

Which nanomaterials have been studied more?

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According to Statnano, the highest number of articles have been written on nanoparticles among the common nanomaterials used in nanotechnology which shows the high importance of nanoparticles in nanotechnology. However, Graphene has the highest amount of h-Index.

Introduction

The term 'nanomaterial' entered the scientific literature of all world states after the appearance of nanotechnology. The concept of nanomaterials was created in the world of science and technology after the invention of scanning tunneling microscope (STM) in 1981 and the discovery of fullerene in 1985 [1].

According to the definition of International Standard Organization ([ISO/TS 80004](#)), nanomaterials are divided into two general categories of nano-objects and nanostructured materials. Nano-object is an object that at least one of its dimensions is at nanometric scale. Nano-objects are divided into three groups according to the definition. Three-dimensional nano-objects are materials that all their three dimensions are at nanometric scale. This group includes many nanomaterials. Fullerene, quantum dots, dendrimers, nanoparticles, and nanopowders are among the most important samples in this group. Two-dimensional nano-objects are objects with two dimensions at nanometric scale. Carbon nanotubes, nanowires and nanofibers are among the most important samples in this group. One-dimensional nano-objects are the materials that have only one dimension at the nanometric scale and their two other dimensions are larger than nanometric scale. Nanocoatings, graphene, self-arranged single layers, and Langmuir-Blodgett films are classified in this group. There exist some nanomaterials that are not classified in any of the three categories.

For instance, to which category do nanocomposites belong? Therefore, another group of nanomaterials has been defined in this standard entitled nanostructured materials. Although none of the dimensions of nanostructured materials are nanometric at normal conditions,

either one of the components in their structure is a nano-object or they have nanometric structure from microscopic or morphological points of view. Nanocrystalline materials and nanostructured coatings are other instances of the objects in this group [2]. It is mandatory to evaluate the role and importance of each of the nanomaterials in the development of nanoscience and nanotechnology because the type of nanomaterials used in the products determines the properties and characteristics of the final product. Therefore, efforts have been made in this report to study the trend of changes in the use of these nanomaterials during the past years by referring to the number of published articles on each of the nanomaterials.

Methodology

It is necessary to study the trend of changes in nanomaterials in the field of nanoscience and nanotechnology since nanomaterials are considered as one of the most important parts of nanotechnology and the majority of the magic in this technology depends on the type of the nanomaterials. In order to study this method, appropriate search string was used to search nanostructures in ISI-indexed articles in ISI Web of Knowledge Databank.

Trend of Changes in Nanomaterials

Figure 1 demonstrates the number of published articles containing various nanomaterials in 2004-2013. Nanoparticles have possessed the first rank among nanostructures with significant difference. Nanotubes, nanocrystallines, nanowires and nanocomposites possess the next ranks after the nanoparticles. It seems that nanoparticles have the most application among nanomaterials. Since nanoparticles of every materials can be produced only by reducing the size of the material, it is natural that nanoparticles are the most commonly used nanomaterials in articles.

In addition, some of nanoparticles synthesis methods are very simple such as grinding of bulk materials, milling, and chemical reduction [4-5], and it helps the production of nanoparticles. Therefore, the use of nanoparticles is the simplest and first step for many researchers to enter the world of nanotechnology. 'Nanoparticles' is a general word, and it sometimes refers

to various nanomaterials such as nanocrystallines, nanorods and nanospheres. This fact is a reason for significant increase in the use of the word nanoparticles in articles.

Nanotubes, specifically carbon nanotubes, possess the second rank after nanoparticles in the history of discovery and application of nanomaterials. Therefore, nanotubes have had great opportunity to be used in research projects all over the world in the last decade. In addition, numerous researches are being carried out on carbon nanotubes due to their specific characteristics in various fields such as electronics [6-7], sensor production [8] and composite strengthening [9].



Figure 1 - Number of Published Articles Containing Various Nanomaterials in 2004-2013

Figure 2 shows the trend of articles related to most commonly used nanomaterials in 2004-2013. Similar to Figure 1, nanoparticles are much ahead of all other types of nanomaterials. The number of articles related to nanoparticles has increased during the past two years with unique slope.

The trend implies to the fact that although some of the production methods for nanoparticles are simple and these nanomaterials have more application among other nanomaterials, the effectiveness of nanoparticles in various sciences has been proved to researchers, and it is one of the reasons why researchers are interested in nanoparticles. The increasing pattern in other nanomaterials is similar to this chart. However, there is a different pattern for graphene. This material entered the field of nanoscience and nanotechnology in 2004, and its discoverers were awarded with Noble Prize in physics in 2010.

During the past few years, unique properties of graphene have been discovered and introduced to the scientific societies by various researchers all over the world [10-11]. Some of the properties may overcome the problems in different industries. That is why many studies are being carried out on graphene, to the extent that it has had a higher growth in comparison with other nanomaterials except for nanoparticles.



Figure 2 - Trends of Nanomaterials in ISI-indexed Articles in 2004-2013

Figure 3 demonstrates h-index for articles containing various nanomaterials based on the number of articles in 2003-2014. H-index is an index that shows scientific efficiency and effectiveness of a subject, person or organization in a quantitative manner. The index is calculated by counting the number of highly cited articles for each person and the number of citations made by other researchers [12]. As is seen, nanoparticles are ahead of all other nanomaterials both in the number of articles and in h-index value.

Graphene has a very interesting position in this chart because it has the highest value of h-index among other nanomaterials. Graphene's first rank in h-index value shows the scientific effectiveness of this nanomaterial in the past decade, and it confirms the importance of this material in nanotechnology development. Taking into account the ascending trend in the number of graphene-related articles and its high value of h-index, it is considered as one of the hottest nanomaterials in addition to nanoparticles and nanotubes. Nanotubes and nanocrystals have the highest value of h-index after nanoparticles and graphene. The lowest number of citations belongs to nanocapsules and colloidal particles.



Figure 3 - H-Index of Various Nanomaterials Based on the Number of Articles in 2003-2014

Countries' Share of the Published Articles

One question in this field is on what nanomaterials has each country focused? [China](#) and the [United States](#) have published the highest number of nanotechnology-related articles [13]. Therefore, it is obvious that these two countries possess the first and second ranks in each nanomaterial. The [United States](#) has published the highest number of articles on quantum dots, quantum wells, colloidal particles, self-arranged single layers, nanocoatings, fullerene, quantum computers and dendrimers while the majority of articles published in [China](#) were related to graphene, nanocapsules, nanospheres, nanofibers, nanorods, nanowires, super

molecules, nanocomposites, nanoporous materials, nanotubes, nanocrystals and nanoparticles.

In the field of nanoparticles, [India](#) and [Japan](#) have published the highest number of articles after [China](#) and the [United States](#). [Japan](#) and [South Korea](#), [India](#) and [Japan](#), and [India](#) and [South Korea](#) have possessed the second and third ranks in nanotubes, nanocrystals, and nanocomposites, respectively. [Iran](#)'s best position in nanomaterials was in nanocomposites while its lowest rank was obtained in quantum wells.

It can be concluded that the highest number of articles have been written on nanoparticles among the common nanomaterials used in nanotechnology which shows the high importance of nanoparticles in nanotechnology. Nanotubes and nanocrystals possess the next ranks after nanoparticles. There is a new nanomaterial named graphene and the number of articles related to it is increasing. Graphene has the highest value of h-index among all other nanomaterials, which proves the importance and potential of this nanostructure. It is expected that graphene would enter the market of nanotechnology products in the coming years stronger than any other nanostructures.

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