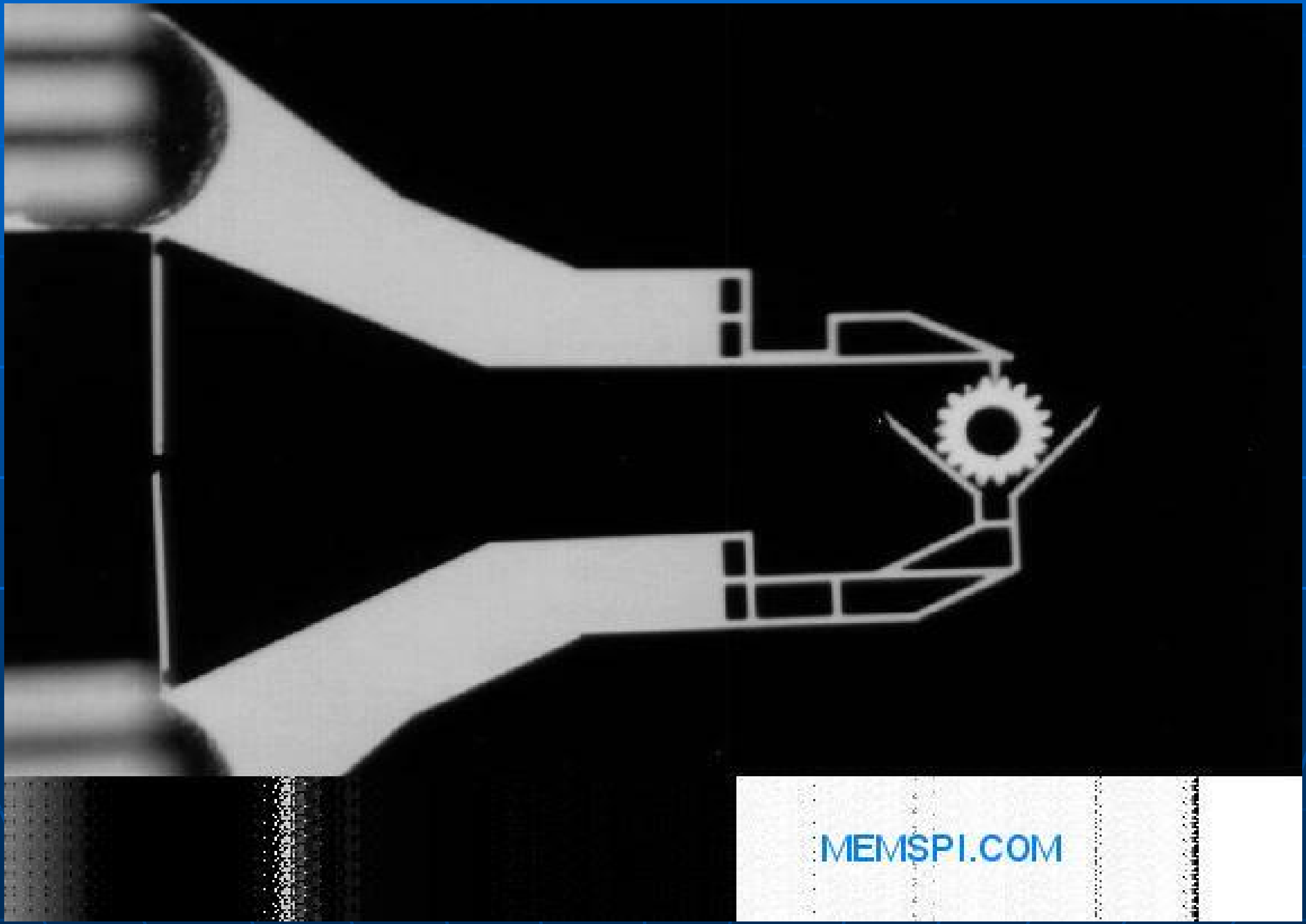
Nanotweezer as compared to clasical tweezer



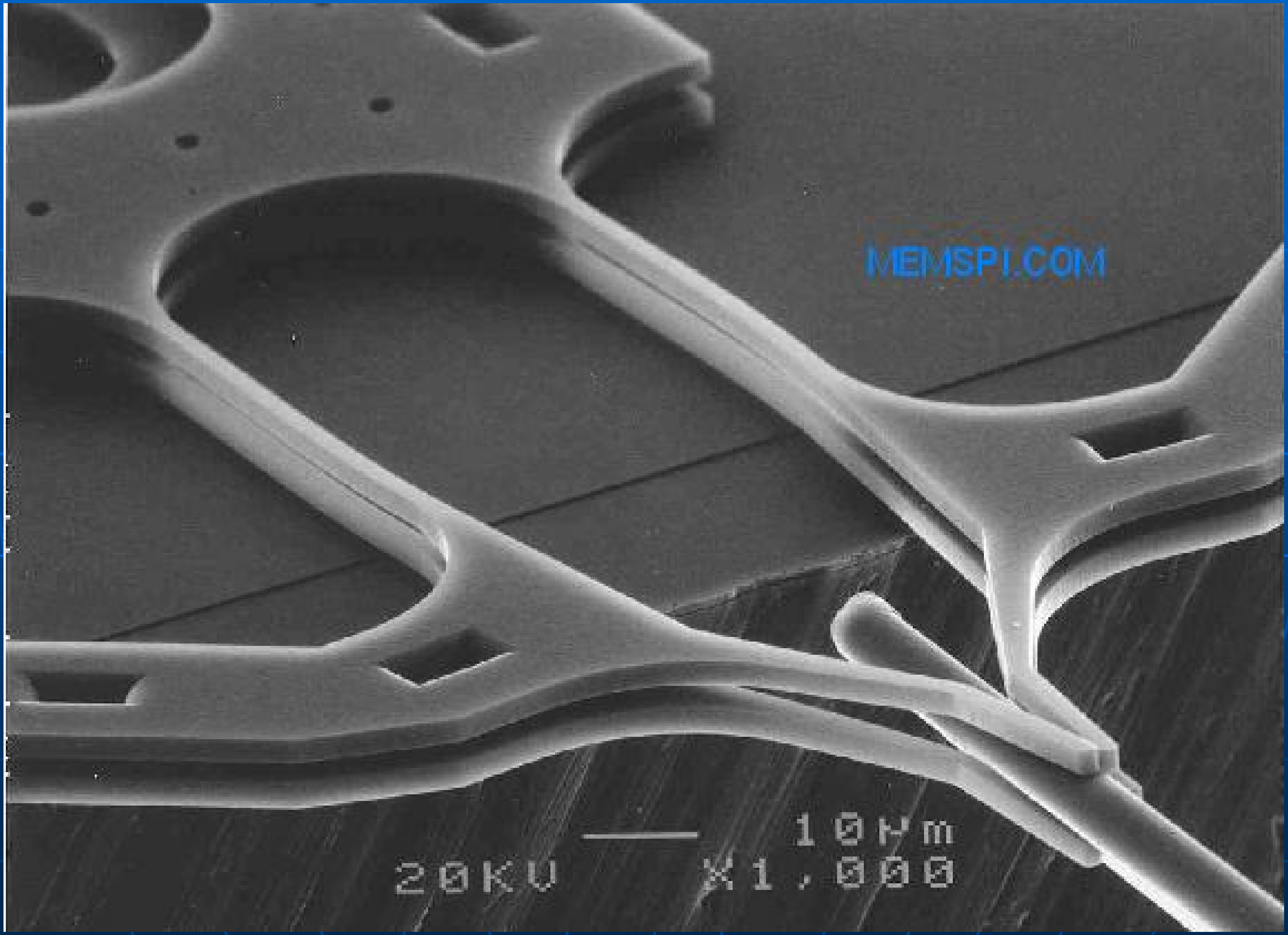
Another version of Nanotweezer



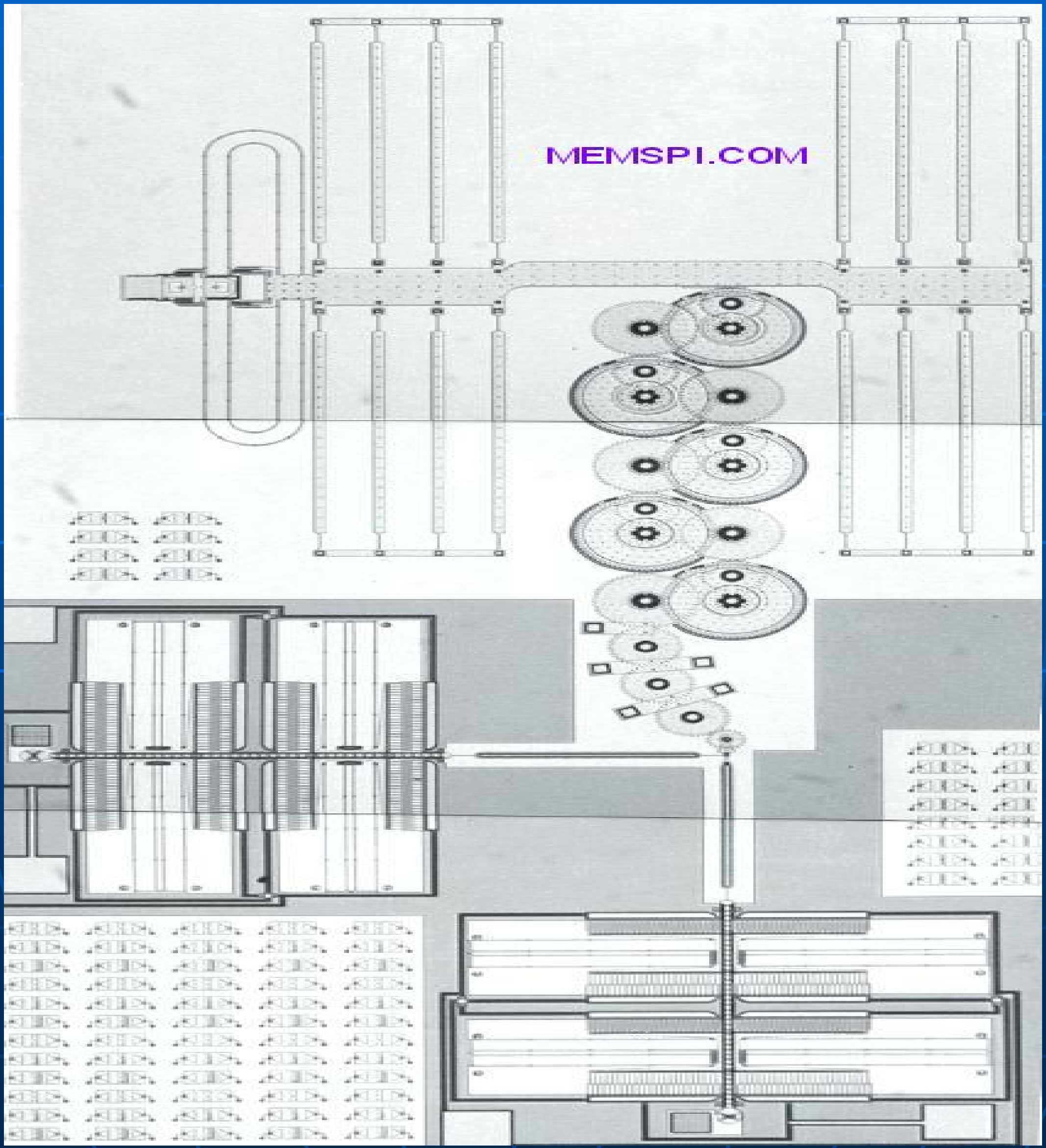
Nano tweezer holding nano gear



Nanotweezer holding a nanofibre



Nano tensile tester



CONCLUSIONS

- Nanotechnology is an interdisciplinary field
- Opportunities and rewards are great. As such tremendous world wide interest.
- Through systematic theoretical and experimental studies, significant insight into electro spinning has been gained.
- The electro-spinning process uses electrostatic forces to drive fibre formation. This process produces nanofibre.
- Based on their final diameter, nanofibres possess large surface to volume ratio.
- High speed photography indicates that the key process is a whipping jet which is believed to be the underlying mechanism leading to nanofibre.
- A quantitative process understanding is a must essential prerequisite to benefit from the full potential of these unique fibres.

- Molecular spinneret will reduce the actual giant plants to the size of one room with substantial reduction in energy consumption and manufacturing costs.

- Single walled carbon nanotubes will revolutionize the textile industry. The concept of fashion will probably disappear and the concept of survival will take over.

- Anti-microbial fibres prevent foul odours and protect against micro-organisms, applications are in socks, sweaters, hats, under-wears, gloves, active wear, sports wear, uniforms, automobile interior, home furnishings, carpets etc.

- Nanofibre is employed in filters to capture viruses as small as those responsible for Severe Acute Respiratory Syndrome (SARS)

FIBRE SPINNING

The present methods of manufacturing fibres are:

Wet spinning, Melt spinning, Melt blowing, and dry spinning.

Future methods:

Molecular spinneret, Electro-spinning, Co-electro-spinning, and Coagulation spinning.

Of all these new techniques, a lot of research is being carried out all over the world in electro-spinning.

I would dare to say that very soon there will be nanofibre on large scale in the market for various applications.

This will contribute in the improvement of our life.

- By using the method of electro-spinning and the process of melt blowing, highly deformable nonwoven membrane structures can be made.
- The miniaturization of electronics has led to the emerging field of intelligent clothing, which integrates functional clothing design with portable technology.
- A lot of research is needed to investigate the mechanical and biological behaviour of polymer nanofibre.
- Textile technology has a lot to gain from this new exciting and challenging field of nanotechnology research.
- Nanotechnology in surface treatment of fibre based materials will change physical and chemical properties of textile materials in all aspects.

OBRIGADO PELA ATENÇAO

THANK YOU FOR YOUR ATTENTION

MUCHAS GRACIAS