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Preparation of stable dispersion of ZnO nanorods and its application on cotton fabric for functional properties

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Abstract. In this systematic study, we describe the influence of various surfactants and polymers on aggregation stability of ZnO nanorods. Triton X-100, PVP and PVA were used to disperse nanorods. The surfactant/polymer stabilizing effect was monitored using the sedimentation study and photographic methods based on the decrease in the height of the interface as a function of time. The dispersion of nanorods when applied to cotton fabric, it exhibited functional properties like antibacterial activity and UV protection. The morphologies of nanorods and functionalized cotton were characterized by using SEM.

1. Introduction

A new class of fluids are nanofluids (NFs) engineered by nanometer-sized materials (1-100 nm) which dispersed in base fluid. Nanofluids are two-phase systems comprising one phase (solid phase) in second (liquid phase) [1-3]. Dealing with nano-materials are an important issue due to their tendency to agglomeration because of their high surface area. The knowledge of settling behavior of particles because of gravity is important to prepare stable nanofluids [4, 5]. In this regard, the susceptibility to coagulate can be overcome using different numerical means. Dispersion of nanoparticles are investigated by many techniques including photographic method reported in literature [6].

It is noted that in previous research application of zinc oxide nanorods was possible only in situ processes. Researchers paid no attention to form the stable dispersion of textile finish based on zinc oxide nanorods to impart functional properties to textile materials. The aim of this research work is to prepare dispersion of zinc oxide nanorods which is stable for longer time under room temperature storage conditions and its application to textiles to render them multifunctional. In this work, the ZnO nanorods were prepared by the hydrothermal synthesis and applied onto cotton fabric, using different finishing formulations by pad-dry-cure method, for attaining considerably improved functional properties, i.e. UV, and anti-bacterial properties.

2. Experimental

2.1. Synthesis of ZnO nanorods

The chemicals used in the synthesis of ZnO nanorods were zinc nitrate hexahydrate (Zn (NO3)2•6H2O Sigma-Al-drich) and hexamethylenetetramine (C6H12N4 Tok90, KASEI). ZnO nanorods were prepared

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by the normal hydrothermal synthesis reported elsewhere [7]. The morphologies and structures of the prepared samples were investigated by scanning electron microscopy and X-ray diffractometer.

2.2. Synthesis of ZnO suspensions
Polyvinyl pyrrolidone (PVP) from Bio basic Canada Inc., Triton-X was obtained from Fisher scientific, UK and PVA from Sigma-Aldrich Czech Republic. All materials Table 1 were analytical grade and were used as received. Distilled water was used for all experimental trials. The ZnO nanoparticles suspensiosn were prepared according to design of experiment mentioned in Table 1.

Table 1: Design of experiment for dispersion of 10% ZnO nanorods

Sample code	**Amount of ZnO nanorod w/vol%**	**PVP w/vol%**	**PVA w/vol%**	**Triton X-100 w/vol%**
1	10	12	-	
2	10	-	3	-
3	10			15

2.3. Fabric treatments
Mercerized cotton fabrics kindly provided by National Textile University (Faisalabad, Pakistan), were used as received. The cotton samples (30 cm·30 cm) were soaked for 10 min in different factors and their levels Table 2 of ZnO nanorods, under gentle stirring.

Table 2 Different levels for fabric sample development

Factors	**UNITS**	**LEVELS**		
		1	2	3
ZnO	%	10	10	10
PVP	%	12	-	-
PVA	%	-	3	
Triton X-100	%			15

3. Results and Discussions
3.1. Morphology of ZnO nanorods
The morphologies and microstructures of the prepared samples were investigated by scanning electron microscopy (SEM). Figure 1 displays an SEM image of closely packed ZnO nanorods in rectangular geometrical shapes.

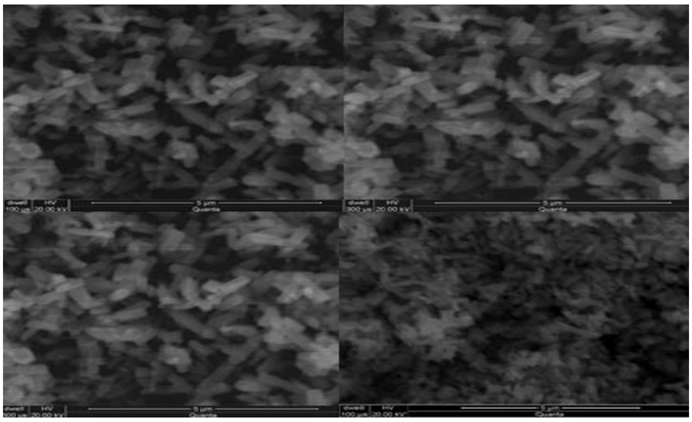

Figure 1: SEM images of ZnO nanorods

3.2. Dispersion stabilization of ZnO nanorods in polymer solutions

3.2.1. Effect of Polyvinylpyrrolidone. In the present work, nanofluids sample at the fixed concentration 10%w/v ZnO nanorods with 12% polymer stabilizer PVP was prepared. The steric stabilizing efficiency of PVP in ZnO nanorods suspension can be explained by a carbonyl group of PVP. Amphiphilic PVP has two electron rich species, oxygen and nitrogen so it can use any of these species to interact with nanostructures. But oxygen of carbonyl group has more feasibility to interact with ZnO nanorods so it plays its vital role in the dispersion.

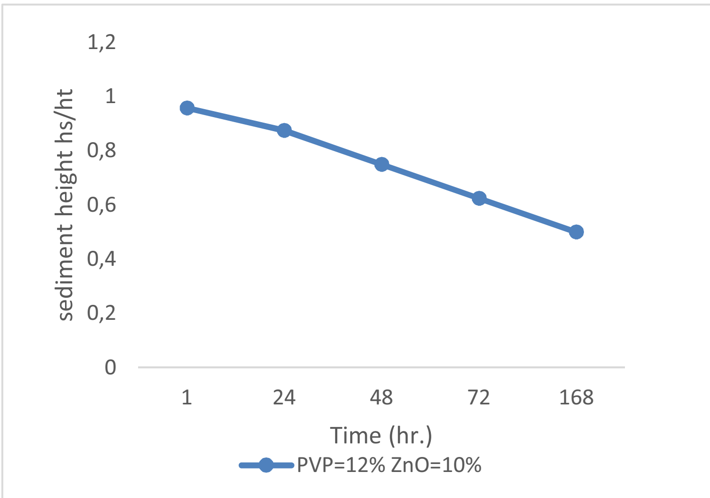

Figure 2: Effect of PVP on stabilization of 10% w/v ZnO nanorods

After 1 week a slight decrease in sedimentation height for PVP 12% was observed which is due to compression settling. This compression settling is due to settling of upper layers of dispersion under its own weight which causes a minor decrease in height of sedimentation.

Figure 2 gives the variation in the liquid-solid interface height as a function of time. Molecular weight of PVP has also influenced on the stability of ZnO nanorods. Its high molecular weight among others dispersants makes its suitable choice for better dispersions.

Table 3: Photographic comparison of 10% ZnO nanorods in PVP

Dispersant	**Dispersant conc.%**	**1 hr**	**1st day**	**2nd day**	**3rd day**	**1 week**
PVP	12					

3.2.2. *Effect of polyvinyl alcohol.* The photographic comparisons of all nanofluids suspensions are shown in Table 4. 3% PVA solution can disperse 1% ZnO nanorods and Figure 3 gives the variation in the liquid-solid interface height as a function of time. Organic surface modification of the ZnO nanorods by PVA has been proven by good adhesion between them. PVA solutions containing ZnO nanorods form transparent multicomponent dispersions which are stable over 1 week.

Table 4: Photographic comparison of dispersion behavior of ZnO nanorods in PVA

Dispersant	**Dispersant conc. %**	**1 hr**	**1st day**	**2nd day**	**3rd day**	**1 week**
PVA	**3**					

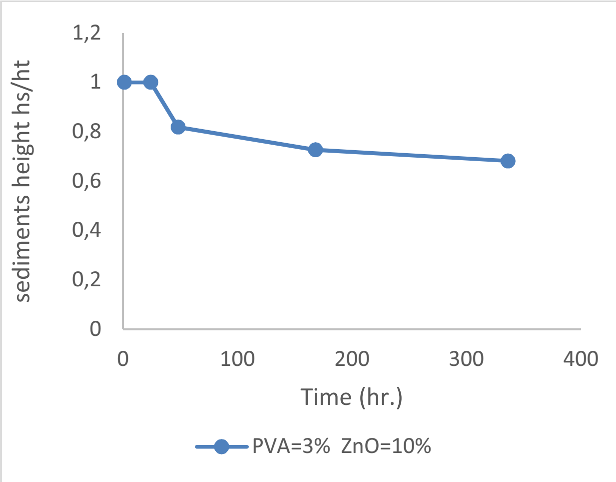

Figure 3: Effect of PVA on stabilization of 10% w/v ZnO nanorods

3.2.3. Effect of Triton X-100. Triton X-100 is a non-ionic and dispersion ability of Triton X-100 is due to its π-π interaction with ZnO nanorods. Stable dispersion results were observed with Triton X-100 = 10 shown in

3.2.4. . After adding the right amount of surfactant, the agglomeration of ZnO nanorods was improved and stability can be observed in. Based on the above data, the dispersion behavior of ZnO nanorods when nanofluids containing 10% of Triton X-100 were better.

Table 5: Photographic comparison of dispersion behavior of ZnO nanorods in Triton X-100

Dispersant	**Dispersant cons. %**	**1 hr**	**1st day**	**1 week**	**2 weeks**
Triton X-100	**10**				
	10				

3.3. Application of ZnO nanorods on cotton fabric
In order to see the presence of ZnO nanorods present on cotton fabric, XRD analysis was carried out. Figure 4 shows XRD patterns of untreated and treated fabric with formulations containing ZnO nanorods.

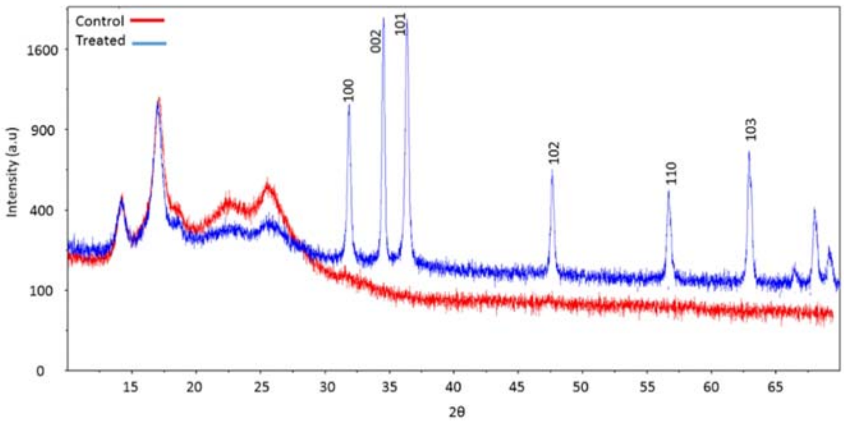

Figure 4: XRD patterns of untreated and treated cotton samples

3.3.1. Ultraviolet Protection Factor. The ZnO nanorods provide UV protection through absorption, reflection and scattering mechanisms. Since the nano objects with their external dimensions in the nano scale may be more reactive than normal bulk material. The influence of ZnO nanorods dose on the protective properties of treated cotton fabric samples is shown Table 8. When ZnO nanorods dispersed in different dispersing agents were applied on cotton fabric excellent results were observed. Improvement in the UV absorption properties of cotton fabric expressed in terms of UPF was observed. As we increase the concentration of ZnO nanorods, the UPF increases and exceeds the threshold of 40 which is the minimum requirement for clothing. The part of UV absorbed by ZnO is consumed in exciting electrons present in valence bands.

Table 6: Input and output responses for treated cotton samples

Sample No.	**Dispersant**	**Dispe r-sant (%)**	**ZnO nanorods w/v %**	**UPF**	**UVA %**	**UVB %**	**Zone E.coli (mm)**	**Zone S.aureus (mm)**
1	PVP	12	10	38.7	93.6	97.9	19	17
2	PVA	3	10	80	95.1	98	19	18
3	Triton X-100	10	10	89	93.4	98	18	15

3.3.2. Antimicrobial activity. There is an increasing demand of antibacterial materials in many textile application areas whilst preventing the fibers from damage and rotting. In most of the cases the antimicrobial effect is obtained through the application of nanoparticles into fibers during a spinning stage. But, organic metal quaternary ammonium compounds, organic silicones, silver nanoparticles have been used for antibacterial finishing of textile materials.

Figure 5-Figure 6 show the antibacterial protection of treated samples against *E.coli* and *S. aureus* respectively. Samples surrounded by bacteria are untreated cotton fabric while treated samples shows the inhibition zones for gram positive and negative bacteria. All the treated samples have zones of inhibitions around them. The antibacterial protection of the fabric sample treated with zinc oxide nanorods could be attributed to release of Zn^+, production of reactive oxygen species (hydroxyl radicals and superoxide ions) and physical interaction of bacterial membrane with nanoparticles.

Figure 5: Antibacterial results against S.aureus of treated cotton

Figure 6: Antibacterial results against E.coli of treated cotton samples

4. Conclusion

Among all dispersing agents the PVA can efficiently inhibit the coagulation of the ZnO nanorods and keep the ZnO nanorods well dispersed in aqueous dispersion solution at nanometric level. The effect of PVP polymer to disperse ZnO nanorods was also significant. The non-ionic surfactants disperse only lesser amount of ZnO nanorods. The synthesized zinc oxide nanorods have a strong antimicrobial activity against some bacteria. Excellent UV absorption results were observed with ZnO nanorods dispersed in PVA polymer. After that ZnO nanorods dispersed in PVP also showed good results on cotton fabric.

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References

[1] Yu W and Xie H 2012 *Journal of Nanomaterials* 2012 17
[2] Bhagat U, More P and Khana P 2015 *SAJ Nanoscience and Nanotechnology* 1 1
[3] Manjula S, Muhesh Kumar S, Raichur A M, Madhu G M, Suresh R, and Lourdu Anthony Raj M A 2015 *Cerâmica* 51 121
[4] Ilyas S U, Pendyala R and Marneni N 2014 *Materials Research Innovations* 18 179
[5] Safaei-Naeini Y, Aminzare M, Golestani-Fard F, Khorasanizadeh F and Salahi E 2012 *Iranian Journal of Materials Science and Engineering* 9 62
[6] Rehman H, Batmunkh M, H Jeong H and Chung H 2012 *Advanced Science Letters* 6 96
[7] Polsongkram D, Chamninok P, Pukird S, Chow L, Lupan O, Chai G, Khallaf H, Park S and Schulte A 2008 *Physica B: Condensed Matter* 403 3713