# Nanotechnology and Its Interface with Automotive Industry

B. Chehroudi, PhD

Although scientist have long been working with "nano' size entities, the birth of the nanotechnology is commonly considered when Richard P. Feynman, a Noble Laureate, gave his famous lecture entitled, "There's Plenty of Room At The Bottom." In this lecture he stated that the entire encyclopedia of Brittanica can be put on the tip of a needle and in principle there is no law preventing such an undertaking. He then challenged the scientific community and set a small monetary reward to demonstrate experiments in support of such a miniaturization. This was addressed by the Northwestern University researchers using a nanotech tool called Atomic Force Microscope (AFM). The term nano refers to a reduction of size or time by $10^{-9}$. As such a nanometer is $10^{-9}$ meter. A human hair thickness is about 50 micron (i.e. $50x\ 10^{-6}$ meter) in size, meaning that a 50 nanometer object is about 1/1000th of the thickness of a hair. To give the readers a feel for the order of magnitudes of small objects, Fig. 1 shows size ranges for viruses, bacteria, atoms, molecules, and others. Size ranges of a few nanotechnology products are also shown in this figure. By far the most popular product in nanotechnology is the carbon nanotubes with their peculiar properties. For example, a single-wall nanotube (0.7 to 2 nanometer in diameter) has the electrical conductivity of copper, thermal conductivity of diamond, highest strength, toughness, and stiffness of any molecule, 100 times stronger than steel, and in compounds, they retain or even improve mechanical properties. It is obvious that nanotechnology, nanoscience, and nanoengineering deal with very small sizes. Officially, National Science Foundation defines it as studies that deal with materials and systems having the following key properties. (1) Dimension: at least one dimension from 1 to 100 nanometers (nm). (2) Process: designed with methodologies that shows fundamental control over the physical and chemical attributes of molecular-scale structures. (3) Building block property: they can be combined to form larger structures. Although the impact of the nanotechnology is rapidly growing and felt in broad areas, microelectronic industry has a tight focus and immediate interest in its growth. As an example, the half pitch of the DRAM (i.e. smallest feature size) is expected to go below the 100 nm mark by 2005. The standard microelectronic fabrication for inexpensive and mass-produced integrated circuit chips can reach to its limit and then we speak of nanofabrication, something not yet converged and subject of intense research.

The essence of the "nano-" science and technology is based on the finding that properties of matters in this size range differ from the bulk material. For example, particles ranging in size from roughly 1 to 50 nm exhibit physical, chemical, optical, magnetic, and other properties that are intermediate between those of the smallest element from which they can be composed (such as a metal atom) and those of the bulk material. As an important automotive application, catalyst performance can be sensitive to particle size because the surface structure and electronic properties can change greatly in this size range. For example, the heat of adsorption for CO and the activation energy for CO dissociation both change with the increasing size of Ni particles catalyst, a pattern that affects the performance of Ni nanoparticles in Fischer-Tropsch synthesis of hydrocarbons from synthesis gas (a mixture of CO and H2). Considering that nearly one-third of the material gross national product in the U.S. involves a catalytic process somewhere in the production chain, the impact of only this one application of the nanotechnology can be immensely felt. In fact, US government forecasts that in just another 10 to 15 years, nanotechnology will impact more than $1 trillion per year in products and services.

Another rapidly growing application of the nanotechnology is in the area of nanocomposite materials with polymeric matrix such as thermoplastics. These are commonly made by processes that lead to impregnation of nanoparticles in the polymeric matrix. Common nanofillers are: clay, carbon black, calcium carbonate, silicon dioxide, and finally carbon nanotubes. Already, Toyota is using polymer nanocomposite in molding composition for timing belt, Mitsubishi uses it for engine cover for GDI engine, and GM employs polymer-clay nanocomposite for occupant step-assist for two of its 2002 mid-size vans (GM Safari & Chevrolet Astro). Another example of use of certain nanoparticles is in paint industry. The color of the car is one of its important selling features. Painting cars is a multi step process involving many layers of coatings. First, there is an electrodeposition layer put on the steel. Then, a primer surfacer is applied, followed by the colored base coat and then the clear coat, which protects the whole paint job from physical and chemical environmental factors. Paint makers are using nanoparticles in paint. For example, PPG Industies is incorporating nanomaterials in clear coats being commercialized for the Mercedes. It was reported to dramatically reduce amount of dullness and cloudiness that develop when you get scratches from washing the car and other environmental factors.

Also, carbon nanotubes could be used to improve batteries. They can in principle store twice as much energy density as graphite, the form of carbon currently used as electrode in many rechargeable lithium batteries. Conventional graphite electrodes can reversibly store one lithium ion for every six carbon atoms. Tiny straws of carbon nanotubes reversibly store one charged ion for every three carbon atoms, double the capacity of graphite. Carbon nanotubes are also being investigated for hydrogen storage. They may be capable of storing amounts comparable to or exceeding the US Department of Energy target of 6.5 % of their own weight in hydrogen, a level considered to be practical for fuel cell electric vehicles.

Finally, due to its size range overlap, applications of the nanoscience and nanotechnology in biological areas, cancer treatment, drug delivery, and many others are rapidly increasing. Nobel Laureate, Richard E. Smalley commenting on the importance of nanotechnology said: “It holds the answer, to the extent there are answers, to most of our most pressing material needs in energy, health, communication, transportation, food, water, etc."

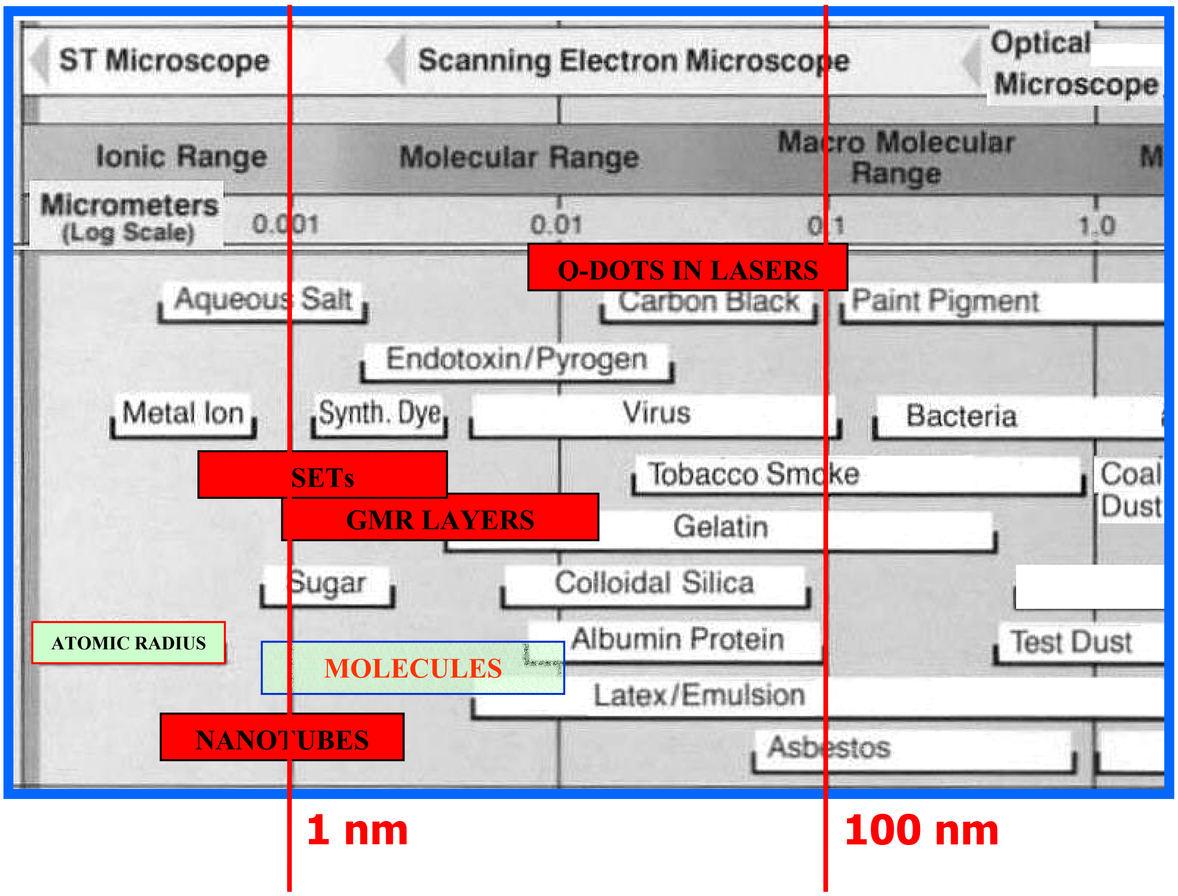


Figure 1. Shows size ranges for many entities as compared to selected nanotechnology products: SET ( single-electron transistor), GMR (Giant magneto resistive), Q-DOTS (Quantum dots).