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Research Article

Investigations of Nanoparticles (Al_2O_3-SiO_2) Addition on the Mechanical Properties of Blended Matrix Polymer Composite

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The manufacture and investigation of the characteristics of nanocomposites with nanoparticles are made by the sol-gel technique. It comprises two substances (aluminium oxide-silicon oxide), as well as the influence of such particles on the mechanical characteristics of a polymeric matrix is described in this study. Tensile, bending, and hardness tests were utilized to assess the mechanical characteristics of the hybrid material. The evaluation results of composite nanoparticles revealed a clear dispersion of chemical components among aluminium oxide and calcium oxide, softness in particulate matter during crystallization at high and low temperatures, the initiation of various nanostructures forms, and distinct stages of an alumina particle. When compared to a polymeric mix without nanoparticle inclusion, mechanical behaviour tests demonstrated a considerable improvement in the mechanical capabilities of the nanocomposites, notably at 2%. Mechanical parameters such as tensile strength are 61.36 MPa, flexural strength is 74.25 MPa, and hardness is 83.27 D at 2.5 wt% at 600°C heat treatment conditions. Under 900°C heat treatment conditions, tensile properties of 54.12 MPa at 1 wt. percent, flexural properties of 79.21 MPa at 2 wt. percent, and shore hardness of 81.21 D at 2.5 wt. percent of nanoparticles were measured.

1. Introduction

Nanotechnology is a large and comprehensive scientific discipline that has exploded in popularity in current decades, and nanoparticles are the foundation of nanotechnologies. Nanostructures are advanced inorganic materials that are gaining professional curiosity due to their remarkable qualities when compared to other types of substances [1]. Nanocomposite particles are made up of two separate materials consolidated into a single hybridized particle, resulting in a multifaceted substance that may be employed in a variety of sectors, such as pharmaceuticals, electronics, and manufacturing, or to improve existing features [2]. As a result, interest in this type of material has grown, as have the tactics employed to make it [3]. Natural fibre may be utilized to make nanostructures, while tapioca plant films could be employed in a spectrum of uses, including packing and reinforcing materials. Commercial resources could be used to make nanomaterials, with the characteristics of the site of the particles regulated. Nanoparticles can be created using a variety of techniques, including mechanical, physiological, and biochemical methods [4]. Chemical treatments are the most common among the approaches utilized since they produce results quickly and in a short amount of time. Clogging, dispersal, and sol-gel are some of the mechanisms used in biochemical procedures [5]. In comparison to other procedures, the sol-gel technique is a must-have approach since it ensures particle uniformity, cleanliness, and fineness [6]. Basic processes in this approach involve dissolving the raw material (nitro, hydroxides, or salts) in a suitable dissolvent, encouraging particle precipitation to produce the gels, and lastly, using the heating process (dryness and carbonization) to make the powder. Only well-suited substances utilized to make nanostructures are patrolled [7]. The sol-gel technique has the following benefits: (i) improved bonding between both the material and the protective coating; (ii) components can be moulded into complicated geometrical patterns; (iii) high-purity materials can be obtained due to earthenware sulphide precursor chemicals disintegrating inside the alcoholic solution for such sol-gel transition; (iv) low process temperature levels; simple, economical; even with no special or expensive equipment; and (v) a successful mechanism to deliver superior adhesives [8]. The blending of polymers has resulted in the production of a modern trend of polymer materials at low densities, low cost, better resistance to corrosion, and strong performance characteristics while keeping the molecule's original properties. The most notable such polymers are epoxy and polyester, which have been the subject of several studies and are differentiated by a wide range of characteristics that may be used for a variety of technological, manufacturing, and medicinal purposes [9]. Different materials, like granules, fibres, or sheets, can be used to reinforce epoxy and polyester polymer. Nanomaterials are one of the most significant materials used to improve biodegradable polymers as they provide stability, strength, and distinctive and great capabilities to reinforce the polymer structure. Various researches on the fabrication of polymer matrix nanocomposites from organic and inorganic materials have been done. They [10] investigated the mechanical characteristics of polyester-epoxy-treated bamboo fibre mix biocomposites, as well as the influence of nanoclay minerals on those parameters. When the microclay mineral ratio was increased to 10% by weight, all dynamic qualities improved, but after that, the characteristics began to deteriorate. Sugar palm fibre was handled by researchers [11] to produce sugar palm nanocrystals viscose. The researchers created biological nanomaterials in the form of thin films. In comparison to the clean film, it had greater crystalline nature, elastic modulus, mechanical characteristics, thermodynamics, and moisture resistance. The study demonstrated that after being strengthened with sugar palm nanocrystals viscose, the bio-nanocomposites' tensile modulus and deformability rose, and the optimal filler particle level was 0.5 percent. Sugarcane bagasse nanocrystal viscose nanomaterials were developed and employed as a renewable reinforcing phase to enhance the water moisture barrier characteristics of sugarcane bagasse carbohydrate film. [12]. In comparison to sugarcane bagasse and nanomixed sugarcane bagasse bio-nanocomposites, the sugarcane bagasse deteriorated quicker in the bioremediation test. To increase the water resistance qualities of sugarcane bagasse carbohydrate film, nanomaterials are being manufactured and used as disposable reinforcement materials. This work [13] studied the influence of Tungsten Carbide on the epoxy resin, finding the mechanical qualities and fracture toughness. To reinforce the polyester material, [14] employed ferric oxide and blended ferric oxide nanoparticles produced by a chemical decomposition method. When compared to polyester augmented with nanoclusters, the results revealed that the polyester reinforced with f-Fe2O3 nanoparticles had better mechanical characteristics. Author [15] investigated the impact of introducing graphene powders to an epoxy-polyester mix as a reinforcing factor. The results demonstrated a significant improvement in mechanical characteristics, particularly at 0.2 percent. Researchers [16] investigated the thermal characteristics of an epoxy-polyester mix with nanoclay as a reinforcing material, finding that increasing the nanoclay content to 5% resulted in enhanced heat breakdown and

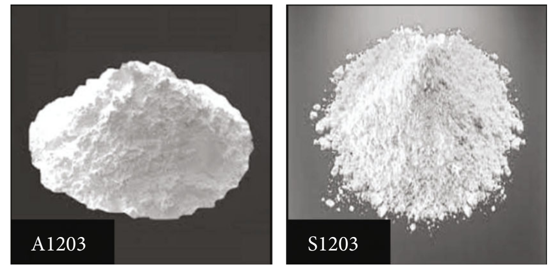

Figure 1: Photographic image of nanoparticles.

Figure 2: Setup for tensile testing.

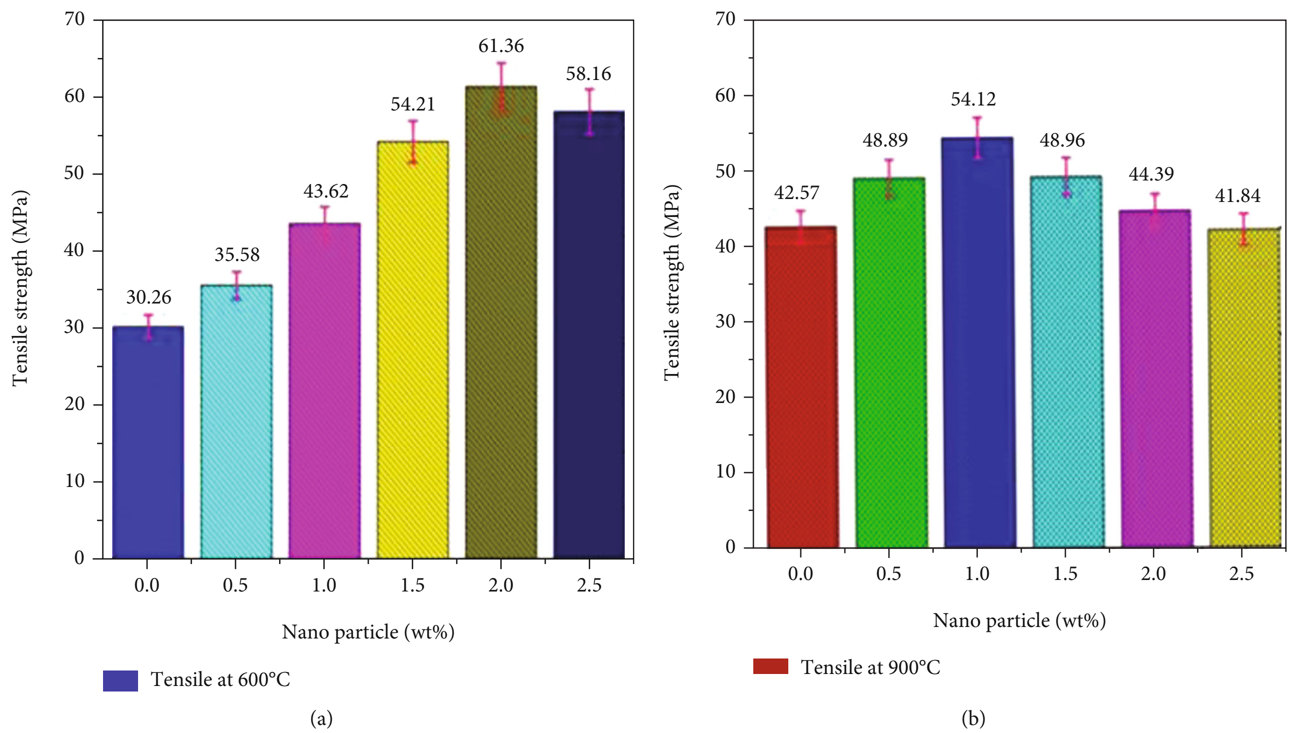

FIGURE 3: Tensile strength of blended polymer-based nanoparticle (Al_2O_3 and Si_2O_3) with heat treatment (a) 600°C and (b) 900°C.

weight loss. Thermal characteristics, on either hand, were enhanced when the glass transition temperature was increased by 4 wt%. It has been discovered in earlier studies that researchers researched the production of nanomaterials from different chemicals. However, researchers did not investigate the production of composite nanostructures and their impacts on the matrice substance's characteristics, particularly the mechanical capabilities. Furthermore, no reference was made to the influence of such nanoparticles on the characteristics of the polymeric mix. As a result, the goal of this research is to complete this assignment using nanomaterials (aluminium oxide and silicon oxide) and describe how they affect the properties of a polymer mixture, and to use a polymeric mixture (4% of epoxy and 96% of polyester) to fabricate the hybridized materials.

2. Experimental Works

2.1. Materials. The GVR chemical plant in Madurai, Tamil Nadu, India, provided the pure epoxy resin and hardeners used in this investigation. The polymer mix is made up of polyester resin, hardener, and accelerators such as methyl ethyl ketone peroxide and cobalt naphthanate, all of which are provided by the same company. The nanocomposite particles were made from aluminium and silicon nitrate nonahydrate from Naga chemicals in Chennai, Tamil Nadu, India, which had a quality of 99 percent. Figure 1 shows the photographic images of aluminium- and silicon-based nanoparticles.

2.2. Nanoparticle and Its Composite Preparation. To make the nano-based particles, both the aluminium nitrate nonahydrate and silicon nitrate were disintegrated in 100 ml of distilled water with constant blending on a heating plate mixer at 60°C till the granules disintegrated, then the disintegrated additives for both kinds were taken in a conical flask and mixed up to 3 hours at 60°C. After that, a 2% detergent solution was injected, followed by droplets of ammonia solution incorporated by constant stirring to build stickiness until gel was produced. The prepared solution was then cleaned through strainer material to remove the gels, which had been heated at 80°C for 6 hours. Pasteurization at 600°C and 900°C for 2 hours is the final phase. The polymer blend was then prepared in order to create composite materials. A mechanical mixer was used to combine a specific proportion of each ingredient (4 percent epoxy, 96 percent polyester), as well as bonding agent, catalysts, accelerators, and promoters with ratio of 2 : 2 : 2 : 2. The produced nanoparticles were then placed at 0, 0.5, 1, 1.5, 2, and 2.5 wt percent in the motorized blender and stirred. The slurry was then placed into a mould and cut as per ASTM standards following solidification and curing. To get an appropriate readout, three specimens were produced for every mixture [17].

2.3. Mechanical Testing. The properties of the different nanostructures were evaluated employing tensile and bending tests performed on a universal testing machine as in Figure 2 with a capacity load of 50 kN, with specimens prepared and executed as per ASTM D 638, flexing samples executed as per ASTM D 790, and shore D hardness samples executed as per ASTM D 2240.

2.4. Fractographic Analysis. SEM was utilized to conduct microscopic (Fractographic) investigations into fractured

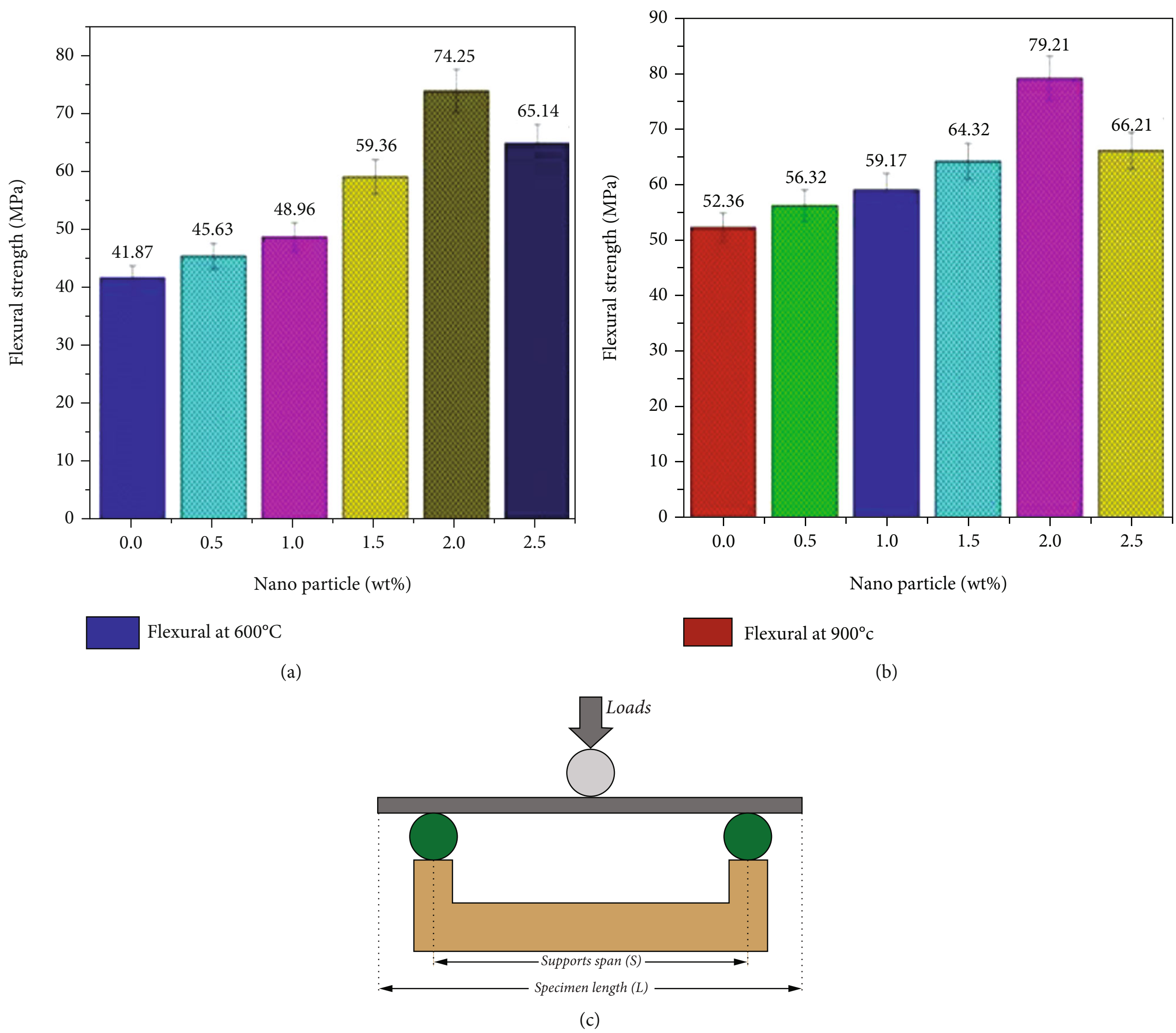

FIGURE 4: Flexural strength of blended polymer-based nanoparticle (Al_2O_3 and Si_2O_3) with heat treatment (a) 600°C and (b)900°C; (c) flexural strength setup by pictorial view.

composite samples. The specimens were laved, dehydrated, and surface coated with 10 nm of gold before SEM clarity to increase the composites' electrical conductivity.

3. Result and Discussion

3.1. Mechanical Properties of Polymer Blend Matrix

3.1.1. Tensile Behaviour. The most important mechanical test is the tensile test. This test involves applying a slog force to a substance and measuring how it reacts to strain. The tension test assesses the material's strength and its ability to expand in so doing. The tension performance in Figure 3(a) shows the effects of introducing composite nanomaterials (aluminium and silicon oxide) at different rates into a polymeric matrix (4 percent epoxy, 96 percent polyester) after heat treatments at 600°C. The results show that the relationship between elongation behaviour and the quantity of particle supplied is proportionate. That indicates that when the amount of powder in the nanocomposite increased, the maximum tensile strength increased as well. This means that the nanoscale particle has a greater surface area, which boosts the foundation substance's soaking capacity and offers greater coverage for the nanoparticle's interface, as well as enhances the toughness of the nanoparticle-base materials contact. Figure 3(b) depicts the tensile behaviour of nanoparticles added to a polymer blend (4 percent epoxy and 96% polyester) after thermal treatment at 900°C. The highest stress resistance of the nanocomposite increased as the proportion of powder increased, although not as much as the findings of the nanopowder generated at 600°C. The dispersal efficiency and adhesive intensity of the nanoparticles with the polymer matrices are responsible for the increase in mechanical characteristics [14]. As a result, the mechanical characteristics of the material deteriorate. A decline in characteristics is caused by the diversity

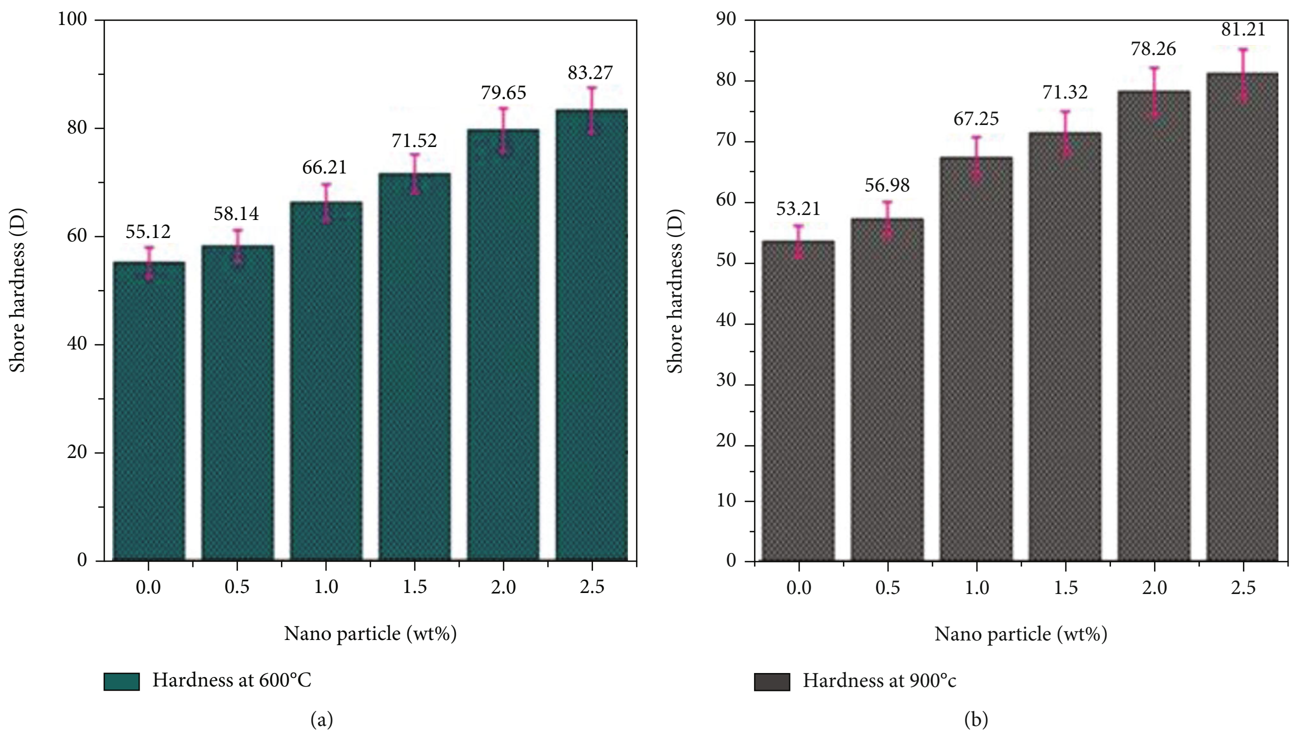

FIGURE 5: Shore hardness of blended polymer-based nanoparticle (Al_2O_3 and Si_2O_3) with heat treatment (a) 600°C and (b) 900°C.

and dispersal of the aggregation of nanoparticles inside the matrix phase.

3.1.2. Flexural Properties. The degree of flexural strength an item can tolerate prior to fracturing or warping is known as flexural strength. The resulting nanopolymerized material, as shown in Figures 4(a) and 4(b), demonstrates that increasing the percentage of nanopowder results in an improvement in flexuralconfrontation levels. It demonstrates that the mixed nanoparticles offer resistance and strength to the polymeric mixtures, as well as making the support material more robust to external loads. SEM further reveals that the smoothness has resulted in a huge surface area. In addition, the irregular form of the composite nanoparticles created at 600°C and 900°C, as seen in SEM, increases the strength of the nanoparticle-base substance contact. The disparity in particle diameter between the nanoscale powders and the aggregation acts as maximum stress centres, which reflect intrinsic faults in the composite material, resulting in a fall in bending resistance values [18]. As a result, we detect a change in resistance. Excessive reinforcement reduces the wet capability of a raw product, resulting in flaws including micro and nanofractures inside the composite, as well as impairment of mechanical qualities [13]. The pictorial representation of flexural strength machine is displayed in Figure 4(c).

3.1.3. Hardness Behaviour. Hardness testing is an important part of many quality control processes. It allows us to evaluate a material's qualities and determine if a substance or material treatment is appropriate and applicable for the task at hand. The hardness testing results after adding nanopowder (aluminium and silicon oxide) generated at 600°C and 900°C to the polymer mixture (4 percent epoxy and 96 percent polyester) with varying weight proportions are shown in Figures 5(a) and 5(b). The hardness values of the polymeric matrix have increased. This implies that composite nanomaterials have a high surface area and thus have a good resistance to scratches, which serves to improve the soaking capability of the ground material as well as the toughness of the interaction between both the nanomaterials and the ground plane [6, 19]. The low proportion of imperfections in the nanocomposites, such as microscopic and nanocracks, enhances the mechanical characteristics [17]. The modest discrepancy in hardness values, as seen in, is attributable to the particulate difference in size inside the powders.

4. Fractographic Study

SEM was used to evaluate specimen surface features at very high resolution using a part of an apparatus known as a digital microscope. The beam of electrons concentrates on the sampling site during the SEM test, causing energy to be transferred to the spot and subsequently translated into a result. In this work, the morphology and histologic features of the composite nanopowders created by the sol-gel technique were studied using scanning electron microscopy. Figure 6(a) shows a different magnification image of composite oxide nanoparticles (aluminium and silicon) generated under the same conditions and carbonization at 600°C. As illustrated, particle dispersion and saturation are concentrated in particular sections of nanoparticles, which aids in the cluster formation among big particles. Figure 6(b) depicts a significant magnification resolution of the composite

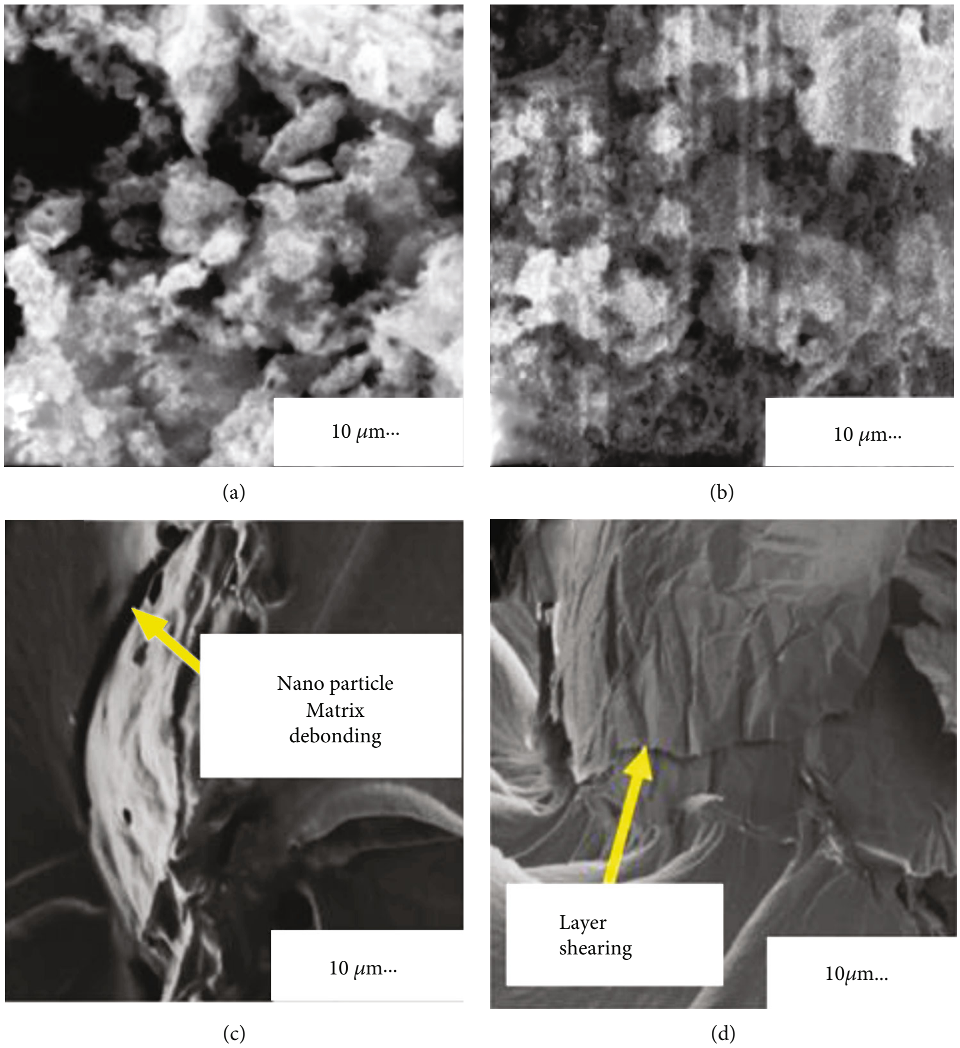

Figure 6: SEM image of composite nanoparticle (Al_2O_3 and Si_2O_3) with heat treatment (a) 600°C and (b) 900°C; (c) failure in tension; (d) failure in flexural.

nanopowder (aluminium and silicon) oxide heated at 80°C for 6 hours and calcined at 900°C for 2 hours. The irregular structure of the nanoparticles aided in the formation of certain particle groupings. Also, due to the various geometric developments of the particles, the resultant particles' shapes are uneven. Figures 6(c) and 6(d) show the nanoparticle matrix failure during mechanical testing. Those figures proved that the brittle failure occurred due to the oxide formation was higher in the particular failed region.

5. Conclusion

(i) SEM examination of the composite nanoparticles indicated an uneven shape and a homogeneous chemical composition of aluminium oxide and silicon with no impurities. Furthermore, the studies demonstrated that particle smoothness is temperature dependent. Heat treatment at 600 degrees Celsius generated finer and more phases than heat treatment at 900 degrees Celsius. In mechanical tests, the quality of the polymer mix augmented with composite nanoparticles increased dramatically. According to the mechanical assessment findings, the best qualities were obtained by reinforcing with nanocomposite powder at a concentration of 2 wt%. Mechanical parameters such as tensile strength are 61.36 MPa, flexural strength is 74.25 MPa, and hardness is 83.27 D at 2.5 wt% at 600°C heat treatment conditions

(ii) Under 900°C heat treatment conditions, tensile properties of 54.12 MPa at 1 wt. percent, flexural properties of 79.21 MPa at 2 wt. percent, and shore hardness of 81.21 D at 2.5 wt. percent of nanoparticles were measured

(iii) The GRA will be implemented to carry out the optimal parameters to future work

Data Availability

The data used to support the findings of this study are included within the article. Further data or information is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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