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The coming era of nanotechnology and the production of polymer fibers: A brief review on nanotechnology

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ABSTRACT

Nanotechnology involve the manipulation of materials on a very small scale in order to build microscopic machinery. Applying the knowledge of the structure of matter, these microscopic materials can be upgraded to complex objects with molecular precision. This area of science and technology is new and is receiving greater attention. Presently, progress is being made towards tailoring the morphology of materials by means of electrospinning process to form polymeric materials and for a variety of applications. In this brief review, the importance and areas of applications of nanotechnology have been examined.

Keywords: Nanotechnology, electro-spinning, nanofibers, polymer fibers.

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INTRODUCTION

It is difficult to predict the future of science and technology. Although, many scientists and technologists have tried to do so, science fiction writers like Arthur Clarke as reported by Drexler [1] explained that it is virtually impossible to predict the details of future technologies for more than perhaps half a century ahead. It is virtually impossible to predict in details which alternatives will become technically feasible over an interval of time. This is simply because if one could see ahead that clearly, one could probably accomplish those things in much less time given the will to do so.

The foundation of technology lies in our ability to arrange atoms. Through out history, variations in the arrangements of atoms have distinguished the cheap from the cherished, the diseases from the healthy. Things around us acts as they do because of the way their molecules behave. Air holds neither its shape nor its volume because its molecules move freely, bumping and ricocheting through open space. Water molecules stick together as they move about, so water holds a constant volume as it changes shape. Copper holds its shape because its atoms stick together in regular patterns; we can bend it and hammer it because its atoms can slip over one another while remaining bound together. Glass shatters when we hammer it because its atoms separate before they slip.

The coming of nanotechnology gives us an insight that what we can do depends on what we can build. This leads to a careful analysis of possible ways to stack atoms. For one thing, assembly machines could be manufactured much smaller even than living cells, and makes materials stronger and lighter than any available today. Hence, better spacecraft. Hence, tiny devices that can travel along capillaries to enter and repair living cells [2]. Hence the ability to heal diseases, reverses the ravages of age, or makes our bodies speedier or stronger than before. Machines could be made down to the size of viruses; machines that could work at speeds which none of us can yet appreciate.

Two styles of technology

Our modern technology builds on an ancient tradition. Thirty thousand years ago, chipping flint was the high technology of the day. Our ancestors grasped stones containing trillions of trillions of atoms and removed chips containing billions of trillions of atoms to make their ax heads; they made fine work with skills difficult to imitate today. Later they made pots by baking clay, then bronze by cooking rocks. They shaped bronze by pounding it. They made iron, then steel and shaped it by heating, pounding and removing chips.

We now cook up pure ceramics and stronger steels, but we still shape them by pounding, chipping, and so forth. We cook up pure silicon saw it into slices, and make patterns on its surface using tiny stencils and sprays of light. We call the products “chips” and we consider them exquisitely small, at least in comparison to ax heads. Our microelectronic technology has managed to stuff machines as powerful as the room-sized computers of the early 1950’s onto a few silicon chips in a pocket sized computer. Engineers are now making ever smaller devices, slinging herds of

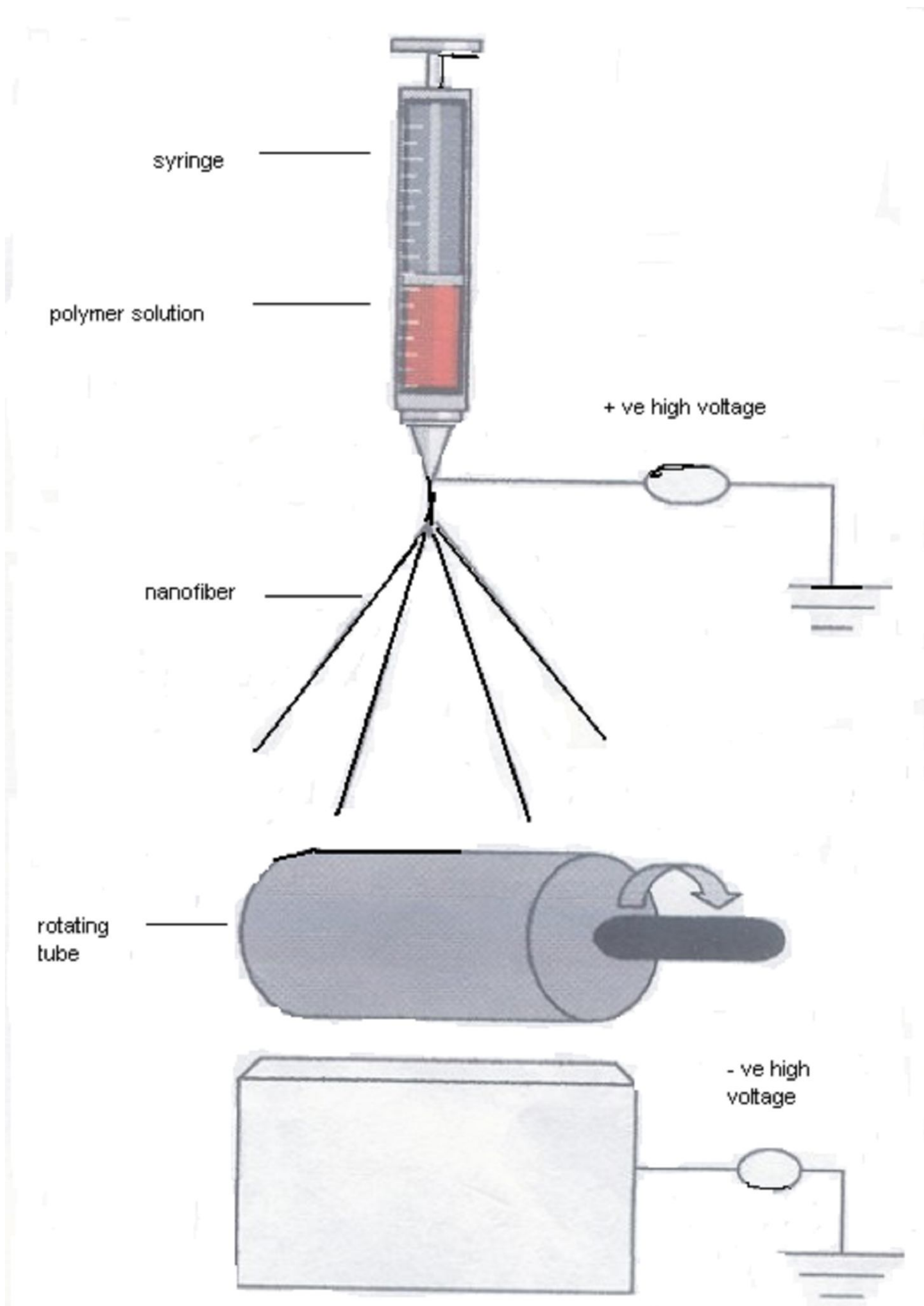

Figure 1: Schematic picture of the electrospinning set up for the fabrication of nanofibers [2].

atoms at a crystal surface to build up wires and components, one tenth the width of a fine hair.

These microcircuits may be small by the standards of flint chippers, but each transistor still holds trillions of atoms, and so-called "microcomputers" are still visible to the naked eye. By the standards of a newer, more powerful technology, they will seem gargantuan.

The ancient style of technology that led from flint chips to silicon chips handles atoms and molecules in bulk; call it *Bulk Technology*. The new technology will handle individual atoms and molecules with control and precision; call it *Molecular Technology* [1]. It will change our world in more ways than we can imagine.

Microcircuits have parts measured in micrometers that is, in millionths of meter but molecules are measured in nanometers (a thousand times smaller). The terms "*Nanotechnology*" and "*Molecular Technology*" can be used interchangeably to describe the new style of technology. The engineers of the new technology will build both nanocircuits and nanomachines.

Nanotechnology is where technology is going [3]. Today's nanoscale science and technology includes research and development on the cutting edge of a broad range of fields. The term "nanotechnology" has been applied wherever scientists and technologists are grappling with the fundamental building blocks of matter, atoms, and molecules.

Nanoscale science and technology includes the frontiers of chemistry, material science, medicine and computer hardware – the research that enables the continuing technology revolution. Work is currently underway [4] to produce nanotechnology equipment to manufacture non-volatile magnetorestrictive random access memory (MRAM) chips, the type most commonly used in personal computers. Dynamic random access memory (DRAM) chips have a volatile memory. Every time a computer is switched on, the information stored on the hard drive has to be reloaded into the memory chip. This is why computers need two to three minutes start up time. The chip also has to be continuously refreshed, draining power from batteries in laptops. The new non-volatile memory chips "remembers" the information when the computer is turned off, eliminating the need for information to be reloaded into the chip every time it is switched on. This enables a computer to start almost immediately, just like a television set.

As nanoscale technologies advance, they will enable the development of molecular manufacturing [5], a more systematic and powerful nanotechnology using nanoscale machines to build large-scale atomically precise products clearly at low cost. This sort of nanotechnology will transform our physical technology from the bottom up, enabling digital control of the structure matter.

Production of nanometer diameter polymer fiber (electrospinning)

Materials with dimensions below 100nm are generally characterized as nanomaterials [6]. Some of the latest attractions in this cutting edge technology are nanofibers, single wall nanotube (SWNT), nanoparticles, etc. Polymeric fibres of submicron diameter can be produced by different methods like electrospinning, meltblowing and spunbonding technologies. Of the different viable techniques, electrospinning is the only well-established process for producing fibers consistently in the submicron range.

Electrospinning is a unique approach using electrostatic forces to produce fine fibers. Electrospun fibers have small pore size and high surface area. There is also evidence of sizeable static charges in the electrospun fibers that could be effectively handled to produce three dimensional structures. The apparatus used for electrospinning is simple in construction which consists of a high voltage electric source with positive or negative polarity, a syringe pump with capillaries or tubes to carry the solution from the syringe or pipette to the spinneret and a conducting collector. The collector can be made of any shape according to the requirements like flat plate, rotating drum etc.

Many researchers [2,6,7,8] have used the apparatus with modification depending on process conditions to spin a wide variety of fine fibers. High voltage is applied to the polymer solution inside the syringe through a connected electrode thereby inducing free charges in the polymer solution. These charged ions move in response to the applied electric field towards the electrode of opposite polarity thereby transferring tensile forces to the polymer liquid. At the tip of the capillary, the pendant hemispherical polymer drop takes a cone like projection in the presence of an electric field. And when the applied potential reaches a critical value that is required to overcome the surface tension of the liquid, a jet of liquid is ejected from the cone tip. Most charge carriers in organic solvents and polymers have lower mobility and hence the charge is expected to move through the liquid for longer distances only if given enough time. After the initiation from the cone, the jet undergoes a chaotic motion or bending instability and is field directed towards the oppositely charged collector, which collects the charge fibers.

As the jet travels through the atmosphere, the solvent evaporates, leaving behind a dry fiber on the collecting device. For low viscosity solutions, the jet breaks into droplets while for high viscosity solutions it travels to the collector as fibers. Over a hundred synthetic and natural polymers were electro-spun into fibers with diameters ranging from a few nanometers to micrometers.

These advanced continuous fibers with nanoscale diameters have revolutionalised the field of structural materials and composite in the last few decades as a result of their high strength, stiffness, and continuity, which in turn, meant processing and alignment that were economically feasible. Fibers mechanical properties are known to substantially improve with decrease in the fiber diameter [9].

Nanofibres are expected to possess high axial strength combined with extreme flexibility. The nanofibre assemblies may feature very high open porosity coupled with remarkable specific surface area. Yet, these assemblies would possess excellent structural mechanical properties.

Nexia of Canada, a leading name in the manufacture of spider silk have suspended its in house conventional spinning of micron-size fibers into the spinning of Biosteel® proteins nanometer diameter fibers [10]. Scientists at the University of Texas have spun super-tough carbon nanotube fibers. The fibers are suitable for weaving into electronic cloth; are four times tougher than spider silk and 17 times tougher than the Kevlar fibers used in bulletproof vest (11). The electrospinning of biodegradable polymer nanofibre tubes for peripheral nerve regeneration have also been reported [2].

CONCLUSION

The uses of nanofibres in composites, protective clothing, catalysis, electronics, biomedicine (including tissue engineering implants, membranes and drug delivery), filtration, agriculture and other areas are presently being developed in laboratories around the world. Clearly, there is a growing interest in the process, but the results reported to date are centered mostly on the empirical production and the proposed uses of polymer nanofibers.

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