Chapter 1
Introduction

It is well acknowledged that Nanotechnology is going to be the next technological revolution that will have a profound effect on all industry sectors and application areas. This new technology, which aims at manipulating the matter at the atomic or molecular level, will have a tremendous impact on the way we work, communicate and live and is, therefore, billed as a major economic driver of the future. An important aspect of nanotechnology is that it is not merely making things smaller but making things differently and more elegantly by going directly to the nature, understanding and leveraging the extraordinary phenomena that have evolved over billions of years.

The Greek word “nano” (meaning dwarf) refers to a dimension, which is one thousand times smaller than a micron. The ability to control and manipulate nanostructures makes it possible to exploit new physical, biological and chemical properties of the system that are intermediate in size, between single atoms, molecules and bulk materials.

The truest example of bottom up nanotechnology is nature. Nature continuously constructs complex, efficient self-organizing and self-regulating molecular machinery and systems for all processes in living organisms. Nature sets the ultimate example for our industrial endeavors. Being able to observe how cells function at the nanoscale has lead to the identification of better drugs and better means of delivering these drugs so they function more effectively.

Nanotechnology has become one of the most important of sectors that is drawing intense interest as it is claimed that it would replace most of existing technology in
use today. It is widely touted to be that important technology that is going to change every aspect of our lives and lead to generation of new capabilities, new products and new markets. It is thus described as an enabling technology that will pave the way for novelty in every stream of technology. Another important aspect associated with nanotechnology is its multidisciplinary nature that makes it very difficult to pin down and prophesize the future impact in any specific sector appropriately. Its impact on society is expected to be widespread and all pervasive.

The molecular machinery of nature, developed during millions of years of the evolutionary process, is among the most fascinating structures on this planet. Out of these, biomolecular motors are of great interest in bio-nanotechnology as these wonderful devices can find a large number of applications in engineering, diagnosis, drug delivery, etc. What is required is to understand their structure and function to take full advantage of biomolecular motors.

Molecular motors are the desire for nanofabricated devices. Generally speaking, a motor is defined as a device that consumes energy in one form and converts it into motion or mechanical power. In terms of energetic efficiency, these types of motors are often superior to currently available man-made motors. Two types of molecular motors are under progress i.e. Biomolecular motors & motors based on organic molecules (synthetic molecular motors). Organic molecular motors are switched on & off using photoactive molecules or are temperature dependent. But limitations of organic molecular motors are their synthesis & also their characterization which involves various spectroscopic techniques.

Biomolecular motors are biological "nanomachines" and are the essential agents of movement in living organisms. These protein-based molecular motors convert the chemical energy in ATP into mechanical energy (Bustamante et al., 2004). The critical elements in molecular motors are the components to mediate the
movement and a fuel to power the catalytic reactions that give rise to the translocation event. In cell, various types of rotary and linear motors exist which help to perform various functions. Rotary motors include ATPase, bacterial flagella, RNA polymerase, helicase and linear motors like actin-myosin (Bloom and Endow, 1995), kinesin-microtubule (Barton and Goldstein, 1996), and dynein-microtubule (Mooseker and Cheney, 1995).

Kinesin and dynein motors move along microtubules and myosins move along actin filaments. The step sizes of these motors are of the order of 10 nm or less. By stepping in a directed fashion along filaments, the motors pull cargo particles which are much larger than the motors themselves. In addition to their importance for the functioning of cells, molecular motors have many possible applications as biomimetic transport systems and are likely to become a key component in the emerging bio-nanotechnology. It is now evident that these motors are required for many cellular processes, including vesicle transport, mitotic spindle formation and cell motility (Goldstein, 2001).

Recently, researchers have begun to shift their efforts towards developing applications that utilize this technology in novel ways, such as part of nanomachines (Knoublauch et al, 2004; Schmeidt et al, 2004) and for the delivery of genes or drugs to the nucleus of cells or to the central nervous system. A successful implementation of these latter applications is on the path of designing an efficient viral mimic because many viruses achieve their high level of infection by hijacking cellular motors (Dohner et al, 2005).

Keeping this in view, it is proposed to study Actin-Myosin biomolecular motor system, which helps in muscles contraction for practical realization of simple, cost effective and easy to fabricate drug delivery, nano-switches and nanorobotics.
Actin-Myosin acts as linear motor & has various applications in the Nanomechanical devices & drug delivery. In-vitro it can be used for transportation of cargos in a “factory on a chip” application & nanofabricated structures to power the Nanomechanical devices. It is possible to extract motors from their native environment, prepare assemblies of them on a plane surface.

The work stated in this thesis is an effort to study the immobilization of myosin on different substrates for nanodevice applications. Myosin will be immobilized both covalently & non-covalently using Poly-L-lysine coated & nitrocellulose –coated glass slides. The covalent immobilization strategy involves the use of heterobifunctional cross-linker N-ethyl-N’-(3-diethylaminopropyl) carbodiimide (EDC). The immobilization level and uniformness of coverage and size of myosin on these substrates is analyzed using Atomic Force Microscopy (AFM).

For practical realization of simple, cost-effective and easy to fabricate drug delivery, nano robots and nano-swithces, the controlled motility of these motor proteins on physical surfaces is to be conducted. A key limitation of this assay is that the motor proteins are disordered on the surface. Thus, methods that can position and orient them would be a major improvement, allowing basic studies of motor-protein function in an ordered arrangement similar to that in the living cell. Furthermore it would open for the use of motor proteins in controlled cargo transportation. Therefore, the effect of various biochemical parameters like pH, temperature, divalent ions, temperature, salts etc. on actomyosin motility in vitro is being studied and an effort is being made to somehow, control the movement of actin filament in in vitro assay system.

The successful understanding and engineering of these motors might lead to applications and solutions to problems beyond those that are only imagined today.
The horizons are broad and the ability to engineer these systems might soon create fact from fantasy.