ZEWAIL CITY: UNIVERSITY OF SCIENCE AND TECHNOLOGY

Introduction to Nanomaterials Synthesis: -
Final Assessment Report:
Introduction to Nanotechnologies and their applications

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IV. Introduction

Nanoscience is the manipulation of materials atomic and molecular structures at nanoscale. Therefore, nanoscience is the study of materials that exhibit remarkable properties, functionality and phenomena due to the influence of small dimensions. In other words, the same material (e.g. gold) at the nanoscale can have properties (e.g. optical, mechanical and electrical) which are very different from the properties the material has at the macroscale (bulk). On the other hand, nanotechnologies are the design, characterization, production and application of structures, devices and systems by controlling shape and size at the nanometer scale. Accordingly, these are referred to as intentionally made nanomaterials. Whereas, non-intentionally made nanomaterials are nano-sized particles or materials that belong naturally to the environment (e.g. proteins, viruses, nanoparticles produced during volcanic eruptions, etc.) or that are produced by human activity without intention (e.g. nanoparticles produced from diesel combustion).

Nanoscience is horizontal-integrating interdisciplinary science that cuts across all vertical sciences and engineering disciplines [1]. Meanwhile, the application of nanoscience to ‘practical’ devices is called nanotechnologies. Not to mention, nature is an expert in making nanoscale structures. Consequently, scientists look to nature for inspiration when researching how to construct at this tiny scale. Biomimicry is often applied by nanotechnologies engineers and scientists, in which they imitate natural models or systems for the purpose of solving complex human problems. One example is that by studying butterfly wings and their nanostructures, scientists have explained how light can interact with surfaces. This has helped design security holograms and hair products. Additionally, many other examples can be found in nature representing how natural nano formations exhibit extraordinary features that can be applied to promising applications. Considerably, a Toucan’s beak exhibits lightweight and strong features due to a rigid foamy inside and layers of fibrous keratin tile nanostructures outside, which in turn is applied in air-craft engineering. Finally, gecko’s ability to walk upside down on a ceiling;

butterflies with iridescent colors; fireflies that glow at night; and plant leaf nano-composition are just some examples of the many naturally existing nanostructures with many applications.

In other words, nanotechnology considers structures having at least one of their three dimensions less than 100 nanometers (nm) [1]. Various natural or man-made nanostructures exist as demonstrated in Fig. 1.

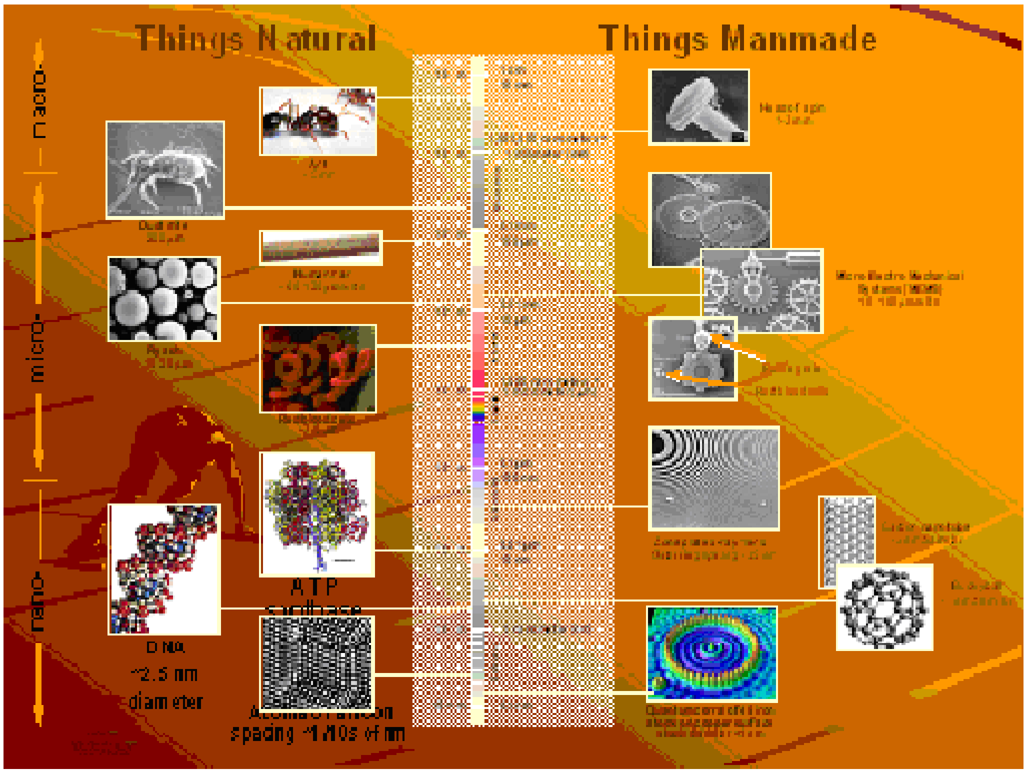

Fig 1. Natural and artificial structures [1]
Source: presentation at the FTF by Dr. Brent M. Segal.

The same material exhibits different properties in nanoscale than those in macroscale due to having relatively larger surface area in comparison to their mass, which makes them more chemically reactive [1]. Additionally, under a few nanometers, the physical laws that govern the particle interactions shift from classic laws of physics to quantum physics, which manages optical, electrical and magnetic behavior with different laws. Furthermore, taking into consideration this definition of nanotechnology and its constituent features to the current research fields, three research trends encompass the field of nanotechnology [1]:

- *Nanotechnology based on dimension:* top-down formulating miniature structures and devices, down to nanometric scales.
- *Nanotechnology based on principles of operation:* investigation of promising new characteristics and properties of substances by manipulating them at atomic or molecular scale.
- *Nanotechnology based on method of fabrication:* bottom-up assembly or molecular self-assembly by conjugating atoms and molecules to form more complex structure.

Finally, Fig. 2 shows the development of nanotechnology (NT) research areas development over time:

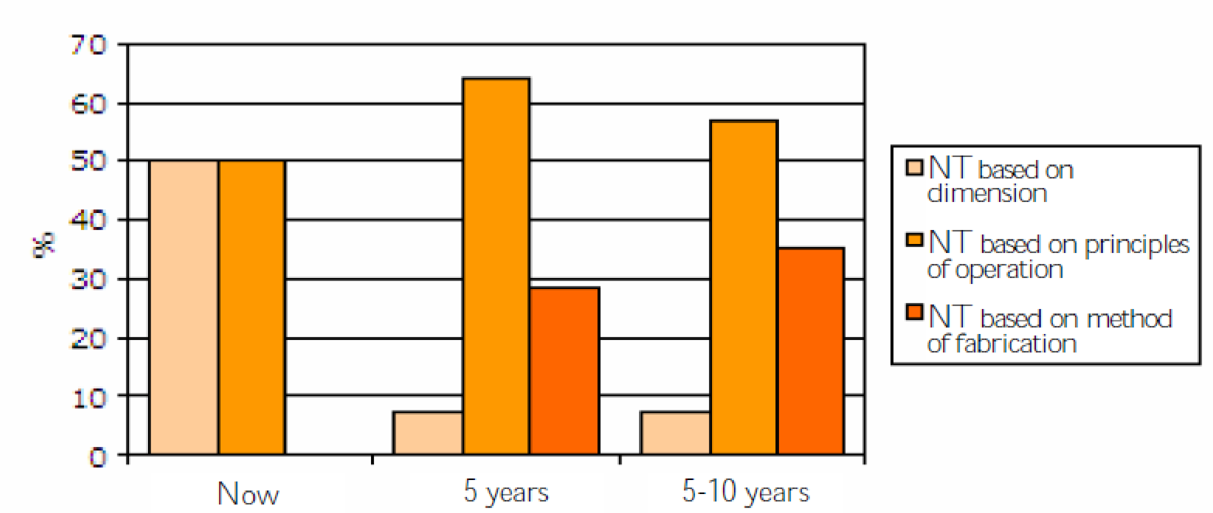

Fig. 2. Development of areas of research of NT [1]

A brief history of the main advances in nanotechnology is retrieved from ref [1] and introduced in Fig. 3:

Fig. 3. Main advances in nanotechnology [1]

In conclusion, nanotechnologies (NTs) encircle a wide range of applications ranging from material science, electronics, medicine, energy, etc. Fig. 4 relates these four areas of application (materials, electronics, medicine and energy) and the three domains of research encompassing NT research areas mentioned in the previous paragraph:

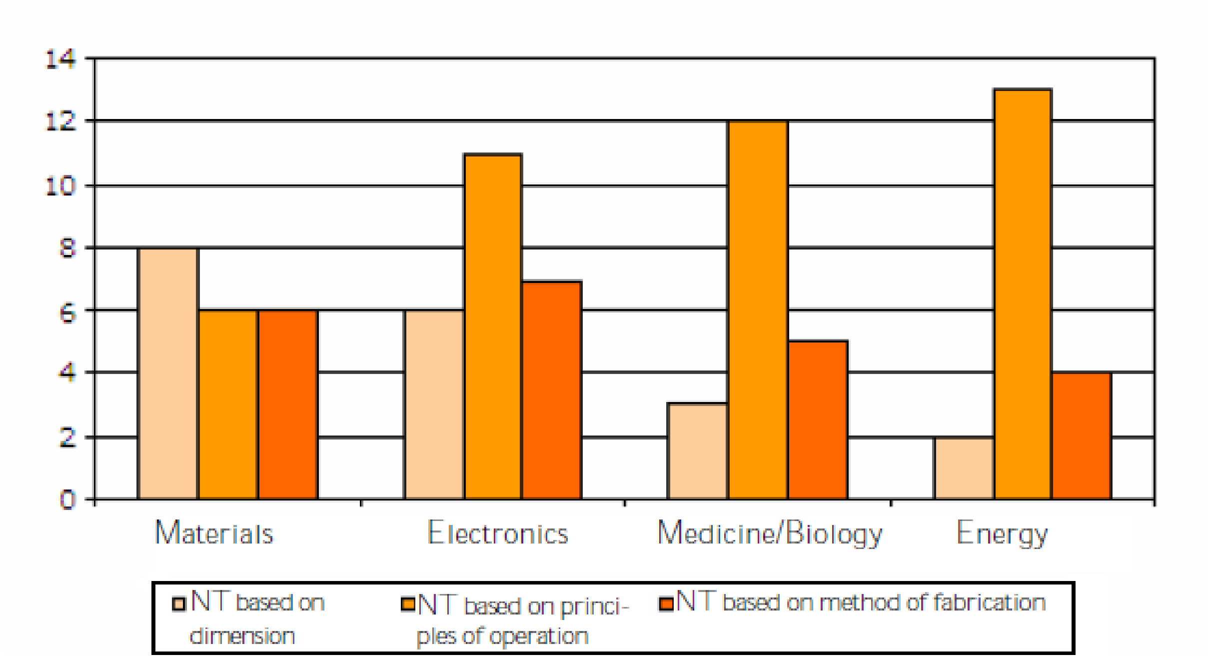

Fig. 4 Trend in nanotechnology in each area of application [1]

The following section will cover the applications of NTs in more details considering the following topics in table 1:

Table 1: List of NTs applications

Topic No.	Application	Pg. No.
1	Biomimetic nanomaterials	
2	Self-assembled nanomaterials	
3	Nanostructured metals and alloys	
4	Nano coatings	

V. NT's Applications

A. Biomimetic nanomaterials

Biomimetics, also termed bionics, biognosis, or biomimicry, is copying and applying concept and behaviors from natural systems in formulating artificial materials, devices and systems [2]. Generally, biomimicry is categorized into two main forms [2]:

- Mimicking mechanisms found in nature. Such as water-proof glue formulated with parallel mechanisms found by studying adhesives constructed by mollusks.
- Utilizing or incorporating nature itself into novel devices. Such as forming new strong but light materials achieved from bone study.

Conclusively, biomimetics at the nanoscale has become much more prominent in the previous years due to advancements in nanotechnologies hardware and software.

B. Self-assembled nanomaterials

"Self-assembled nanomaterials represent non-covalent components assembled into nanosized materials with defined nanostructures" [3]. Like self-assembled nanostructures found in nature, such as subcellular organelles, vesicles produced by cells, etc., artificial self-assembled nanomaterials utilize the same interactions and kinetic/thermodynamic assembly processes in formation [3]. Accordingly, a brief overview of the concepts and classifications of elf-assembled nanomaterials are shown in Fig. 5:

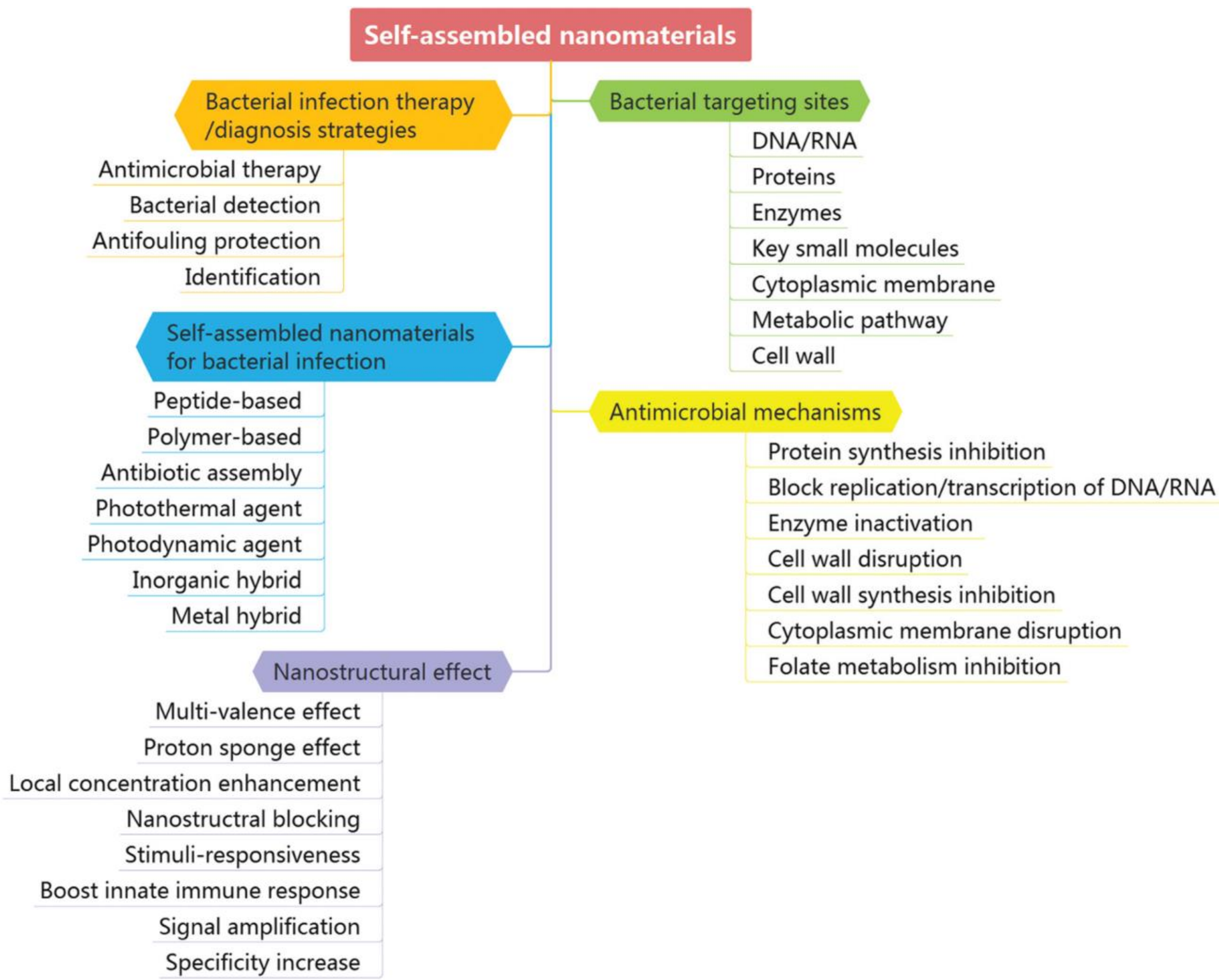

Fig. 5. The self-assembled nanomaterial design concepts, classifications, bacterial targeting sites, antimicrobial mechanisms and nanostructural effect during applications in bacterial infection therapy and diagnosis [3].

C. Nanostructured metals and alloys

Promising new research in the NTs field has focused on producing materials with new and useful characteristics [4]. It is worth mentioning, production of nanocomposite thermites for self-propagating high-temperature synthesis (SHS) applications has gained high favor in recent years [4]. The composite material constitutes particles at the nanoscale having atomic scale proximity but being reaction-triggered [4]. Moreover, these substances consist of a mixture compromising nano-scale metals, metal oxides, and/or organic and inorganic polymer binders [4]. Conclusively, they are applied in overlapping technologies ranging from materials synthesis to local energy generation applications [4].

D. Nano coatings

Essentially, nano-coating or ceramic coating is the procedure of enclosing a surface layer that repels dry particles, water, oil, and dirt upon a body material [5]. Nano coatings can be in both liquid and solid form and introduce various beneficial characteristics [5]. For example, a nano coating can achieve surface scratch resistance, improve hardness, or make it bacteria resistant. Table 2 shows the various types and applications of nano coatings received from ref. [5]:

Table 2: List of nano coatings types applications

Types	Applications
Anti-corrosive coatings	Coating applied to metals that prevents chemical compounds interacting with corrosive materials, thus preventing reactions like oxidation.
Waterproof and non-stick clothing	Hydrophilic coating on clothing that has non-stick applications in furniture, electricals and glass.
Antibacterial coating	Coatings that inhibit growth of microorganisms, which is applied for public transport.
Thermal barrier coating	Aviation industry utilized this type and is usually applied to metallic surfaces.
Anti-abrasion coatings	Applied to prolong the life cycle of the surface by reducing friction.
Self-healing coatings	The filled nano-capsules within coating aid in repairing the surface from scratching. Everyday items including phones and automobile paints apply these coatings.
Anti-reflection coatings	Coating that reduces light reflection on incident side while not increasing transmission.
Anti-graffiti coatings	Not visible by the naked eye, coatings aid governments and companies in removing graffiti.

VI. Summary

Initially, nanotechnologies (NTs) engineering and nanoscience were introduced, defined and explained briefly with examples. Followed by an overview of natural and manmade nanostructures. Furthermore, classification of NTs research fields was carried. Not to mention, a brief overview of the main advances in NTs history was introduced. However, current applications trend as then introduced. Finally, a few specific NTs applications were covered in more detail, covering biomimetic nanomaterials; self-assembled nanomaterials; nanostructured metals and alloys; and nano coatings.

VII. References

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