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Nanotechnology applied for improving research in electrical domain - a survey

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ABSTRACT

Research activities in the field of nanotechnology have paved way to improvisation and progress in various fields globally. Since its tremendous development, it has extended its hands in almost all domains and in the past few decades it has also been a foundation for new technological advancement in electrical domain in particular. This field has given the way in development of new materials which has really improved the electrical characteristics like dielectric, insulation of materials which are conventionally used and therefore enhanced their performances in various applications. This paper tries to bring out a glimpse of its applications in past developments and future opportunities listed by various authors particularly in the field of electrical engineering.

Selection and peer-review under responsibility of the scientific committee of the Emerging Trends in Materials Science, Technology and Engineering.

1. Introduction

Nearly seven decades have gone since the concept of nanotechnology was introduced by Nobel laureate Richard Feynman. In the year of 1959 his famous speech "There's plenty of room at the bottom" he grasped the attention of the globe. This field depends on the inputs from various domains like chemistry, physics, material science, biology, engineering and pharmaceutics. Research organization at various level globally publish huge amount of articles [1] and they are listed in the Table 1 and data shows that china in particular has pioneered in this field through their publications which also is represented pictorially in Fig. 1.

The information provided in the Table 2 and Fig. 2 would clearly emphasis that the importance given to research in the field of nanotechnology [2].The data is based on the information obtained from United States Patents and Trademark Office (USPTO) and European Patents Office (EPO) during the year 2017.

In India the number of patents filed in this field of nanotechnology since 1997 to 2010 is around sixty four out of which twenty four are filed by industries and sixteen are filed by Council of Scientific and Industrial Research (CSIR), seven from Indian Institute of technologies (IITs) and remaining are filed by private individuals [3]. Nanotechnology is diversified in many ways by various authors in the literature as top-down nano and bottom-up nano [4–6]. A detailed study about the classification of the nano materials as nano materials, nano electronics, bio-nanotechnology, and nano manufacturing and tools is done in [7]. Improvisation of electrical conductivity in nanofluids is presented in a detailed manner in [8,9].

2. Nano material usage in electrical field

Several industries have improvised its products by applying nano science and nanotechnology. The introduction of the nanotechnology concepts has brought considerable improvements in the performance and the reliability of the conventional materials. These nano technological efforts considered and utilized in Electrical industries in the manufacturing of its components, such as motors, generators and electrical transformers, the main elements in the electricity network has shown remarkable changes. The thermal withstanding capacity and the performance of single phase induction motor are done using nano fillers. The motor windings are coated using a enamel filled with Alumina and silica nano particles in the ration of 1:4 is done in [10] which has shown a considerable reduction in the temperature to 9.5% and 8.6% during daytime and nighttime respectively and also an improvisation in efficiency of 19.07% and 13.08% during daytime and night time respectively can also be visualised in Fig. 3 and Fig. 4.

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Table 1
Top 10 nanotechnology research organization based on research publication (till 2012) [1].

Rank	Organization	Country	Scientific publications
1	Chinese Academy of Sciences	China	29,591
2	Russian Academy of Sciences	Russia	12,543
3	Centre national de la recherche scientifique	France	8,105
4	University of Tokyo	Japan	6,932
5	Osaka University	Japan	6,613
6	Tohoku University	Japan	6,266
7	University of California, Berkeley	United States	5,936
8	Spanish National Research Council	Spain	5,585
9	University of Illinois	United States	5,580
10	MIT	United States	5,567

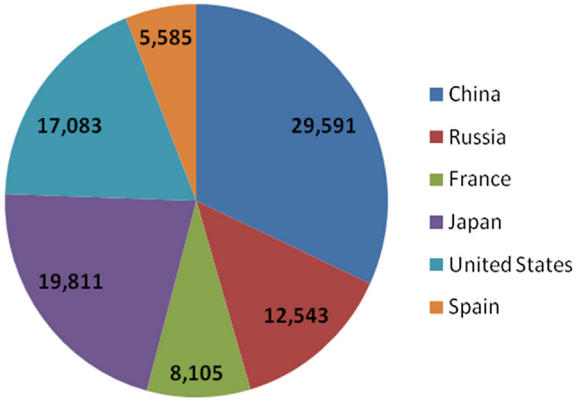

Fig. 1. Number of Scientific publications country wise (till 2012).

Table 2
Top ten countries in the number of nanotechnology granted patents published in USPTO and EPO in 2017 [2].

Rank	Country	Granted patents in USPTO	Granted patents in EPO
1	USA	4725	669
2	South Korea	1044	166
3	Japan	733	265
4	China	524	64
5	Taiwan	490	15
6	Germany	378	354
7	France	235	236
8	UK	144	89
9	Netherlands	122	69
10	Canada	119	29

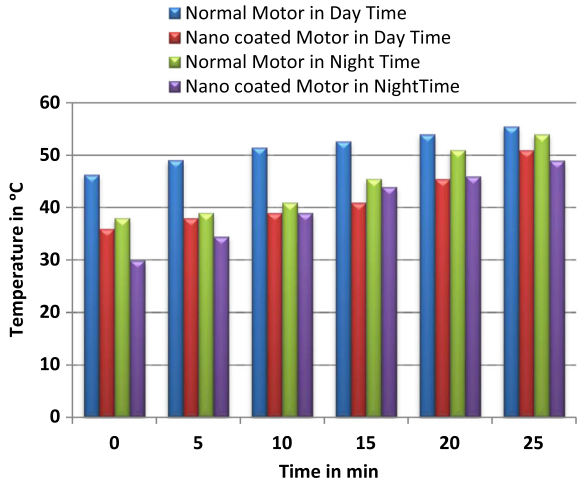

Fig. 3. Comparison of thermal withstanding capacity of various motors during day time and night time [10].

Novel hybrid TiO2/Al2O3/MoS2based enamel insulation for a 3 phases squirrel cage induction motor was proposed to improve the thermal and electrical properties showing an enhancement in the thermal withstanding capacity of the induction motor as 9%-12% in hybrid nano-coated induction than normal enamel filled induction motor [11]. Also there was a considerable reduction in electromagnetic interference from 11% to 22% using this hybrid nano-coated enamel insulation in this 3 phase squirrel cage induction motor. This could also be visualised ing Fig. 5 and Fig. 6 respectively.

Recent researchers quote that Carbon Nano Tube (CNT) fibres which are found to be lesser in weight and highly conductive could play a vital role in replacing copper normally used as winding material nowadays. Such low resistive CNT yarn may offer better accelerated efficiency improvement of electrical machines. Similarly the epoxy materials reinforced with nano particles are widely used in power transformers, bushing etc.,. These nano-coated epoxy materials posses improved electrical and mechanical characteristic like breakdown voltage, dielectric strength, surface resistivity, volume

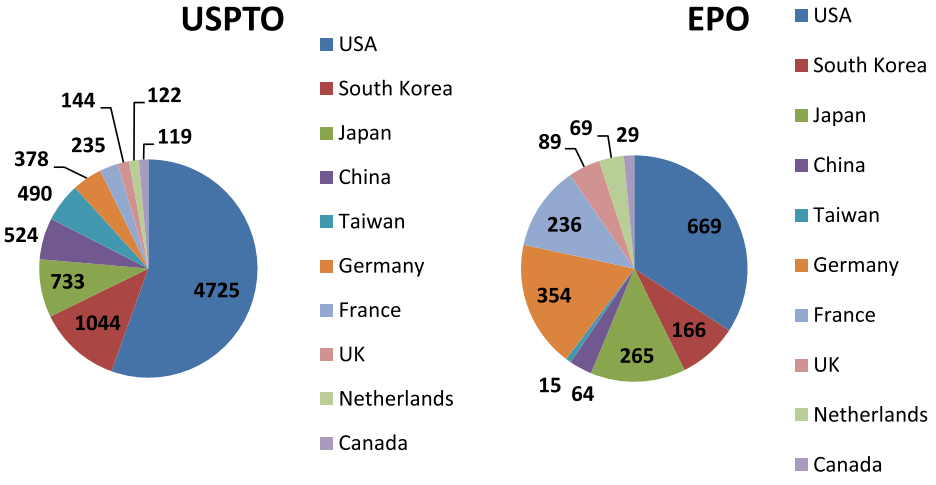

Fig. 2. Number of nanotechnology based patents granted in USPTO and EPO till 2017.

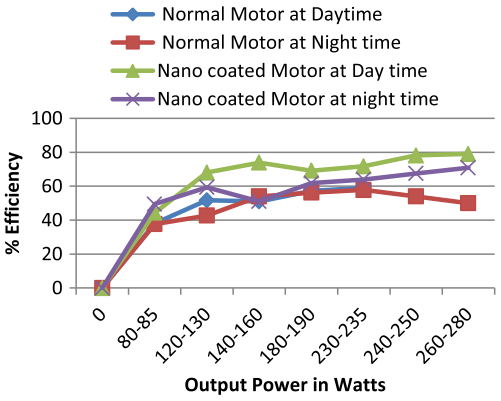

Fig. 4. Comparison of Efficiency in % of various motors during day time and night time [10].

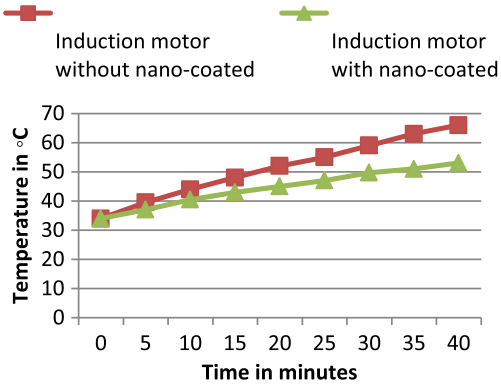

Fig. 5. Comparison of thermal withstanding capacity of various motors.

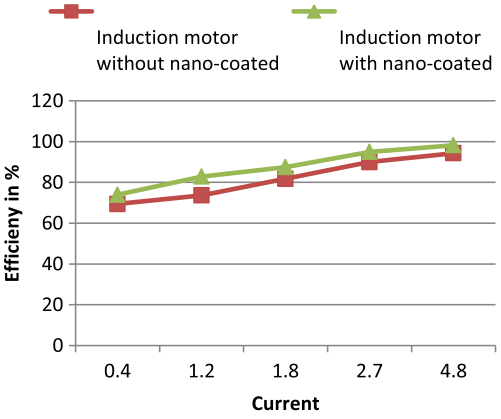

Fig. 6. Comparison of Efficiency in % of various motors.

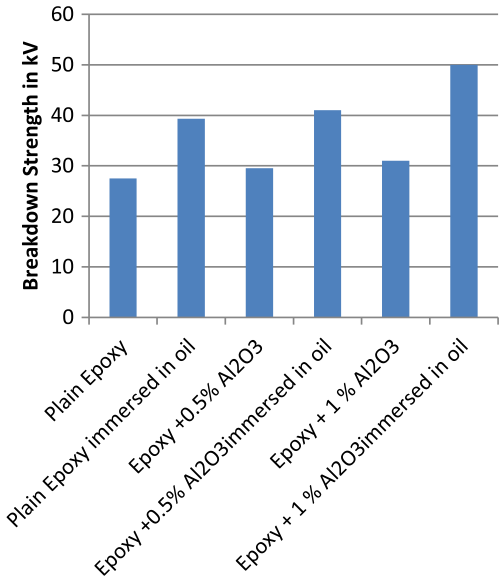

Fig. 7. Breakdown strength of different samples.

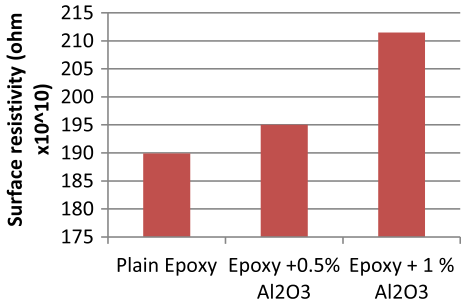

Fig. 8. Surface resistivity of different samples.

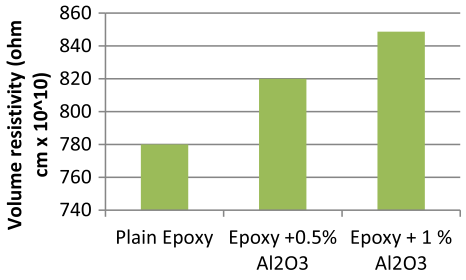

Fig. 9. Volume resistivity of different samples.

resistivity and tensile withstand capability compared to conventional epoxy without nano-coating [12]. The data taken from [13] are plotted in Figs. 7, 8, and 9 to emphasis the nano particle usage with epoxy materials. Figures depict that the increase in the % addition of nano-coating to epoxy materials would improve the electrical and mechanical characteristics considerably.

Nano materials also play a vital role in improvising the characteristics of materials used in energy sector like energy production, power transmission, and energy storage. The author in [14] significantly explains the trends in energy applications based on nano materials. Smart window based on nanotechnology can be used to reduce artificial shades thereby providing better solution for cooling and light in building. Aerogels usage may improve mechanical stability and emphasis the thermal insulation more energy efficient. Nano fluids without change in the flow property and improved thermal property can be produced. These nano fluids are found to be lighter and less heat exchanging character. Nano material added Photo voltaic cells which is included with quantum dots, nano wires and plasmonically active metallic nano particles could add beneficial in capturing more light from the source. Wind forms utilizing blades manufactured using nano composite which have very good strength to weight ratio and also stiffness to weight ration improves the robustness and efficiency of the farm. Heat generated from human body can be used by power portable electronics [15]. In general gases with are responsible for failure of power transformers are ethane, ethylene, methane and acetylene.

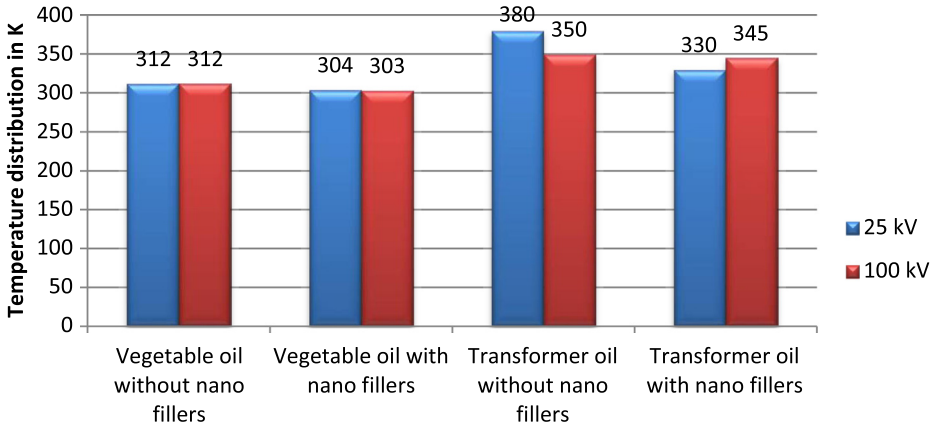

Fig. 10. Temperature distribution character in Vegetable oil and transformer oil with and without nano fillers.

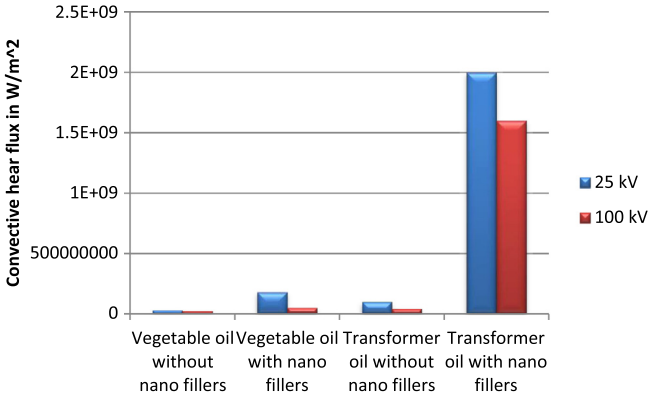

Fig. 11. Convective heat flux character in Vegetable oil and transformer oil with and without nano fillers.

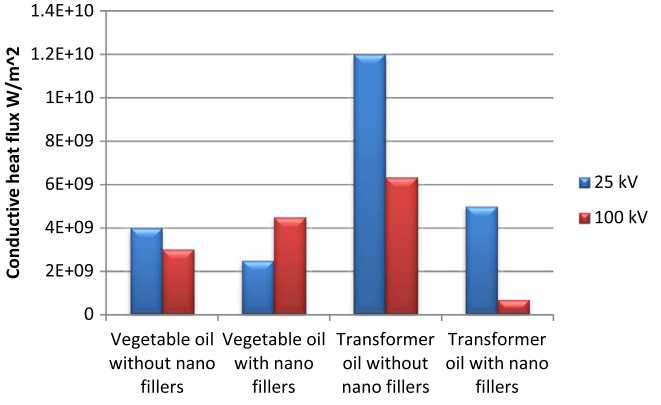

Fig. 12. Conductive heat flux character in Vegetable oil and transformer oil with and without nano fillers.

Nano Sno_2 based sensors can be used to identify the dissolved gases in transformer oil and online monitoring could be made effective [16]. The properties of the transformer oil with and without nano fillers is tested in, [16] using COMSOL 5.3 a. Also in, [16] the temperature distribution, Conductive heat flux and Convective heat flux of transformer oil and vegetable oil are tested for 25 kV and 100 kV transformers and the improvement in the characteristics of the transformer oil and vegetable oil are tabulated. The graphical representations of the results are given in the Figs. 10, 11 and 12.

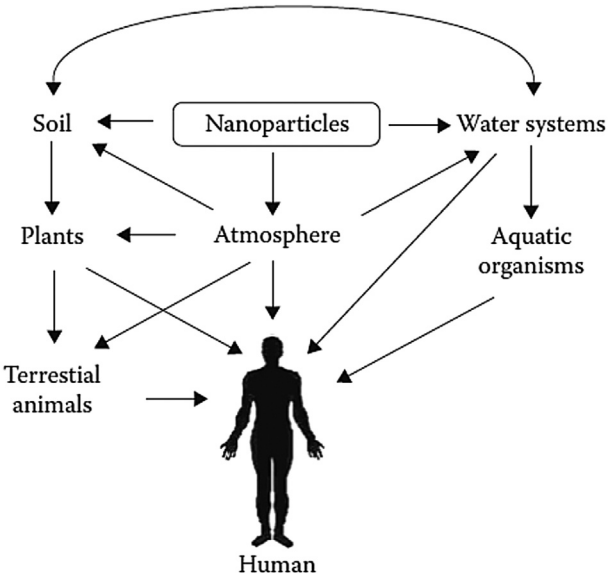

Fig. 13. Way of interaction of nano particles with human [17].

3. Health and environmental concerns

It is understood that the technology behind the nano material usage has brought bliss to many domains like engineering, medicine, and social life etc., the other part of this technology should also to be considered which creates environmental hazards and health issues to biosphere. Some nano materials may not be toxic in nature but it might create hazardous issues when combined with other wastes which a sounds alarm. Carbon nano materials which are used frequently can cause cytotoxicity to human cell lines. Nano materials in different form interacts with human as pictorially presented in Fig. 13 The factors which could influence the toxicity in production of nano materials are fictionalization and the production process. Much more methods that could identify the influence of nano materials creating hazardous issues to the biotic atmosphere has to improved and developed. The need for more thorough assessment of toxicity of carbon nanostructures, refinement systems to prevent disposal of nano waste to the environment and the expansion of apparatus for personal safety from exposure to these nanostructures are also factors to be given much more importance. Exposure of fullerenes in large quantities has considerably affected the balanced nature of biosphere and especially there are case studies explaining the effect of addition of

toxicity to aquatic environment. This impact on the aquatic environment would indirectly affect the human health while consuming the organisms exposed to this toxic substances.

4. Conclusions

Nano science and nanotechnologies put forward number of fresh and excellent opportunities. Most of the available nanotechnologies create no new risks to health or the environmental issues. We have little concern about manufactured nano particles and nano tubes that are in a form where they are free to interact with humans or the environment. Few advantages brought to the enhancement of Electrical and Mechanical properties are described in this paper. Many authors described the advantages of using nano materials in the field of research and development of Electrical field and we are able to provide a drop from the ocean. The entire manuscript provides a glimpse of the research happening around the world in different stages in the field of Electrical engineering. The important points and results discussed by different authors as data have been exposed as pictorial representations in this paper.

CRediT authorship contribution statement

P. Nedumal Pugazhenthi: Conceptualization, Methodology, Writing - original draft. **S. Selvaperumal:** Writing - review & editing. **P. Gnananaskanda Parthiban:** Visualization, Investigation. **R. Nagarajan:** Supervision. **G.S. Naganathan:** Validation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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