Analsysing and Enhancing the Mechanical and Superhydrophobic Property of a Material with the Aid of ZnO-Polystyrene Nano Colloid Composite

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ABSTRACT

In this research, enhancement of superhydrophobic property of a material is carried out with the aid of Zinc oxide & Polystyrene Nano composite colloid. Here ZnO is processed in order to achieve the Nano structure such that it can be mixed with polystyrene without any complex process. Processing of ZnO includes nano-crystalization by grinding followed by crystal size graphing in order to confirm the Nano size of the ZnO crystal for colloidal mixing, ultra-centrifuge method was followed to purify the ZnO. Optimization of mixing ratio was followed to achieve the better composition for coating. Coating was carried out by spin coating method for better coating results. Investigation results of coated and uncoated specimen was carried out with aid of SEM test, Hardness test (Brinell), Corrosion test and contact angle measurement in order to support the results in the presence of hard water and soft water. Results revealed the enhancement of mechanical property and Superhydrophobicity is achieved at greater extent.

KEY WORDS: Zinc oxide, polystyrene, SEM, Hardness test (Brinell), Corrosion test, Contact angle, ultra-centrifuge, Nano.

1. INTRODUCTION

In current research hydrophobic surface gained extreme interest among researcher because of its advantage over industrial application and micro structural physical properties. Biomimetic normally known as artificial material posing a characteristics similar to the natural material, for example superhydrophobic material has a special property of liquid repellent property due to its enhanced hydrophobicity property which is similar to Lotus leaf property of repelling water. This hydrophobicity property of superhydrophobic material drawn the high interest towards researcher and development of its application in automobile industries, space craft manufacturing. Also that property of anti-sticking, self-cleaning properties enhanced its vast application. Among the superhydrophobic material such as MnO_2/PS Nano composite, ZnO-PS Nano composite, precipitated Calcium carbonate, Carbon Nano-tube composite, potassium titanate whiskers and polyetheretherketone (PEEK), ZnO-PS composite drawn a favourable superhydrophobic properties since it has vase application in manufacturing rubbers, plastic, ceramic, glass due to its superhydrophobic property of water contact angle more than 150^o. The surface roughness and wettability also seemed will be more acceptable. Surface wetting behaviour can be take into four different regions less than 10^o to 90^o, 90^o to 150^o and above 150^o. up to 90^o water contact angle surface of the material is considered as hydrophilic due to its strong attraction towards water, whereas above 150^o posies superhydrophobic where the percentage of water attraction towards the surface of the material is very low. On taking the account of zinc oxide polystyrene Nano composite the advantage whereas follow its one of the most economical way of the creating superhydrophobic coating in numerous systematic way such as Gel based system, Aero sell spray and by dipping the object. In contrast on the effect of Zinc oxide polystyrene Nano composite has more durable property on gel based coating than other (Sanjay, 2012; Emiliano, 2011).

Cheng (2007), in their paper title fabrication of Superhydrophobic and Superoleophilic polystyrene surface by a facile one-step method discuss about preparation of superhydrophobic and Superoleophilic surface with the aid of polystyrene in the absence of any modification simultaneously, they discuss about microbeads and Nano fibre structure, preparation through electro spring method and property of oil sorbent (Cheng, 2007).Wang.et.al in his research article The effect of self-assembly modified potassium titanate whiskers on the friction and wear behaviours of PEEK composites discuss about self-assembling of Polytetrafluoroethylene (PTFE) polyetheretherketone (PEEK) in the presence of potassium titanate whiskers and n-octade cyltrichlorosilane (OTS). It discusses about tribological mechanical properties of PTFE and PEEK with respect to matrix formation dispersion and interfacial compatibility in which OTS seemed to be better self-assembling surface property (Wang, 2010).

In Corrosion behaviour of superhydrophobic surface; A review, Adel (2014), proposed a review on surface wetting and stability of superhydrophobic material with respect to specific surface material such as morphology, roughness and surface chemistry. Also he compared the theory superhydrophobic such as contact angle and young equation and rough surface with Wenzel and Cassic Baxter models. The competence technique for manufacturing superhydrophobic material such as sol-gel process, layer by layer self-assembly icing chemical and electro chemical deposing respectively. Finally, he concludes the stability of superhydrophobic surface with respect to solvent stability, Ph. stability, Thermal stability, Humidity stability and UV stability (Adel, 2014).

Lin (2002), in their paper Superhydrophobic surface from Natural to Artificial discuss about naval method to construct superhydrophobic surface with respect to high contact angle, multi scale structure that have significant effect of reduce angle of water droplets, on the other hand micro array structure have constant influence on Superhydrophobicity (Lin, 2002). In the paper Superhydrophobic surface develop by Mimicking Hierarchical Surface Morphology of Lotus leaf discuss about the primitive property such as self-cleaning, anti-corrosion and non metability collecting known as lotus effect. It discusses with reference to high water contact angle of above 150^o and slow slide angle less that 10^o stance the major explosion of artificial superhydrophobic material. Also they briefly reviewed about Mimicking natural superhydrophobic property of lotus to artificial material with respect to micro and Nano structure using various polymers. In this current research ZnO polystyrene was employed to evaluate superhydrophobic and subject to hardness, corrosion and SEM test and results were evaluated separately (Sanjay, 2014).

2. EXPERIMENTATION

Pre-processing of coating material: In pre-processing of coating material ZnO was purchased from local vendor – Chennai of research quality. ZnO employed in pre-processing of coating material is found to have 5.8 g/cm^3 density with high melting point at 1989^{o}C. Also it has high solubility range of 0.0004% at 17.8^{o}C and Refractive index of 2 (Liu, 2009; Goval, 2007). Table 1 shows the property of ZnO. Zinc oxide obtained was in the form of crystalline, further processing involves grinding of ZnO to powder form for subjection to UV testing in order to manipulate the crystal size. This crystal size graphing was recorded in order to fix the required size/acquire the required size for processing. Figure 1&2 represents the ultra violet spectroscopic for crystal size graphing of ZnO.

Table 1. Properties of ZnO

Chemical Formula	ZnO
Appearance	White solid
Density	5.8 g/cm^2
Melting point	1989^{o}C
Solubility in water	0.0004% (17.8^{o}C)
Refractive Index	2

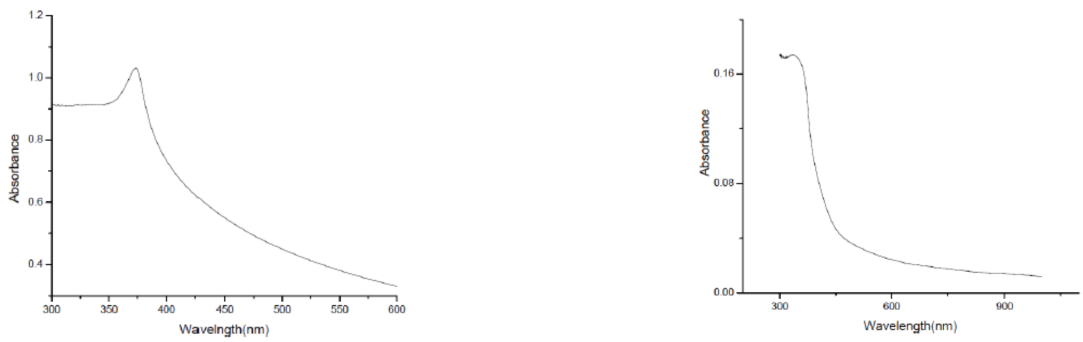

Figure. 1 & 2. UV spectrometer analysis for crystal size graphing of ZnO

Further ZnO was surface washed in the presence of methanol in Ultracentrifuge (C.24 BL). Table.2, specifies the technical attributes of Ultracentrifuge used.

Table.2. Technical Specification of Ultracentrifuge

Maximum capacity	3.0 Litre
Speed	20000 RPM
Weight	128kg
Timed run	Up to 99 hours, 59 min
Rotor capacity	4×750 mL
Electrical requirements	60Hz, 120V

In Ultracentrifuge for varying the RPM between 2000-4000 RPM for the period of 20-30 mins ZnO was subjected to surface wash with methanol. Resulting ZnO obtained was sedimented in rotor tube at ultrapure stage.

Fabrication of ZnOPS composite coating material: In the process of fabrication ultrapure ZnO obtained was mixed with polystyrene in the liquid state at 260^o to 270^o. Initially varying polystyrene ratio of 2 to 6 % of ZnO was tested. In which 9.5:0.5 % of ZnO to polystyrene stands the best and optimized colloidal mixture (Xue, 2010). The mixing of ZnO to Polystyrene was carried out in the presence of integrated thermocouple for generating heat and thermal magnetic stirrer. Properties of polystyrene was show in table.3.

Table.3. Properties of Polystyrene

Density	0.94-1.04g/cm^2
Melting point	240^{o}C
Refractive index	1.6
Young's modulus	3000-3600 MPa
Tensile Strength	46-60 MPa
Specific heat	1.3 kJ/(kg.K)

Specimen to be testing with superhydrophobic coating was initially surface grinding and cleaned with methanol. Various techniques intended for coating material on specimen were as follows get based system, aero-sol spray and by dipping the object (Zhang, 2008; Ganbavle, 2011). Here gel-based system was employed because of its optimized usage of coating material and even spreading of coat on the surface. Technical specification for Spin coater machine NXG-P1 was illustrated in table.4.

Table 4. Technical Specification of Spin Coater.

Maximum Speed	10000RPM
Acceleration/Deceleration	1-25.5 seconds
Weight	17.3kg
Vacuum input	17 to 25 Hg
Power input	115V, 230AC

Specimen to be coated is fixed on the holder at 20-35 bar pressure in order to avoid slipping of specimen during coating. Initially disc is rotated at the speed of 3000rpm for 30 seconds with acceleration during this process colloidal calculation is made to be dropped at the centre with the aid of micro pipette for the higher accuracy this step is again repeated for varying rpm for increasing time and constant acceleration for even coating of Superhydrophobic colloidal coat on the specimen at constant rate (Goyal, 2007).

3. RESULT AND DISCUSSION

Specimen coated with Zinc oxide polystyrene composite coating to enhance the superhydrophobic property of the base material was subjected to hardness test, corrosion test and SEM test and results were summarised as below.

SEM test: Scanning Electron Microscope analysis was employed on powder zinc oxide. It was analysis of particle, failure analysis on mixing with polystyrene external morphologic characteristic and orientation of the material with respect to specimen. Here SEM instrument used for analysis has a capacity of X25 to X1,000,000 magnifications, maximum accelerating voltage of 30 kV with built in energy filter, aperture angle control lens and dictator and general beam. And figure 3, 4, 5, 6 shows the Nano structure of ZnO at standard accelerating voltage of 20 kV was varying magnification resolution of X20K, X30K, X10K and X55K, it can be concluded at particle size is Nano structured enough to be coated on specimen. Technical specification of scanning electron microscope is shown in table 5. The close size of the coated of the particle can be measure up to 1μm, 0.5μm and 0.2μm (Nosonovsky, 2006).

Table 5. Technical Specification of Scanning Electron Microscope

Magnification	25 to 1,000,000
Accelerating voltage	0.1kV to 30kV
Digital image	1280×960 pixels
Energy filter	New r-filter
Aperture angle control lens	Built-in
Detectors	Upper detector, lower detector
Gentle beam	Built-in
Rotation	360^o

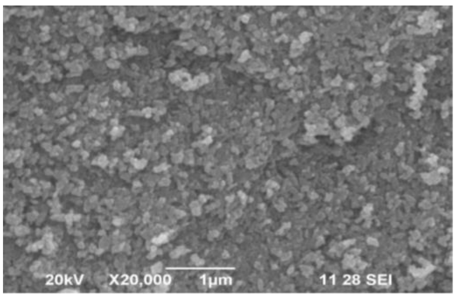

Figure.3. SEM image at 20K Optical Zoom

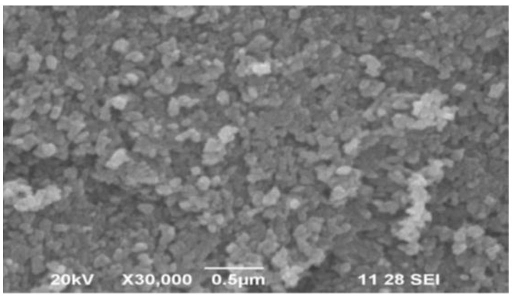

Figure.4. SEM image at 30K Optical Zoom

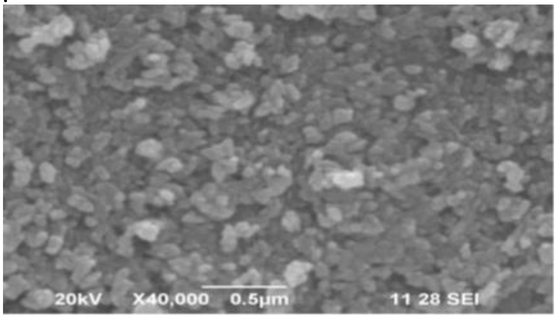

Figure.5. SEM image at 40K Optical Zoom

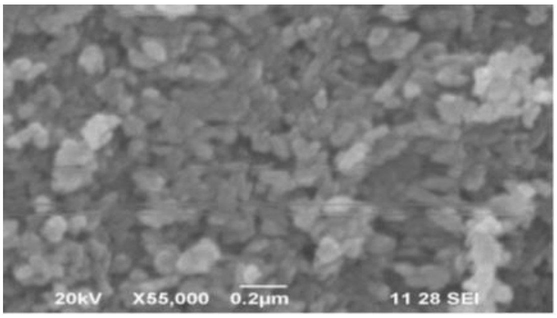

Figure.6. SEM image at 55K Optical Zoom

Hardness test: Hardness test is experimented on coated and uncoated specimen (ZnO PS coating). This is carried out in order to explore the stiffness/temper or resistance of metal to plastic deformation commonly by indentation. Brinell hardness test is carried out in which indenter will standard ball diameter of 10mm was employed. Table 6 represents the technical specification of brinell hardness testing machine employed. Here load apply is 3000 N. Diameter of indentation on the specimen with coating and without coating was observed under microscopic environment. The trail was repeated for 3 times and average of Brinell hardness number (BHN) was found to be 391 for the specimen with coating on comparing with specimen without coating of 242 BHN, from this we can concluded the hardness of the material increases after coating due to the effect of ZnOPS composite coating (Marmur, 2004). Reading and calculations were shown in table.7.

Table.6. Technical Specification of Brinell hardness Testing Machine

Maximum load	3000 N
Size of base mm	165×425
Diameter of the indenter	2.5mm, 5mm, 10mm
Machine height	650mm
Maximum test height	225mm
Weight	65kg

Table.7. Calculation for Brinell hardness number

Ball Diameter (mm)	**Load applied P in N**	**Diameter of indentation ‘d’ (mm)**		**BHN**	
		With Coating	**Without Coating**	**With Coating**	**Without Coating**
10	3000	4.6	5.3	370.46	237.21
10	3000	4.3	5.1	458.19	267.85
10	3000	4.7	5.4	346.45	223.43

Corrosion test: Main aim of the experimental investigation is to reduce the rate of corrosion and to enhance the superhydrophobic property of material with aid of Nano composite coating. Here the specimen (coated and uncoated) is subject to corrosion under heavy water (of high salt and iron constant) and soft water (employed of laboratory purpose) observation were made at the internal of 6 hrs up to 56 hrs the experiment is repeated twice and the result shows rate of corrosion by formation rust over the specimen seems to the higher with uncoated specimen whereas specimen coated was stable and rate of corrosion seems to be very low (Wu, 2005). Figures 5 & 6 shows that inference taken at 28 hrs of observation under hard water and soft water.

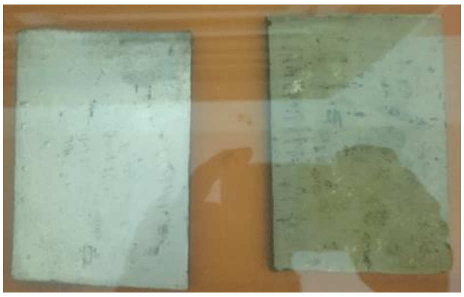

Figure.7. Observation in Hard water

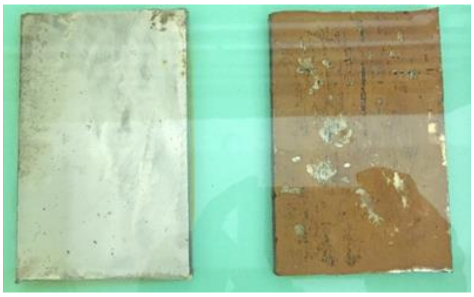

Figure.8. Observation in Soft water

Contact angle measurement: Superhydrophobicity of the object is determined by its contact angle with water droplets. Here water is made fall on the specimen surface was illuminated with the aid of high beam light in order capture the water droplet and specimen with aid of high resolution camera. The image output obtain was subject to microscopically analysis. Figure.9, shows the contact angle measurement of image taken. In which the contact angle for superhydrophobic material.

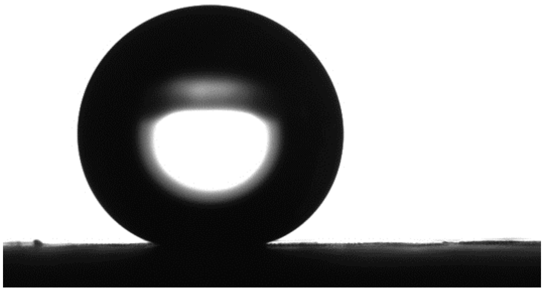

Figure.9. Contact Angle Measurement Image

4. CONCLUSION

- Formulation of Nano composite coating (ZnOPS) was carried water static experimental condition. Enhanced ratio of polystyrene zinc oxide was found to be 11:0.5 which is optimal mixing ratio for colloidal coating.
- Ultracentrifuge and spin coater were employed to purify the ZnO and to make the superhydrophobic coating on the test specimen.
- SEM test was carried out between zooming of 20k to 55k at 20kV and molecule of microscope size $0.2\mu m$ to $1\mu m$ were found.
- Hardness test and corrosion test were carried out on specimen with coating and without coating in which specimen with Nano composite coat seems to have better Brinell hardness number and high corrosion resistance.
- Ultimate property of Superhydrophobicity i.e. contact angle between water drop and specimen was measured at the aid of Goniometer in which result obtained source contact angle of 154^o.

Above result were interconnected and interpreted to quantify the superhydrophobic layer coating on specimen and the result sources positive variation and better superhydrophobic layer formation.

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