



Science

A REVIEW ON USAGE OF NANO-PARTICLES IN NUCLEAR POWER PLANTS

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Abstract

Nuclear power plants are big in construction and possess complex facilities. These plants usually operate at very large temperatures and the materials used in their construction experience considerably higher levels of radiation. It is therefore very important to understand the effects of radiation on these materials. Radiation is responsible for defects which affects the strength and performance of the materials. In this review paper, we have suggested one idea for constructing an efficient nuclear power plant by using nano-particles. This paper also details about nano-particles in an elaborated way and a few of them can be used for constructing nuclear power plants (NPP).

Keywords: Radiation, Nano-particles, Steel, Nuclear Power Plants (NPP).

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1. Introduction

Fissile materials like ${}^{235}_{92}\text{U}$ are used in a nuclear reactor where a continuous fission reaction occurs as shown in Fig. 1. This continuous reaction releases high radiation and enormous heat energy, i.e. nearly 200 MeV.

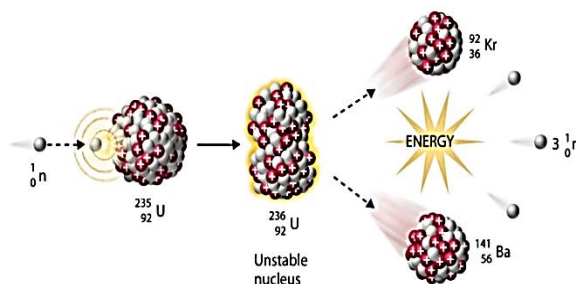


Figure 1: Fission reaction with ${}^{235}_{92}\text{U}$

Due to this radiation and heat, sometimes these reactors may breakdown by developing cracks (breakages) in the materials from which these reactors are constructed. To avoid this type of situation, nuclear reactor must be made up of those materials which possess red-hot hardness.

The hot hardness is a property in which a material is capable of bearing high radiation and heat for a long duration without developing cracks in it.

Taking these factors into consideration, many scientists and researchers are working very hard and conducting lots of experiments on the topic - what if nano-particles are used for constructing a nuclear reactor!

In this review paper, few research ideas and approaches are studied for constructing a nuclear power plant using nano-particles.

1.1.Nanotechnology And Nano-Particles

Nanotechnology deals with a new approach for making things by understanding and controlling the fundamental building blocks (i.e. atoms, molecules) [1]. Nanotechnology is well-defined and well- structured. A material science based approach to nanotechnology leads to the development of nano - particles. Those materials with structure at nano-scale always exhibit unique electro-mechanical properties [2].

1.2.Synthesis

In order to attain our desired properties, a method has to be designed for nano-particles by controlling their size ($\approx 1 - 100\text{nm}$). Basically, there are two models used for developing nano-particles:

- i. Top down model
- ii. Bottom up model

These two models are fundamentally different, both in the approach for creating structures and in the underlying science that will make them possible [3].

In “*Top down*” model, as shown in Fig. 2, the size of structures is reduced to nano size by means of machining and etching techniques.

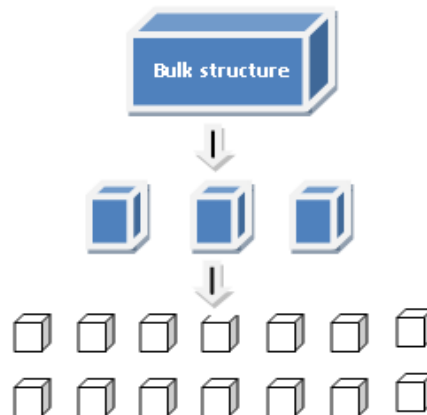


Figure 2: Top down model

Bottom up, model, shown in Fig. 3, suggests the précised or concentrated self-assembly of atoms and molecules to create structures. Generally, it is also known as the molecular nanotechnology [4]. Bottom up model is categorized into – ‘Chaotic process and controlled process’.

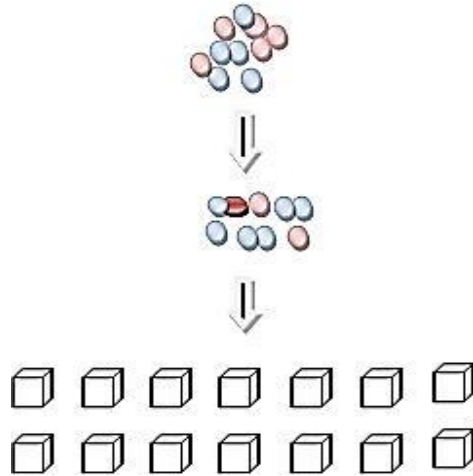


Figure 3: Top down model

2. Nuclear Materials

The fission reaction produces enormous amount of heat. Also, Nuclear Power Plants operate at very high pressure and temperature. So, the materials used in their construction experience significantly higher levels of radiation, temperature, and pressure. Due to these factors, there is a chance of occurrence of cracks in materials used for the construction of Nuclear Power Plants. Therefore, there is a need of such materials in the construction of nuclear reactors, which deliver the capacity to keep up against high temperature and radiation flux in an extremely corrosive environment for a long duration deprived of failure [5]. So, in order to shape these goals, one has to focus on developing such materials which can withstand these extreme conditions. One of the available solutions to achieve this is the use/design of nano-particles which are compatible with nuclear power plants deprived of any failure.

2.1. Use of Nano-Particles in Nuclear Industry

The goal is to design a material which will work in extreme conditions (i.e. very high pressure, temperature, etc.) without any failure. To accomplish this goal, designing a material from its atomic level can be a possibility. Nanostructured metals and composites suggest a way to accomplish this goal because they comprise of interfaces that attract, absorb and annihilate the line and defects [5]. Controlling radiation-induced-defects via interfaces plays a crucial role in the removal of damages and also transmits the stability in nano-particles under certain circumstances where bulk materials demonstrate void swelling and/or embrittlement [5].

Steel is the widely used material in nuclear power plants (for control rods). The utilization of nano-particles in the steel will help in enhancing the mechanical, thermal, and physical properties of the steel. The structural failure of the steel is due to the cyclic loading. This delivers a considerable impact on the nuclear power plant's life-cycle. This may result in cracks

initiation. The addition of copper nano-particles in steel minimizes the surface unevenness. This results in the confinement of the amount of stress risers and further in fatigue cracking [6].

3. Conclusion

The outcome of the survey shows that designing a material from its atomic level will aid us in achieving our goal. It further depicts that constructing a nuclear power plant by using nano-particles increases safety, stability, durability, and also minimizes the tedious work of regular inspection. The forthcoming era belongs to the nanotechnology. The development of nano-particles will take us to a revolutionary world of design and manufacturing with much better energy, efficiency, sustainability, and adaptability to the changes.

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