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Synthesis and enhanced mechanical properties of nano Zinc Oxide in Polyvinyl alcohol and Polyvinyl pyrollidone composite film

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ABSTRACT

Zinc oxide nanoparticles have been synthesized by chemical reaction method. Polyvinyl alcohol (PVA) composite film filled with nanometric, monodispersed zinc oxide nano particles prepared by PVA solution and nanozinc oxide. Polymer blend with ZnO nanoparticle composite film has prepared by casting technique. The property of nano composites depends greatly on the chemistry of polymer matrices. The dispersion of nano particles in the polymer matrices is a general prerequisite for achieving desired mechanical and physical properties. Particular attention is paid on the structural and mechanical properties of a composite film by SEM and Measurement of tensile properties. The results also shows that, the ZnO NPs were uniformly dispersed in the polymer matrix and the particles remained their original size (20-150 nm) before incorporate in to the polymer matrix.

Keywords: *Zinc Oxide nano particles; Polyvinylalcohol; Polyvinylpyrrolidone;Composite film; SEM-stress; Strain measurements.*

INTRODUCTION

Polymer systems are widely used due to their unique attributes: ease of production, light weight, and often ductile in properties can often be found even at relatively low filler content [1-3]. A composite is a heterogeneous substance consisting of two or more materials which does not lose the characteristic of each component. This combination of materials brings about new desirable properties. Traditionally, composites were reinforced with micron sized inclusions. Recently, processing techniques have been developed to allow the size of inclusions to go down to nano scale. For this work, the nano-sized inclusions are defined as those that have at least one dimension in the range 1–100 nm.

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Experiments have shown that nanoscale reinforcement brings new phenomena, which contribute to material. Zinc oxide has many applications in sensors, piezoelectric transducers, catalysts, transparent conductors and surface acoustic wave devices. In particulate/polymer composite system, the polymer particle surface interaction is a critical factor that influences the final properties of the polymer composites system [4-6]. The quality of the interaction determines to a significant extent the load-transfer efficiency and hence the mechanical properties. Naturally, this factor increases in significance as the size of the particles decreases, and the effect becomes dominant when the particles are at the nanometer scale. The nanoparticles can have a strong affect on the configuration and conformation of the surrounding polymer which leads to alterations in the bulk properties of the composite [7, 8]. Consequently, Nanoparticles have special effects on polymers since the particle size is of the same order as the polymer chain gyration [9].

Nano technology is now recognized as one of the most promising areas for technological development in the 21'st century. In materials, research, the development of polymer nano composites is rapidly emerging as a multidisciplinary research activity whose results could broaden the applications of polymers to the great benefit of many different industries. PNCs also may exhibit composite or enhanced mechanical and physical properties to standard composites with a lower volume addition of filler. There is a growing interest in the development of nano composite consisting of organic polymers and metal oxide nano composites [9-10]. Polymer composites film with Nanoparticles has become strongly promising naval smart polymer matrix nano composite to satisfy the ever increasing design requirements of the recent structural applications. Metal oxide nano particles can be used to enhance the stiffness, toughness, and probably the life of polymeric materials [11, 12]. Characterization of the nano particles dispersion is necessary to optimize the structure –property relationship. In this work, we focus on a fabrication, structural and stress, strain properties of Nano Zinc Oxide in Polyvinyl alcohol and polyvinyl Pyrollidone composite film composite film.

EXPERIMENTAL

Materials and Preparation of Zinc Oxide Nano particles

Chemicals were all of analytical reagent grade quality and used without further purification. De-ionized and doubly distilled water were used throughout this study. 100 ml of Zn (NO_3) $6H_2O$ aqueous solution (0.1 mol /l) and 100 ml of NaOH aqueous solution (0.1 mol/ l) were mixed to obtain zinc hydroxide [Zn $(OH)_2$] precipitate. The precipitate was separated from the solution by a centrifuge at 3000 rpm for 5 min. The obtained Zn $(OH)_2$ was dispersed into distilled water and was again separated by a centrifuge. This procedure was repeated 3 times, and the impurities in the precipitate were removed. The Zn $(OH)_2$ was then dispersed in 50 ml of H_2O_2 aqueous solution whose concentration was 1 mol l/1. The dispersed solution was heated at 348 K for 2 h in a closed glass vessel (200 ml). The resultant solution was a translucent sol of the zinc peroxide nanoparticles. The obtained sols were dried at 348 K for 6 h. The obtained powder was kept at 453 K temperatures for 2 h to prepare Zn O particles. The prepared solution was casting on a glass substrate uniformly and kept in vacuum desiccators. A film of PVA-ZnO NPs was obtained after the solvent evaporation. The film was then, washed with double distilled water to remove any soluble impurities. Scanning Electron Microscopy (SEM) picture of these particles were taken using JSM-840 microscope.

RESULTS AND DISCUSSION

Morphology of Thin film

The current knowledge on oxide materials allows affirming that most of their physico-chemical properties display acute size dependence. Physico-chemical properties of special relevance in Chemistry are mostly related to the industrial use of oxides as sensors, ceramics, absorbents and/or catalysts. A bunch of novel application within these fields rely on the size-dependence of the optical, (electronic and/or ionic) transport, mechanical and, obviously, surface/chemical (redox, acid/base) properties of oxide nanomaterials. Hence we study the enhancement of mechanical properties of polymer film with zinc oxide nano particles. SEM images of PVA-ZnO NP composites are shown in Figures 1-4. When PVA polymer was added to ZnO materials, crystallites were initiated and grown in the immediate vicinity of the surface. In our study, we have observed the similar crystal growth in the SEM images of PVA-ZnO NP materials this clearly shown the particle size agglomeration in PVA content. It has already demonstrated that, zinc oxide nanomaterials are inherently piezoelectric. However, the objective of this study is, to study the effect of nano particles on polymer film. Thus, the following zinc oxide nano particles are synthesized and fabricate the PVA-ZnO nanoparticles polymer film and PVA-ZnO nanoparticles-PVP polymer composite film. The difference in the structure of the various materials has seen in these observations.

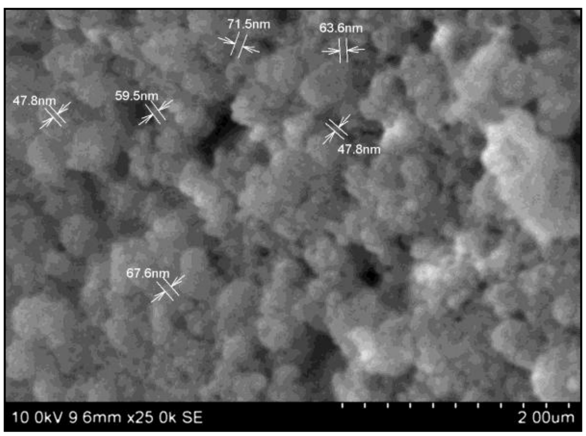

Fig. 1. Figure shows the SEM image of pure Zinc oxide nano particles.

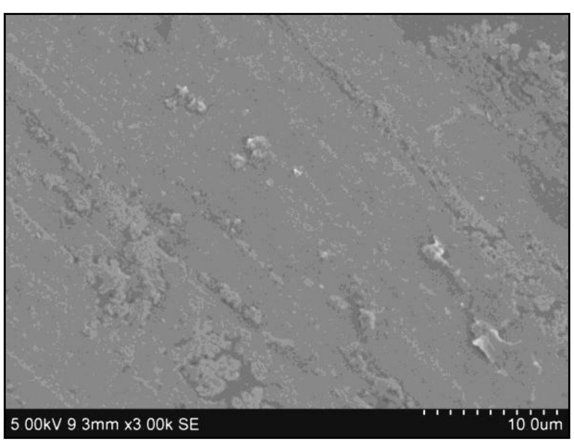

Fig. 2. Figure shows the SEM image of pure PVA film.

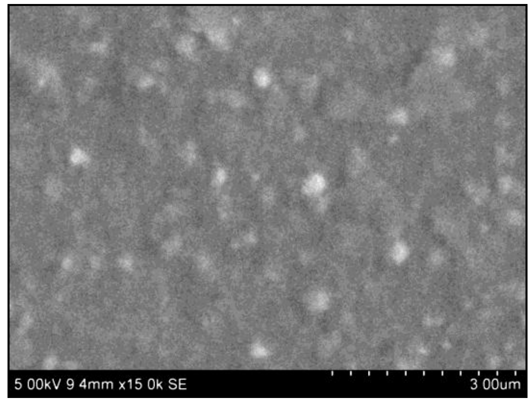

Fig. 3. Figure shows the SEM image of PVA-Zinc Oxide nano composite film.

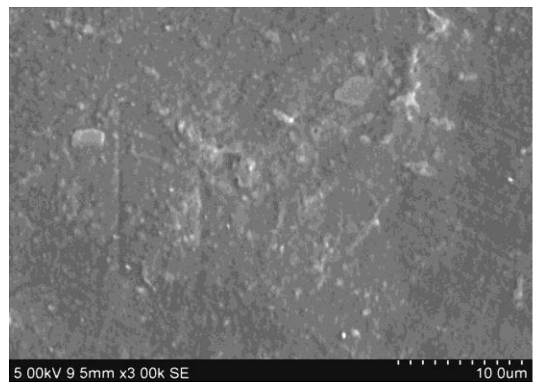

Fig. 4. Figure shows the SEM image of PVA- ZincoxideNanoparticle-Polyvinyl pyrrolidone composite film.

From the Figure 3,it is observed that, zinc oxide nano particles are uniformly dispersed in the polyvinyl alcohol solution whereas, it is randomly distributed in the polymer film with PVP and it is concluded that small agglomerations is formed in this film[9,10,13].

Measurement of stress & strain

The mechanical properties of PVA-ZnO NP and PVA-ZnO NP-PVP composite film are evaluated by stress-stress test. It is well known that the mechanical properties of nano composites are strongly affected by nano filler dispersion and agglomeration. SEM is commonly used to know the surface structure of different materials. In general, the stress in a solid (or a group of interacting particles in the form of a solid) is defined as the change in the internal energy (in the thermodynamic sense) with respect to the strain per unit volume. When the internal energy is equal to the strain energy of the solid, then Hooke's law may be derived from of the stress tensor (σ_{ij}), for a linear-elastic material [14]. Furthermore, if the strain energy is expressed in terms of applied force acting over the surface area of a solid, then a more familiar form of stress as force per unit area is derived. In the early (low strain) portion of the curve, many materials obey Hooke's law to a reasonable approximation, so that stress is proportional to strain with the constant of proportionality being the modulus of elasticity or Young's modulus, denoted E:

$$\sigma_e = E\,\epsilon e \qquad (1)$$

The variation of stress and strain of a polymer composite film with nano zinc oxide with polymers composites are shown in Figure 5 and Figure 6. Upon testing, stress and strain are calculated from the film dimensions, where the film width and thickness are measured. The stress and strain is increases for composite film. Stress is increased with linearly with elongation with increasing of breaking strain. The stress–strain curves of both composites subjected to loading conditions are compared with pure polymer composite film. As strain is increased, many materials eventually deviate from this linear proportionality, the point of departure being termed the proportional limit. Here the material is undergoing a rearrangement of its internal molecular or microscopic structure, in which atoms are being moved to new equilibrium positions. It is concluded that, addition of nano particles and with PVP enhanced the mechanical properties of a material [15-17].

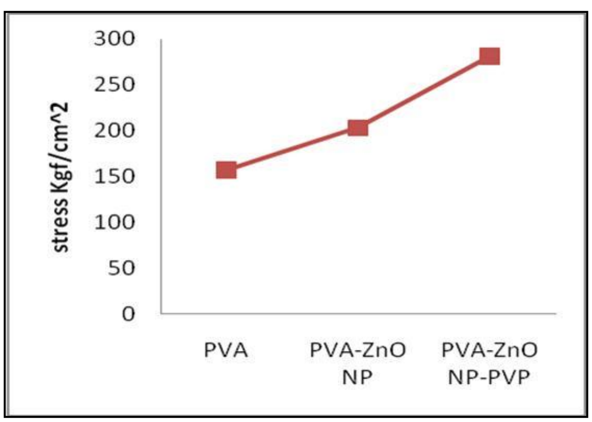

Fig. 5. Graph between the stress and composite film.

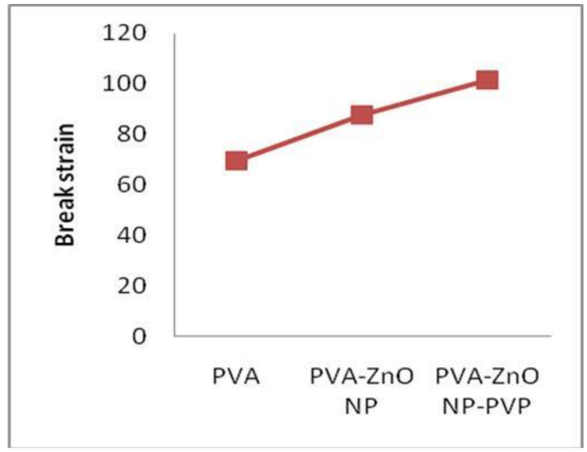

Fig. 6. Graph between the breaking strain and composite film.

The SEM shows the very detailed three dimensional images at very high magnifications. The surface structure of a polymer nano composites, nano fibers, nano particles and nano coatings can be imaged through SEM with high clarity. SEM images depict the surface morphology of ZnO nanoparticles, ZnO-PVA and PVA-ZnO-PVP which are shown in Figures 1-4, respectively. The ZnO particles are agglomerated to form clusters through intermolecular interactions (Figure 1). The polyvinyl alcohol and zincoxide nanoparticles are observed to aggregate in the form of clusters at a micrometric scale level, indicating a weak adhesion between the nanoparticles and the polymer matrix (Figure 3). However, in Figure 4, a well-dispersed nanoparticle was observed, indicating an interaction between the nanoparticle and the PVP-PVA matrix. The variation in the concentration of polymer is to change the morphology of ZnO-PVA-PVP composite and the interaction between the particle and the polymer matrix favors a more compact solid structure [18, 19]. Metal oxides enhanced the mechanical properties of the polymer composites [20]. In general, tensile properties such as tensile strength, elastic modulus, and stress at break increase while elongation decreases [21, 22]. The stress and breaking strain of nano zinc oxide particles with polyvinyl alcohol and PVA-PVP composite film are shown in Figures 5 & 6 and it shows the compatibility of a polymer matrix. In addition to loading rates, nanofiller may also be important at high strain rates. Effect of nano particles can affect the strength of materials. Breaking stress and strain were measured for different polymer composites with nano zinc oxide particles. In summary, our work demonstrated that, the mechanical properties of PVA film and PVA - PVP film can enhanced with nano zinc oxide particles. The authors are currently interested to study effect of mechanical characteristics—including size, shape, and geometry—on polymer composite(Table 1, 2). Also, we are interested to study the nanoparticle shape and geometry significantly influences static mechanical behavior of the corresponding nanocomposites, such as Young modulus and tensile strength [23, 24].

Table 1. Dimensional measurement of zincoxide nanoparticles in polyvinylalcohol and polyvinyl pyrrollidone composite film.

Film Name	Thickness of the film	Width of the film	Gauge length of the film
Units	mm	mm	mm
PVA	0.3000	25.0000	50.0000
PVA-ZnONp	0.2000	25.0000	50.0000
PVA-PVP-ZnONp	0.1400	25.0000	50.0000

Table 2. Tensile properties of zincoxide nanoparticles in polyvinyl alcohol and polyvinyl pyrrolidone composite film.

Name of the composite film	Max_Force Of the film	Max_Stress Of the film	Breaking Force Of the film	Breaking Strain Of the film
Units	kgf	Kgf/cm^2	kgf	%
PVA	11.7889	157.185	4.93527	69.556
PVA-ZnONp	10.1653	203.306	7.37619	87.632
PVA-PVP-ZnONp	9.84666	281.6605	2.686315	101.669

CONCLUSIONS

Zinc oxide nano particles synthesized by chemical method and its was characterized by the SEM. ZnO NP-PVA film and PVA-ZnO NP-PVP composite film were synthesized and its dimensions were measured . Also, from the stress-strain graph, it is concluded that, the dispersion of zinc oxide nanoparticles enhance the mechanical properties of a composite film. Hence, Metal oxides improve tensile properties but every metal oxide behaves different according to its physical, mechanical and chemical properties. Fine dispersion of the particles provided better surface adhesion with polymer blending. ZnO NP gave higher yield strength, tensile strength and elastic modulus due to its stiff structure in this result.

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