A review of the current research in nano dynamics research

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Abstract

This paper aims to review the available literature on the recent trends in nano physics and the dynamics of nano physics. In order to do this, open-source articles from Google Scholar were used. An attempt was made to select studies spanning the past few decades so as to analyse the trends in nano physics and nanotechnology over the years, especially since advances in this field have improved exponentially in recent years. Using a set of criteria, approximately 500 scholarly works were initially analysed and then reduced to a smaller number. The selected papers were then explored in detail. It was found that the field of nano physics has had a bearing on other fields across the sciences. It has paved the way for nanotechnology, which in turn has led to the development of nanoscience – a discipline that lies at the intersection of various fields using nanotechnology. Although this means that nanotechnology has allowed for pioneering research in fields as diverse as ICT and renewable energy, there are environmental and social impacts that must be considered. The proliferation of nano physics and nanotechnology into every aspect of life dictates that research regarding these fields must be made more widely available so as to allow for better awareness.

Keywords: Nano physics, nanotechnology, nano physics dynamics, nano science

Introduction

Nano means one billionth. Simply understood, the term is used as a prefix to denote the scale at which research is being done, for example, nanotechnology, nanometer, nanoparticles, etc. It is represented as 'n' and can be used in reference to measuring units of time (nano second) and length among things. Nanoscale is one-billionth of a meter and is smaller than the wavelength of light. Thus, the study of matter at this scale is referred to as nanotechnology. The research that comprises nanotechnology can vary from chemistry and biology to physics and engineering. The foundation for the ideas and concepts related to this was laid by the lecture titled *Plenty of Room at the Bottom* by Richard P Feynman. In this lecture, Feynman (1959) laid out 'the problem of manipulating and controlling things on a small scale' and gave examples of application across diverse fields (Feynman, 1959). Hence, although the study of such a small scale was not intended for any one area of study, it has been found to be valuable for research in science and especially for physics. With this context, it is easy to understand that nano physics relates to 'the physics of structures and artefacts with dimensions in the nanometre range or of phenomena occurring in nanoseconds' (TheFreeDictionary). Sattler (2010) continues to explain and states that 'nanophysics brings together multiple disciplines, using theoretical and experimental methods to determine the physical properties of materials in the nanoscale size range' (Sattler, 2010: ix). Some of these properties include 'the structural, electronic, optical, and thermal behavior of nanomaterials; electrical and thermal conductivity; the forces between nanoscale objects; and the transition between classical and quantum behavior' (Sattler, 2010: ix). This has led nano physics to become an independent branch of physics, interacting with other disciplines such as engineering and life sciences. Nano science, then relates to the understanding of properties of various materials at this nano scale. Additionally, it also involves understanding the impact and

effect of decreasing the size of these materials to such a small scale (The Royal Society, 2004). Research at this scale has enormous benefits for diverse fields and has therefore seen an increase in the amount of investment it has received not only from corporations but also from governments. However, while the benefits of nanotechnology and nano physics are evident, it is not an area devoid of its share of limitations and risks.

It is in this context that this review paper seeks to address the gap that exists in providing an overview of the strides made in nano physics in recent decades. Although there is a plethora of information on the technical aspects of nanotechnology and nano physics, a preliminary and overarching analysis, one that also encompasses the risks posed by nano science is still lacking.

In the following sections, the search conducted will be explained, followed by the findings of the review and what the various studies reveal about the recent trends in nano physics dynamics. This will be followed by a conclusion that will sum up the arguments and discuss the scope for future interventions and research.

Methodology

In order to find relevant research studies specific terms were used in Google Scholar. These were the following:

- Nano physics
- Nano physics dynamics
- Nanotechnology + research trends
- Nano physics research
- Nano science research

For each individual search term, 100 results were considered, for a total of 500 results. For these, an initial examination was conducted, using research studies that spanned several decades. However, an attempt was made to concentrate on studies after 2000. This is because even though nanotechnology is not a recent phenomenon, technology and research into nano physics and nanotechnology has progressed manifold in the past few years. This study seeks to fully understand the landscape of such research. This is especially in light of the advancements made in technology in the past few years and the various fields that have been influenced by such advancement in the study of nano physics, nano science and nanotechnology.

Results

In order to fully understand nano physics and its influence across fields, Purohit, Khitoliya and Purohit (2012) state that the bottom up and the top-down approaches of nanotechnology must be understood. In the bottom-up approach, they explain, ‘materials and devices are built from molecular components which assemble themselves chemically by principles of molecular recognition’ (Purohit, Khitoliya & Purohit, 2012:3). In other words, smaller components are arranged into complex assemblies. Conversely, in the top-down approach, smaller devices are created ‘using larger ones to direct their assembly’ (Purohit, Khitoliya & Purohit, 2012:3). This allows for their application to be varied across fields, commodities and sciences.

Nano technology has been a valuable component of scientific research for several decades. It has been utilised by industries in the form of semiconductors, for instance, and has seen exponential

growth in the past two decades in order to enhance our understanding of the dynamics of how matter behaves at such a small scale (The Royal Society, 2004).

Mobasser and Firrozi (2016) find that sustainable energy is one such field that has benefited enormously from the study of nano physics, nano science and nanotechnology. This is because 'nanostructured solar cells' provide a clean and affordable resource for renewable energy (Mobasser & Firrozi, 2016:84). In addition to this, they state that nanotechnology has been employed in the use of new types of batteries that are not only more efficient but also more sustainable (Mobasser & Firrozi, 2016). Efficient lighting systems too, have benefited from the use of this technology in leading the way for renewable sources of energy to be deployed and made widely available. It is found that nanotechnology also has the potential to improve the filtration and purification of water, thereby proving to be a valuable resource in making clean and safe drinking water available to people (Mobasser & Firrozi, 2016).

Nano engineering has also proved to be useful in the development of what Mobasser and Firrozi (2016) call 'future transportation applications' (Mobasser & Firrozi, 2016:85). This is because nano engineering of the various materials used for transportation applications such as steel and concrete allows for the longevity of these materials. In addition to longevity, nano engineering also makes these materials more resilient, thereby allowing for an improvement in their performance (Mobasser & Firrozi, 2016). In addition to the discussion about the value of nano physics for renewable energy and the efficiency of materials used in transportation, nanocrystalline materials have also been found to be more resilient and longer-lasting. Examples of this would include tungsten carbide, titanium carbide and their counterparts, which are often used for the purpose of making drills which are in turn utilised 'to bore holes in circuit boards' (The Royal Society, 2004:10). Other valuable uses of nano physics include nanoparticles and nanowires (The Royal Society, 2004). However, while these are all materials that are used on a larger scale, items of daily use have also benefited from nano physics. Examples of such daily use of nano particles include paints, which utilise the technology in order to improve performance.

Discussion

The review paper thus far has focused on the examination of the meaning and the role of nano physics that has allowed for technological advancements and innovation. It is evident from the above that although nano physics pertains chiefly to the structure of materials at the smallest scale, their impact cannot be overstated. The uses of nano physics vary from engineering and sustainable energy to paints and fuel. It has also been argued that nanotechnology sits at the intersection of multiple disciplines. While this allows for the field to be more interdisciplinary in its research, it also makes it difficult to segregate the impact it can have on a specific field without considering how it interacts with other fields. This interdisciplinary nature of nanotechnology has led to the birth of an entirely new discipline which has come to be known as nanoscience (Sattler, 2010:1). This has meant that over the years, the research conducted regarding nanotechnology has also had to be interdisciplinary. Nanotechnology has also been extensively used outside physics and chemistry, for example for the advancement of information and communication technology. A prime example of this can be found in the development and usage of computer chips (The Royal Society, 2004). Another example of the use of nanotechnology from the field of information and communication technology or ICT is that of information storage. This is noted with the development of devices such as the compact disk

(CDs) and Digital Versatile Disk (DVDs). It is anticipated that the trend for 'miniaturisation' will continue in this field, thereby making nanotechnology indispensable for ICT (The Royal Society, 2004:18).

Nano science has been used with great success in the field of bio-nanotechnology, especially with regard to 'disease diagnosis, drug delivery and molecular imaging' (The Royal Society, 2004:20).

While the benefits of nanotechnology and nano physics have been explored in the review paper thus far, it is also imperative to understand its limitations and risks. One of the key concerns that are found regarding the use of nanoparticles pertains to its toxicity. Studies have suggested that with the increased presence of nanoparticles especially in medical applications, it is yet unclear as to whether these materials are biodegradable or not as well as what their long term effects may be (The Royal Society, 2004). In addition to this, research into the toxicity of nanoparticles and fibres is still in its nascent stages. The effects of such particles on the environment and on other species still need to be investigated further. This is especially with regard to nanoparticles that are found in the soil and in water, leading to their contamination and what has been labelled as 'eco toxicity' (The Royal Society, 2004:46). This toxicity, in turn, has the potential to contaminate food and have severe health impacts on humans and animals.

Nanotechnology also presents certain social and ethical issues, both positive and negative, that must be examined. One such issue is the economic benefit that nanotechnologies have the potential to provide for a country's economy. An increase in the efficiency of the materials utilised in industries and for various services would allow for a subsequent decrease in waste over time. Another issue is the potential it has to create a divide between richer and poorer countries and the access the poorer countries have to cutting edge technological advancements that could benefit their citizens. With an increased reliance on nano science and nanotechnology in various fields, corresponding efforts must be made to make this technology and research more accessible. Additionally, it is argued that 'low cost technology solutions to health and environmental problems' may be found at an even lower cost and in a more sustainable manner with the use of nanotechnology in the near future (The Royal Society, 2004).

An ethical concern has also been raised regarding human enhancement that is made easier with the use of nano science. Cochlear and retinal implants have proven to be valuable by-products of nanotechnological advancements. However, concerns have been raised about human enhancements and its potential misuse. Perhaps the most significant among these concerns is gene therapy and its potential for exploitation for eugenics (Buchanan, Brock, Daniels & Wikler, 2002). A debate also arises while discussing the use of nanotechnology for military purposes. While the use of nano sensors for the early detection of chemical and biological threats is welcome, it is anticipated that the use of nanotechnology for military purposes could result in a new arms race (Arnall, 2003). In addition to this, nanotechnology, genetics and robotics in themselves also have the potential to 'spawn (a) new class of accidents and abuses' (The Royal Society, 2004:56). Therefore, it is imperative to fully assess the positives and the negatives of nano science while also ensuring that the advantages of its usage are made accessible to countries that can benefit from it the most. Perhaps the most vital case for this can be made in the context of utilising nano science to make clean drinking water available to poorer regions of the world as has also been discussed in earlier sections of this review paper.

Conclusion

This review has attempted to provide an overview of the current trends in research in nano physics and its dynamics. The field, which pertains to how matter behaves at the nano scale, has seen exponential technological advancements in the past few decades. Nanotechnology and nano particles are now used in nearly every field and have allowed for innovations regarding diverse areas such as ICT and renewable energy. Hence, nano physics has paved the way for a more interdisciplinary nano science. However, given the field's interdisciplinary nature, this means that its risks and weaknesses must also be examined from an interdisciplinary lens. Concerns have been raised regarding the use of nano particles and its implications for not only human health but also animal health and the environment as a whole. In addition to this, the impact of nanotechnology regarding the social and ethical issues that it raises, require closer examination. While the focus has tended to be on the successes and advantages of nano science, the risks and concerns require research with as much rigour. In order to fully appreciate the dynamics of nano physics and its implications on nano science and other fields, a holistic view has been argued for. The risks involved with the rising proliferation of nano physics and nanotechnology into every aspect of human life, require wider awareness about the research, its advantages as well as its disadvantages and threats. In addition to this, there is a need for robust policymaking to be informed by such research. This review paper takes the first step in this direction by providing the means to understand these dynamics in an overarching sense. There is scope for examining this area further, and attempts must be made to adopt an interdisciplinary approach to do so in the future.

References

Arnall A H (2003). Future Technologies, Today's Choices: Nanotechnology, Artificial Intelligence and Robotics – A Technical, Political and Institutional Map of Emerging Technologies. Greenpeace Environmental Trust: London

Bayda, S., Adeel, M., Tuccinardi, T., Cordani, M., & Rizzolio, F. (2019). The History of Nanoscience and Nanotechnology: From Chemical-Physical Applications to Nanomedicine. *Molecules (Basel, Switzerland)*, *25*(1), 112. https://doi.org/10.3390/molecules25010112

Buchanan A, Brock D W, Daniels N & Wikler D (2002). Chance to Choice: Genetics and Justice. Cambridge University Press: Cambridge, UK

Feynman, R. (1959). *Plenty of Room at the Bottom* [Lecture]. Retrieved from https://web.pa.msu.edu/people/yang/RFeynman_plentySpace.pdf

Mobasser, Shariat & Firoozi, Ali. (2016). Review of Nanotechnology Applications in Science and Engineering. *Journal of Civil Engineering and Urbanism*. 6. 84-93.

Purohit, K., Khitoliya, P., & Purohit, R. (2012). Recent Advances in Nanotechnology. *International Journal Of Scientific & Engineering Research, Volume 3*,(Issue 11).

Sattler, K. (Ed.). (2010). Handbook of Nanophysics. Boca Raton: CRC Press, https://doi.org/10.1201/9781420075410

The Free Dictionary (2020). Retrieved 22 November 2020, from https://www.thefreedictionary.com/nanophysics

The Royal Society. (2004). Nanoscience and nanotechnologies: opportunities and uncertainties. Retrieved from https://royalsociety.org/topics-policy/publications/2004/nanoscience-nanotechnologies/