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Research Article

STUDIES ON ENAMEL BASED ZINC OXIDE NANOCOMPOSITES COATED INDUCTION MOTOR

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ABSTRACT
The zinc oxide enamel nanocomposites in structural materials is applied in various fields in engineering & Technology. It is worthwhile to observe that the presence of zinc oxide nanoparticles led to a noticeable enhancement in chemical, mechanical and electrical properties. The novel zinc oxide/enamel nanocomposites play vital role in the design and performance of engineering materials. Also, performance of ZnO nano composite based enamel coated induction motor was studied. Performance testing of motor was done as per standards. Speed control of nano coated motors can be done in future.

Keywords: *Nanocomposites, Zinc Oxide, Enamel, Induction Motor*

INTRODUCTION
Zinc oxide (ZnO) has considerable customary attention due to its unique morphology and dimension-dependent optoelectronic properties (Nakayama *et al.*, 2007). It has special properties, such as high chemical activity, and novel optical, mechanical, electromagnetic, thermodynamic and electro dynamic properties, and displays a wide spectrum of applications, including gaseous sensors (Tomchenko *et al.*, 2003), fluorescent materials (Chen *et al.*, 1995), photocatalysts (Marcì *et al.*, 2001), and additives in many industrial products (Ghosh *et al.*, 2000).
Furthermore, ZnO is an environmentally friendly material, which is desirable especially for bio-applications, such as bio-imaging and cancer detection (Wu *et al.*, 2007). Zinc oxide has attracted increasing attention due to its excellent optical and electrical properties, inexpensiveness, relative abundance, chemical stability towards air, ability to produce significant quantum confinement effect and non toxicity, making it a suitable additive for textiles and surfaces that come in contact with humans (Roy *et al.*, 2003; Jai *et al.*, 2009). Since, ZnO is an important trace element for humans, it is environment friendly and suitable for in vivo applications. Zinc oxide has high refractive index and high thermal conductivity as well as antibacterial and UV-protection properties.
Over the past decade, polymer Nano composites have attracted considerable interests in both academic and industry owing to their excellent mechanical properties like elastic stiffness and strength with only a small amount of these Nano additives. This is caused by the large surface area to volume ratio of Nano additives when compared to the micro and macro additives. Other superior properties of polymer Nano composites include barrier resistance, flame retardency, scratch/wear resistance, as well as optical, magnetic and electrical properties.
Single Phase induction motors consume 60% of industrial electricity. Just 1% increase in efficiency of all the motors in India will save 500 MW powers which needs the initial generation cost of 2000 crores. In the last few years, a great deal of attention has been given to the application of Nano dielectrics in the field of electrical materials. Nano dielectrics are a class of materials containing at least one phase at the nanometer scale. Compared to micro fillers, Nano fillers have been reported to mitigate more efficiently the space charge formation in polymeric materials. It has been reported that the use of Nano fillers improves the corona resistance of polyimide films. In addition, the use of Nano composites of Silicon Di-Oxide (SiO_2) and Titanium dioxide (TiO_2) in low density polyethylene has shown a smaller decrease in the resistivity of the polymeric matrix compared to micro fillers.

Various favorable phenomena have been elucidated on dielectric and electrical insulation properties of emerging polymer Nano composites. Nano-fillers in polymer Nano composites are so defined in size that they are less than 100 nm.

It can be recognized that interfaces will play a significant role in the properties of Nano composites. Chemists have paid much attention to interfaces to develop such new materials for the past decade. Series of literatures have been published to give deep insight into interfaces of polymer Nano composites from the viewpoint of physics including the quantum mechanics and the electromagnetic theory. They give a symbolic message "Interfaces and Nano dielectrics are synonymous".

A concept of "interaction zones" is introduced to explain some performances such as change in permittivity and recombination. Some morphological ordering is recognized in Elmo left layered silicate Nano composites from the measurement of the wide angle X-ray diffraction. It is important to take chemical and physical understanding into consideration to fully understand what takes place in polymer Nano composites.

Synthesis and fabrication of materials in nanometer size plays an important role in the modern world of science and technology particularly in the field of engineering and medicine applications. At the twenty-first century, we entered the Nano world. Nano revolution was actually happened in the mid-1980 with the invention of scanning tunneling microscopy.

In the last few years, a great deal of attention has been given to the applications of Nano dielectrics in the field of electrical insulating materials. Nano dielectrics are a class of materials containing at least one phase at the nanometer scale. It has been reported that the use of Nano composites in the matrix of polymeric materials can greatly improve the thermal, mechanical and electrical properties of polymeric Nano composites.

Various studies have been made by comparing the performance of Nano- to micro- particle filled composites. In our project we deal with using Nano material composites for the insulation in 3-squirrel cage induction motor. Recent studies reveal that for 8 to 10 degree rise in temperature the life of the insulation gets reduced to 50%. Our main idea is to increase the life time of the motor insulation by replacing the regular capacitor with a nano filler one. We have chosen ZnO composites because they have good thermal properties.

The Nano composites have good electrical properties and very low dielectric losses so it helps in improvement of efficiency of motor. In this paper we are studying the enamel/ zinc oxide coating on induction motors.

Experiment

Synthesisation of (ZnO) Nano Composites

The synthesis and study of Nano particles, has become a major interdisciplinary area of research over the past 10 years. The size, morphology as well as the properties of Nano particles basically depends on the methods of preparation. All the processes can be broadly divided into two processes, physical methods and chemical methods.

ZnO is a white powder that is insoluble in water, and it is widely used as an additive in numerous materials and products including rubbers, plastics, ceramics, glass, cement, lubricants, paints, ointments, adhesives, sealants, pigments, foods, batteries, ferrites, fire retardants, and first-aid tapes. It occurs naturally as the mineral zincite, but most zinc oxide is produced synthetically.

The properties of ZnO are:

- Hard, wear-resistant,
- Excellent dielectric properties from DC to GHz frequencies,
- Resists strong acid and alkali attack at elevated temperatures,
- Good thermal conductivity,
- Excellent size and shape capability,
- High strength and stiffness,

Mechanical Properties

SiO_2 and TiO_2 which has excellent mechanical property can be understood from the following table 1.

Table 1: Mechanical Properties of ZnO

Mechanical	**Units of Measure**	**ZnO SI/Metric**
Density	g/cm^3 (lb/ft^3)	5.606
Porosity	%	0
Elastic Modulus	GPa (lb/in^2x10^6)	73
Shear Modulus	GPa (lb/in^2x10^6)	31
Refractive Index	----	1.46
Poisson's Ratio	—	0.17
Compressive Strength	MPa (lb/in^2x10^3)	1108
Micro Hardness	Kg/mm^2	600
Fracture Toughness K_{IC}	$MPa*m^{1/2}$	-
Maximum Use Temperature (no load)	°C	1100

The structure of Zinc (II) oxide is given in figure 1.

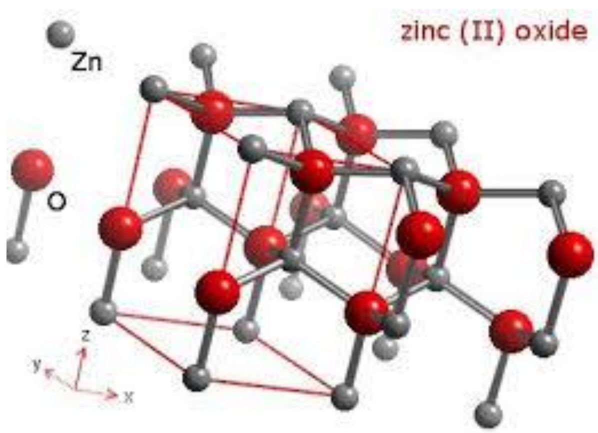

Figure 1: Structure of ZnO

Thermal Properties

Thermal properties like Conductivity, Specific heat, Thermal expansion coefficient of the ZnO as Nano filler is listed in the table 2 which shows that both have good thermal conductivity. In the window building industry "thermal conductivity" is expressed as the U-Factor, which measures the rate of heat transfer and tells you how well the window insulates. U-factor values are generally recorded in IP units (Btu / (hr·ft·F)) and usually range from 0.15 to 1.25. The lower the U-factor, the better the window insulates.

Table 2: Thermal Properties of ZnO

Thermal	**Units of Measure**	**ZnO SI/Metric**
Thermal Conductivity	W/m*°K ($BTU*in/ft^2*hr*°F$)	1.38
Thermal Expansion Coefficient	10^{-6}/°C or 10^{-6}/°F	0.55
Specific Heat	J/Kg*°K (Btu/lb*°F)	740

Electrical Properties

Various electrical parameters like Dielectric Strength, loss factor and resistivity are listed in the table 1 for pure Zinc Oxide is listed in the table 3.

Table 3: Electrical Properties of ZnO

Electrical Properties	Units of Measure	ZnO SI/Metric
Dielectric Strength	ac-Kv/mm (volts/mil)	30
Dielectric Constant	@ 1 MHz	3.82
Dissipation Factor	@ 1 kHz	0.00002
Volume Resistivity	Ohm*cm	10^{12} -10^{14}

The different form of Zinc oxide is given in Figure 2 (a, b, c and d).

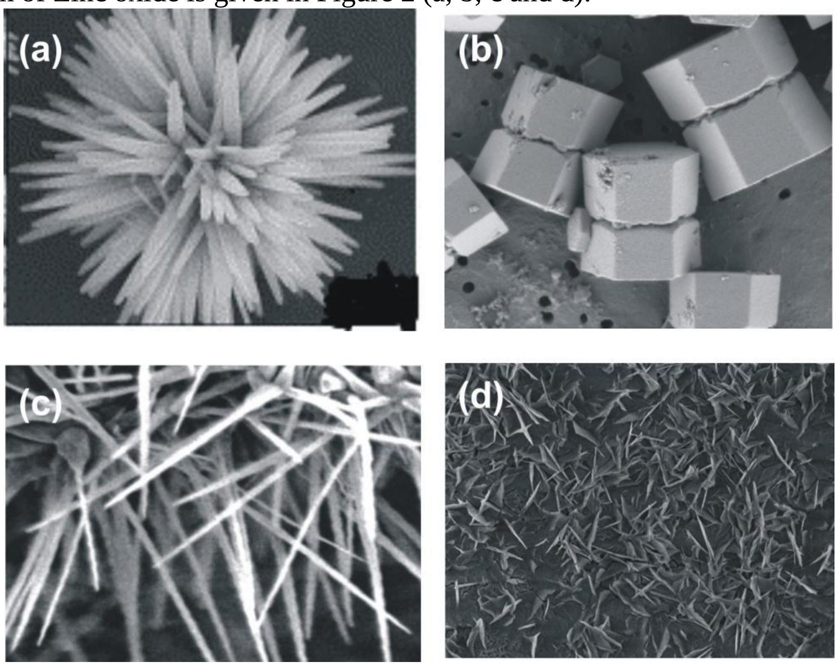

Figure 2: Different Forms of Zinc Oxide

Ball Mill Method

Ball mill is an efficient tool for grinding many materials into fine powder. The ball mill is used to grind many kinds of mine and other materials. It is widely used in chemical industry. There are two ways of grinding: dry process and the wet process. The ball mill is key equipment for regrinding. It is widely used for the cement, the silicate product glass, ceramics and etc. Here, the Silicon dioxide and Titanium Di-oxide nano material is synthesized by using ball mill to convert micro particles to nano particles. It is shown in figure 3.

Figure 3: Ball Mill

Operation

- The pulverize 6 planetary mono mill is universally applicable for quick dry or wet grinding of inorganic and organic samples for analysis, quality control, materials.
- The sample material is crushed and disintegrated in a grinding bowl by grinding balls.
- The grinding balls and the material in the grinding bowl are acted upon by the centrifugal forces due to the rotation of the grinding bowl about its own axis and due to the rotating supporting disc.
- As a frictional effect, the grinding balls running along the inner wall of the grinding bowl, and impact effect, the balls impacting against the opposite wall of the grinding bowl.

Characterization of ZnO

The ZnO particles were subjected to scanning electron microscopy and studies to analyze the surface and structure of the nano particles. The principle of scanning electron microscopy and the obtained SEM pictures and their interpretations are explained in this chapter.

Scanning electron microscopy (SEM)

Scanning electron microscopy shown in figure 4 uses a focused high energy electron beam to image the surface of a variety of samples and collect information on morphology and elemental composition. A scanning electron microscope is a highly versatile tool and can be used to study biological specimens, geological materials, nanoparticles, circuit boards, and many other sample types.

A SEM consists of an electron gun, focusing lenses, stage or specimen holder, and several types of detectors. The electron gun contains a heated metallic filament, usually tungsten, which provides the source of electrons. These electrons are accelerated toward an anode plate and then focused by condenser lenses and an objective lens. A deflector coil causes the focused electron beam to be scanned across the surface in a raster pattern.

Figure 4: Hitachi SU- 1510 Scanning Electron Microscope

There are two types of electron microscope – the scanning electron microscope (SEM) and the scanning transmission electron microscope (STEM). The samples must be conducting (in order to accelerate electrons into the sample) and hence a biological sample must have a gold layer deposited on its surface if it is to be investigated by SEM or STEM. In the STEM, the sample is a very thin specimen and contrast within the image is due to the spatial variations in intensity of the transmitted electron beam through the specimen, as the beam is raster scanned over the specimen. In SEM, the image may be produced in a number of ways from variations in the intensity of secondary electrons back–scattered from the specimen through to X-ray emission produced by inelastic collisions of the primary beam with bound electrons in the specimen. The idea that gave rise to the electron microscope is that, just as light is refracted and focused by an optical lens, the electron, due to its charge, will produced Cambridge Instruments Ltd.

The electrons are emitted by an incandescent cathode source, accelerated towards more positive grids through either electrostatic or magnetic field lens onto an object. The specimen is supported on a very thin film to minimize the scattering of the electrons as they pass through the sample. Depending on the thickness and composition of the object, the electron beam experiences different attenuation as a function of position.

The beam travels through two more lenses before being imaged onto a fluorescent screen (in original models) or photographic plate or directly onto a scintillator placed on the face of a photomultiplier tube or a CCD device.

A scintillator is a semi-transparent material, which emits a flash of light when a charged particle traverses it. The spatial resolution of this type of microscope is determined by the wavelength associated with the electrons and this wavelength may be 100,000 times smaller than optical wavelengths at the typical accelerating voltages used in electron microscopy.

Sample preparation

The process of converting liquid state enamel into solid state sample is called as curing.

- Types of curing
- Thermal curing: The oligomer which is having a repeat unit (1 to 10) is converted into polymer by using thermal curing.
- Radical initiator curing: In this method, curing agents such as amines, anhydrates and acids are used as curing agents.
- Curing method for enamel
- The curing method used for enamel is radical initiator curing. In this process DDM is used as curing agent. The procedure used in this curing process is as follows:
- 80% of enamel and 20% of epoxy resin is taken. DDM is taken in proportion to epoxy resin. For 1g of resin 0.27 g of DDM is added.
- Melt DDM for 10 minutes for 60-80o C.
- Mix enamel, resin and melted DDM in a beaker.
- Pour the mixture in the die which is coated by a Teflon sheet.
- Heat the die at 120O C for 2 hours and 130O C for 3 hours.
- Cool the die and take the solid sample.
- The photographs of various prepared samples are shown in figure 5.

1:1 nano composites

3:1 nano composites

Pure sample

Figure 5: Photographs of Various Samples

RESULTS AND DISCUSSION

Zinc Oxide Fluorescence Studies

The luminescent properties of ZnO significantly depend on the perfection of the crystal structure and content of various defects in the crystal.

Zinc oxide is one of the most important semiconductor materials with a direct wide band gap (Figure 6) (3.37eVor375nm), good transparency, and strong room temperature luminescence.

ZnO-nano particles possess various functions for uses such as pigments, piezoelectric devices, luminescent devices, gas sensors, catalyst and cosmetic materials in our today society.

In particular, ZnO-nano particles in the range of 100-200nm have been commonly used in sunscreen products because of their ability to filter UVA as well as UVB light. The synthesis of ZnO has been carried out and their luminescence properties studied successfully.

The usefulness of the ZnO was established and multiple uses were accomplished. ZnO has been one of the most promising materials for electrical devices, including transparent conductive films, light emitting diodes and photo catalyst (Vanheusden *et al.*, 1996).

Moreover, because it has been chemically and optically stable and has a low toxicity, its use as a fluorescent label for bio imaging has been anticipated.

The fluorescence of ZnO has been observed in the UV region due to the exciton luminescence of the band gap and in the visible region due to oxygen defects and/or interstitial zinc caused by UV excitation (Xu *et al.*, 2003).

Scanning Electron Microscope (SEM) Studies

The ZnO nano particles synthesized by ball mill method was analyzed using SEM analysis shows that the ZnO nanoparticles showed a size distribution of 100-134 nm (Figure 7) SEM of ZnO indicated that uniform particle and shape distributions was observed.

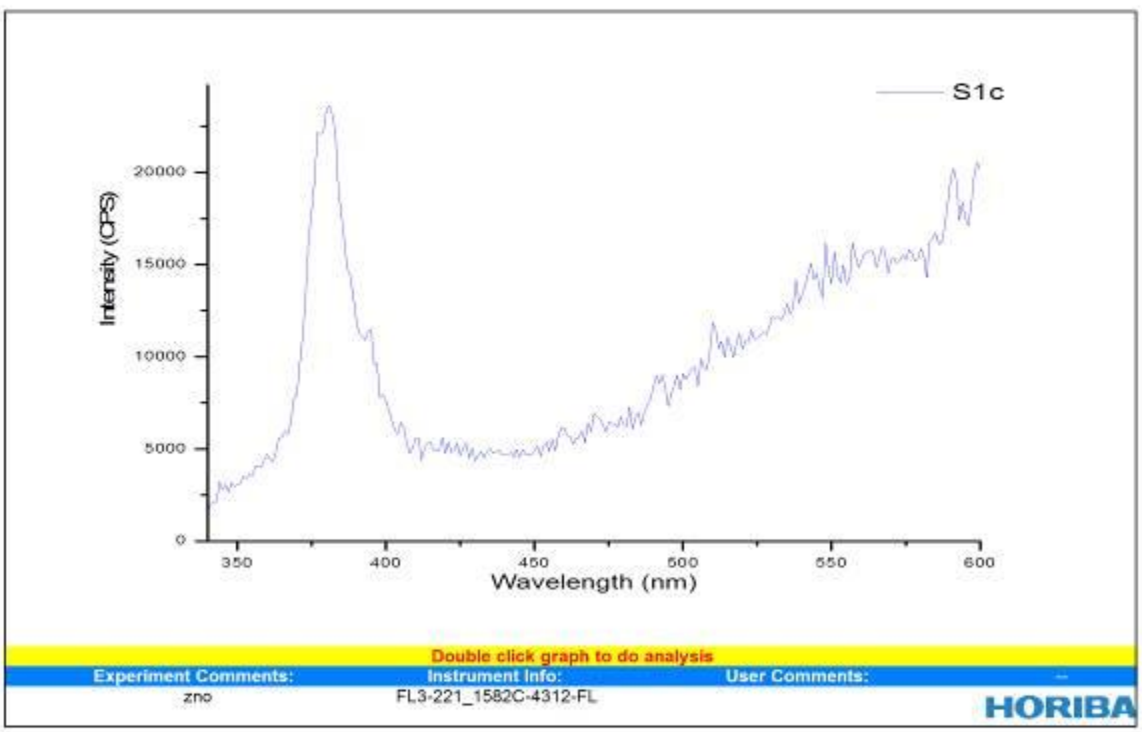

Figure 6: Zinc Oxide Fluorescence Graph

Load Test on Normal and Nanocoated Induction Motor

Efficiency was analyzed by conducting load test in the induction motor. Figure 8 shows the circuit arrangement for the load test.

The Load Test Reading on Normal Single Phase Induction Motor and Nano coated Single Phase Induction Motor were calculated for various loads and tabulated in Table 4 and 5.

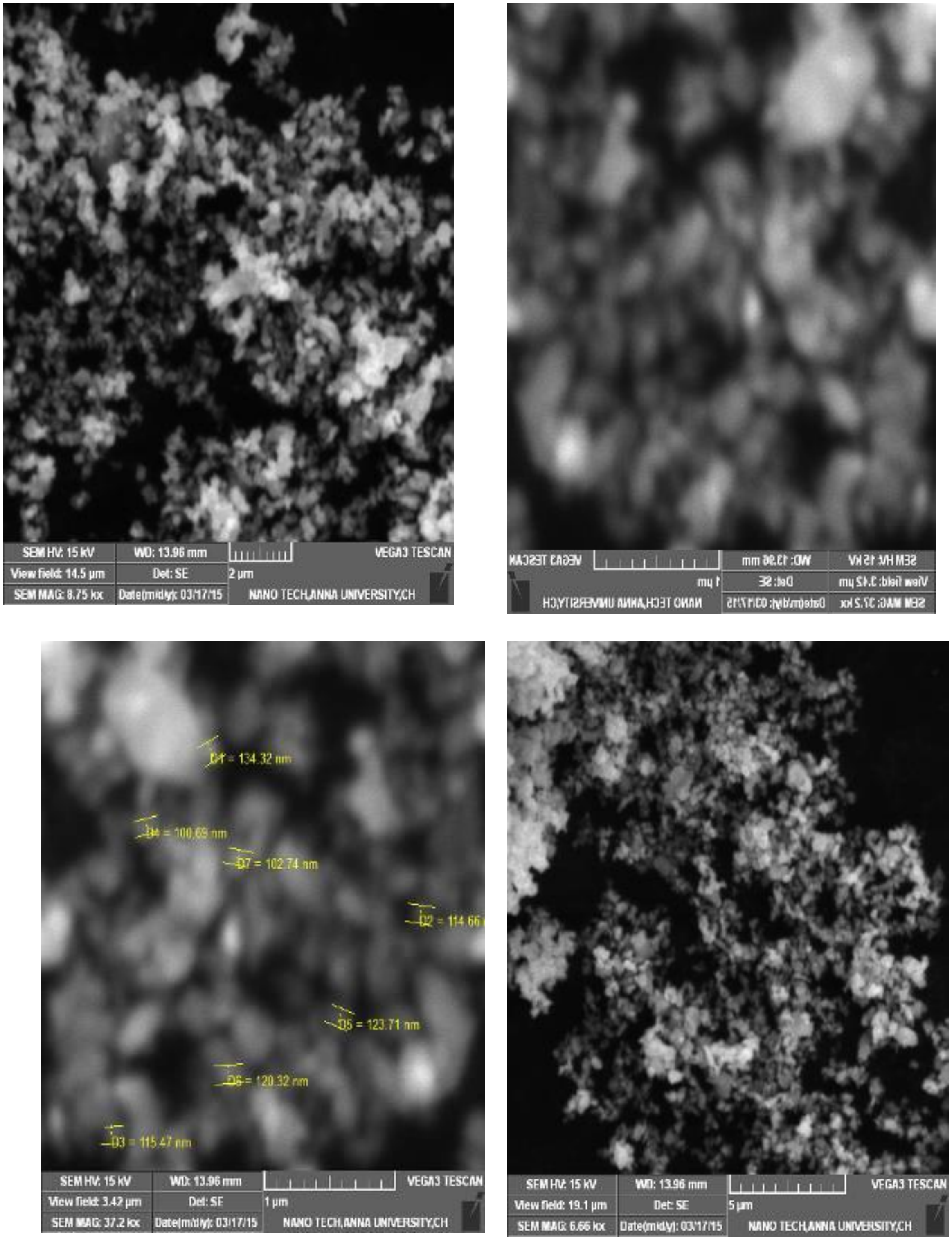

Figure 7: SEM Images of Zinc Oxide Nanoparticles

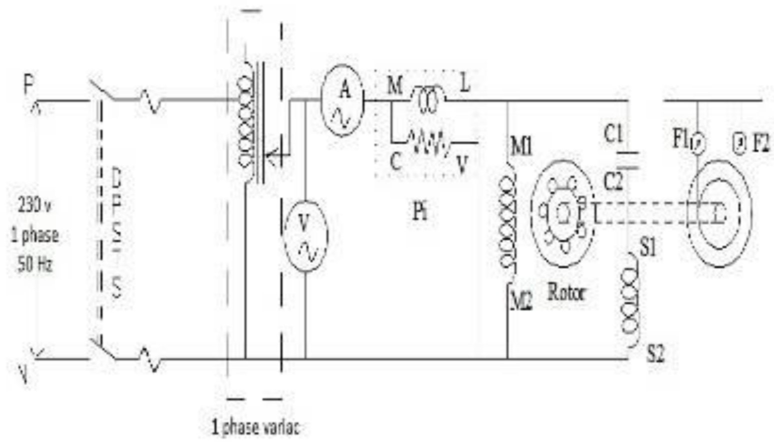

Figure 8: Circuit Arrangements for Single Phase Induction Motor Load Test

Table 4: Load Test Reading on Normal Single Phase Induction Motor

S. No.	V	I	Power in Watts	Spring Balance Reading S1	S2	Speed	Torque	Output Power in Watts	Efficiency
1	220	0.8	180	0	0	1450	--	--	--
2	220	1.15	220	3	2	1375	0.7355	105.94	48.15
3	220	1.2	240	4	2.8	1366	0.8829	124.3	51.79
4	220	1.3	260	6	4.6	1340	1.03	144.5	55.59
5	220	1.35	280	7	5.4	1328	1.18	161.71	57.19

Table 5: Load Test Reading on Nano Coated Single Phase Induction Motor

S. No.	V	I	Power in Watts	Spring Balance Reading S1	S2	Speed	Torque	Output Power in Watts	Efficiency
1	220	1.1	200	--	--	1436	--	--	--
2	220	1.15	220	2	1	1406	0.7357	108.32	49.23
3	220	1.2	230	3.5	2.3	1400	0.882	129.62	56.35
4	220	1.3	240	5	3.6	1396	1.03	150.57	62.74
5	220	1.35	260	5.5	3.9	1390	1.17	170.3	65.5

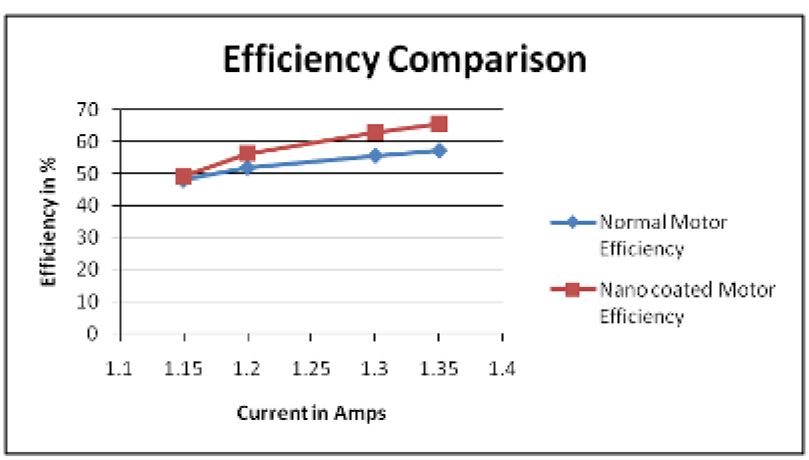

Figure 9: Comparison of Efficiency of Single Phase Induction Motor before and after Nano Coating

The following observations were clear as per this study: The graph in Figure 9 shows the Comparison of efficiencies of Single phase Induction motor before and after nano coating on copper winding. The efficiency of the Load Test Reading on Normal Single Phase Induction Motor is 57.19 and 65.5 before and after nano coating. The efficiency of the induction motor was increased 8 % by adding nano filler to the enamel used as the coating for the windings in the single phase induction motor. The increase in the efficiency of the motor was mainly due to the reduction in the dielectric and harmonic losses of the motor.

Conclusion

It was observed that the operating temperature of an electric machine has a very strong relationship with the life duration of the insulation. The insulating materials mostly used for coating the machine windings were organic in nature, and were adversely affected by thermal decomposition. But the addition of nanocomposites to the enamel has increased the temperature withstanding capacity of the induction motor. Hence, the life time of the motor will be increased.

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