SIRI SYARAHAN UMUM PROFESOR

NANOSTRUCTURED MATERIALS : LESS IS MORE

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Table of Contents

Forward

The rise in the global population with improved living standards has resulted in the need for more consumables than in the past. The human population has grown from 6 billion in 1999 to 7 billion in 2012, i.e., one billion was added within a duration of 12 years, and it is expected to reach 10 billion by 2050 -2060. However, the planet Earth is facing a depletion of its natural resources, leading to a situation of sharing its limited resources for a larger population; which would require strategic solutions. Nanoscience and technology has emerged as a promising solution based on many properties of nanomaterials as they had provided us with a better way to do things using lesser amounts of materials. Nanostructured materials are defined by ASTM as "materials containing features between approximately 1 and 100 nm and to differentiate those properties different from properties found in either molecules or the bulk (interior) of larger, micron-sized system". Nanomaterials are in use since ages without actually knowing the reasons, probably the earliest being in glazes for early Chinese dynasty porcelain. Artists in Umbria, Italy had generated and used nanomaterials in the art of fabrication during Renaissance period. Serious research activities on nanotechnology began only a couple of decades back especially after the seminal lecture by Prof. Richard P. Feynman entitled "there are plenty of rooms at the bottom".[1] Tremendous progress has been made since then on process development of nanomaterials production with its controlled structure and properties.

This monograph has been prepared with an intention to provide a clear understanding on the origin of properties of nanostructured materials. The development of surface upon nanostructuring and their control on optical and electronic properties of solid is a long researched topic and a clear understanding is reached on this topic. This monograph is organized in two chapters: the first chapter explains the properties of the nanostructured materials with emphasis on surface

properties and the next chapter explains how the properties of the nanomaterials with added performance in a nanostructured renewable energy device, known as, sensitized solar cells. Nevertheless, the surface of nanostructured materials does not only offer beneficial effects but, equally importantly, undesirable effects also. Therefore, the intention of most research on nanostructured materials has been to use the beneficial effects bypassing the detrimental ones. Alternatively, modification of nanostructured materials' surface by tuning on their morphologies has been an intense topic.

Acknowledgements

This monograph has been prepared for the Professorial Inaugural Lecture at my workplace, Universiti Malaysia Pahang (UMP), where I have been since March 2010. I have seen the way the University is emerging from the diligence and vision of her leadership – in a sense, I am given an opportunity to be the part of an emerging University for which I am deeply indebted to the Board of Directors, especially Professor Dato' Dr. Daing Nasir Ibrahim, the honorable Vice Chancellor of UMP. I was treated specially and differently ever since I had reported to my first Dean, Professor Mashitah Mohd Yusoff (presently the Dy. Vice Chancellor of Research & Innovation). She spent many hours every now and then amongst her busy schedule as an administrator, researcher, and lecturer to secure me research grants in which was instrumental in my promotion as the Dean of Research Department. I am also deeply indebted to Professor Jamil Ismail, Dean of Faculty of Industrial Sciences & Technology for his continuous support for my work. I have a huge list of colleagues and collaborators, this page is not enough to list them – you are gratefully remembered!

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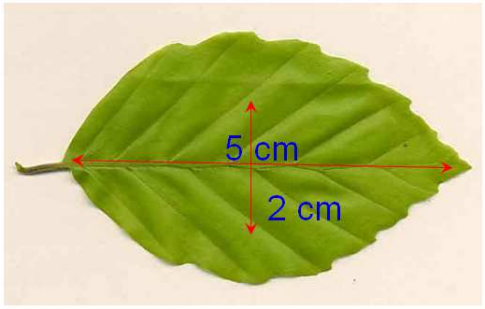
Chapter 1

Nanomaterials and Properties

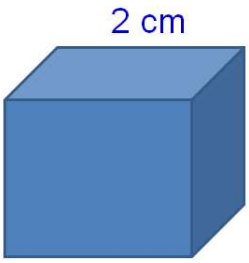
A general way of defining nanostructured materials and their properties are described in this chapter.

1.1 How much is the volume of a material in its surface?

The properties of nanomaterials could be primarily related to the amount of surface they possess. They are also defined by how much fraction of the volume of a material is in its surface. For example, consider a leaf as in Figure 1.1 and compare how much of its volume is in its surface. One would see that ~40% of the volume of the leaf is on its surface whereas a cube of side 2 cm has only 3% of it on its surface.



Surface area =2 × 10 = 20 cm^2
Volume = 10 × 0.05 = 0.5 cm^3
Surface/volume = 40%



Surface area =24 cm^2
Volume = 8 cm^3
Surface/volume = 3%

Figure 1.1: Difference in surface fraction of a leaf and a cube.

To define nanocrystals based on the surface, consider a typical microstructure of a solid material as displayed in the Figure 1.2. These are collections of filled circles representing atoms occupied in respective positions in a crystal lattice – a collection of this filled