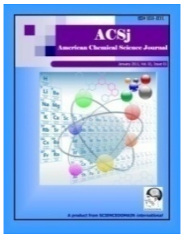

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Study on Synthesis of Nanopolymer Composite with Electroless Coated Reinforcement

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

In this paper synthesis and characterization of a new hybrid polymer composites reinforced with electroless nickel coated glass fiber with the addition of 0.5 % of nano iron oxide as filler is reported. Nano Iron oxide is introduced into the matrix as fillers at the minimum concentration and its influence on the mechanical and wear behavior are studied. The nano additive added to play a major role in strengthening the composite. To further enhance the strength and wear resistance, polyvinyl ester matrices reinforced with electroless Ni-P coated glass fiber reinforcement is synthesized. The glass fiber reinforcement is coated for the first time into electroless Ni-P successfully after carrying out many trials. The surface morphology is examined by means of SEM. The experimental result shows that after coating the reinforcement with electroless Ni-P, the ultimate tensile strength, compressive strength, flexural strength, impact strength and wear resistance is improved by 17.90%, 9%, 12.98%, 33% and 4.58% respectively. After adding nano iron

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oxide as filler material at 0.5 weight percentage concentration of Ni-P coated glass fiber reinforced PMC, the properties such as ultimate tensile strength, compressive strength, flexural strength, impact strength and wear resistance is improved by 43.54%, 23.9%, 23.93%, 34% and 19.25% respectively.

Keywords: Nano filler; nano composite; hybrid polymer matrix composite; electroless coatings.

1. INTRODUCTION

Vinyl ester resin is one of the most widely used thermoset resins in polymeric composites due to their excellent resistance to the wide range of chemicals and to their outstanding combination of thermal and mechanical properties. These very positive properties are the result of their molecular structure. The secondary hydroxyl groups are present at the backbone of the resin are responsible for producing composites with very good mechanical properties [1,2]. Polymers and composites are finding ever increasing usage for numerous industrial, shipbuilding applications. Vinyl ester based Polymer Matrix Composites has received increasing attention to recent decades of engineering materials. The introduction of glass fiber to a polymer matrix produce a composite material that results in an attractive combination of physical and mechanical properties which cannot be obtained by monolithic alloys [3]. Nano structural materials such as nanoparticles (NPs) or nanofibers have been used as fillers in both the polymeric nanocomposites to improve the mechanical, electric, electronic and optical properties, and the metallic Nanocomposite to control the electrodeposition. Polymer nano composites reinforced with inorganic nanoparticles have attracted much interest in their lightness, homogeneity, cost-effective processability and tunable physical properties [4,5,6].

Transition metal oxide such as copper oxide (CuO and Cu_2O), iron oxide (FeO, Fe_2O_3 or Fe_3O_4) and zinc oxide (ZnO) nanomaterials have special physicochemical properties arising from the quantum size effect and high specific surface area, which may be different from their atomic or bulk counterparts. Polymeric nanocomposites embedded with inorganic nanoparticles have attracted much interest in their high homogeneity, flexible processability and tunable physical properties such as mechanical, magnetic, optical, electric and electronic properties. Vinyl-ester resin, as a structural polymer, was chosen as a polymer matrix in current study due to the fact that the cured resins are thermosetting with a network structure possessing high resistance to the moisture and chemicals, and good mechanical properties [7,8]. Processing of glass fiber reinforced vinyl ester composites with nanotube enhancement of interlaminar shear strength was tried out and nanotubes improved the shear strength [9]. Hybrid effect of nano particles with carbon fibers on the mechanical and wear properties of polymer composites and Preparation and evaluation of mechanical and wear properties of hybrid FRP composites were attempted by earlier researchers and reported [10,11].

However literature review shows that coating of glass fiber reinforcement of polymer matrices had not been carried out and recently few attempts were made to improve the strength of polymer matrix composites by adding some nano additives. To look for further improvement in mechanical properties electroless Ni-P coated glassfiber reinforced polymer matrix is synthesized.

2. EXPERIMENTAL PROCEDURE

2.1 Materials and Chemicals

Fiber glass, used for matrix reinforcement was E-glass woven roving's supplied from Saint-Gobain Vetrotex. Commercial vinyl ester, Derakane 510A-40 a bisphenol epoxy based vinyl ester resin (VE) with a density of 1.23g/ml and 38% styrene content, was supplied by Dow chemicals. For room temperature cures of vinyl ester resin, the formulation by weight ratios was: 2% methylethylketone peroxide (MEKP) as catalyst, 0.3% cobalt octovate as accelerator and 2% dimethylasiline as promoter is used as the retarder the extension of the reaction gel time. For the coating of glass fiber different chemicals are used for different purpose. Nickel sulphate, Sodium tricitrate and Sodium hydroxide from Qualigens, Sodium hypophosphite from Loba, Ammonium chloride, Ammonium solution and HCl from Merk, Palladium and Stannous chloride from Alfa Aesar were used for coating purpose.

2.2 Coating of Glass Fiber

Glass fiber is a non-conducting material hence electroless nickel coating is preferred. The coating process involved two major steps such as pre-treatment and electroless coating process [12]. Before plating the substrate, it must be thoroughly cleaned and pretreated for proper coating [13]. The electroless coating bath consists of a source of nickel, reducing agent, stabilizer and regulator. The concentrations of chemicals used for the bath are taken from [14]. Ammonium solution is used to maintain the pH value of the bath. The temperature and pH must be maintained at 80±2ºC and (7-8) pH for proper coating process. The coating will take place for 60 minutes.

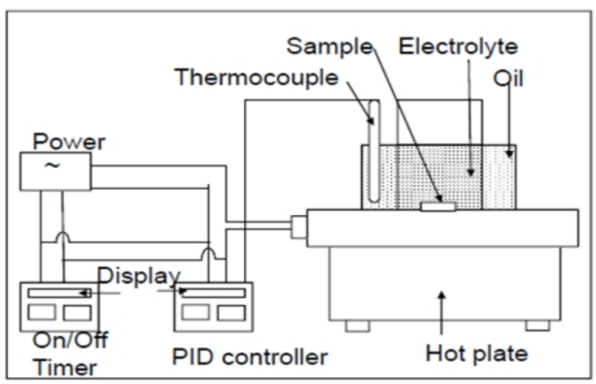

Fig. 1. Electroless coating set-up

2.3 Functionalization Process

Functionalization is the process of modifying the surface properties of the nano materials to improve the bonding with the matrix. For functionalization of nano iron oxide 1.25 mg of iron oxide is taken with 2 ml of MPS (methacryloxy propyl trimethoxysilane) and 20 ml of THF (tetrahydrofuran) in the glass beaker and mixed thoroughly. The colloidal suspension was ultrasonically stirred for 1 hour and allowed it to sediment at room temperature. The sedimented nano particles were rinsed with excess amount THF to remove excessive MPS and dried completely in oven.

2.4 Sample Preparation

Hand-layup technique is used for making of hybrid polymer composites. The accelerator, catalyst and promoter are added to the vinyl ester and mixed. Wax is applied over the mould surface. The mixed mixture of resin is poured over the mould and then the glass fiber is placed over the resin. Pour the resin over the glass fiber to the required thickness. Roll it using rollers to remove the entrapped air bubbles. Close the mould and allow it to cure for about 24 hours. The PMC of required size is prepared. Cut the specimens as per ASTM standard. The reinforcement and matrix are used in 1:5 ratios.

3. RESULTS AND DISCUSSION

The sample identities are as follows: Sample A- Bare glass fiber reinforced polymer matrix composite. Sample B-Nickel coated glass fiber reinforced PMC. Sample C- Nickel coated glass fiber reinforced PMC with the addition of 0.5 weight percentage nano iron oxides as filler material. To find out the various strength of specimen at least 5 measurements under the same conditions were carried out and the average was reported as a nominal value for all tests. Standard deviation of the readings ranged from less than ±5% of the nominal value.

3.1 SEM Microstructure

In order to investigate the nickel coated into the glass fiber the SEM has been analyzed at 2500X. The Fig. 2(a) shows the image of bare glass fiber and Fig. 2(b) shows the Ni-P coated glass fiber. The bubbles shaped spherical particles over the surface of the glass fiber are the proof for the nickel particles present on the coated fibers [15]. The Fig. 2(c) shows the SEM image of PMC without the presence of filler and Fig. 2(d) shows the SEM image of PMC filled with nano iron oxide. The small white dots are the nano iron oxide present in the surface of the PMC. The microstructure clearly shows the nano iron oxide particles are uniformly dispersed and present on the polymer matrix.

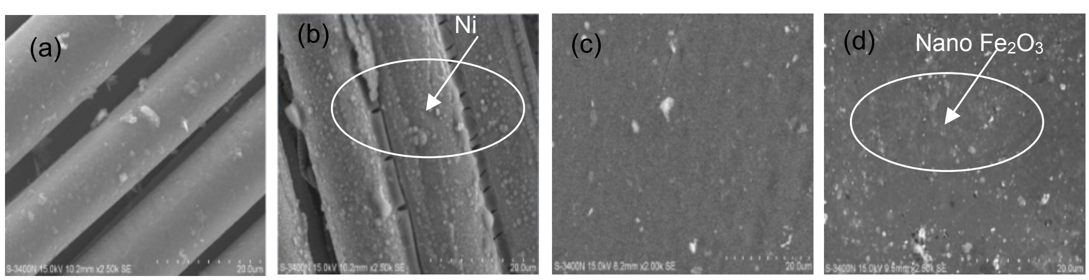

Fig. 2. SEM micrograph at 2500 X. (a) Bare glass fiber (b) Ni-P coated glass fiber (c) Pure resin PMC (d) Nano Fe_2O_3 added PMC

From the Fig. 3(a) and Fig. 3(b) it is clear that the nickel and phosphorus are equally dispersed over the entire surface. Fig. 3(c) clearly shows the distribution of nano iron particles over the PMC.

3.2 EDX Analysis

Figs. 4(a) and 4(b) show the presence of different element in the glass fiber. The Fig. 4(a) indicates the maximum peak of silica and other trace elements as small peaks. The Fig. 4(b) clearly indicates the maximum peak of nickel and the small peak of phosphorus.

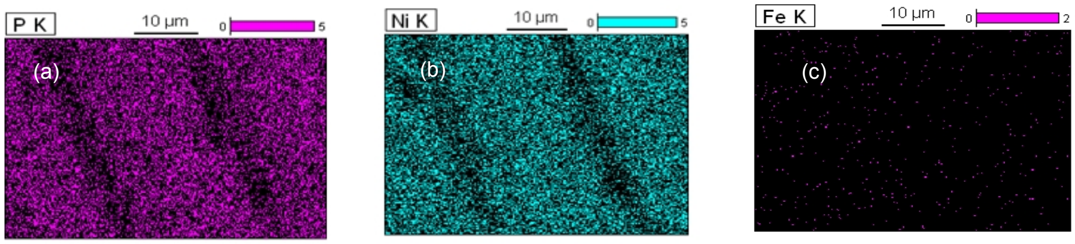

Fig. 3. (a) Coated nickel particles (b) Coated phosphorus particles (c) Distribution of Iron oxide in PMC

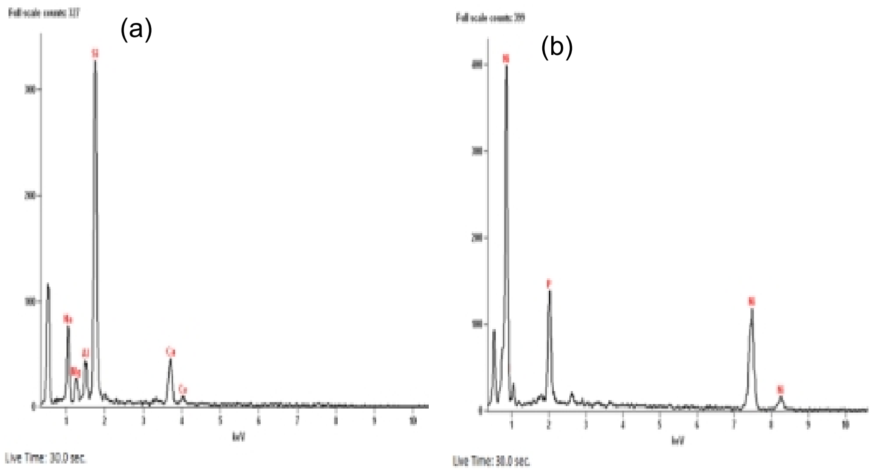

Fig. 4. (a) EDX for the bare glass fiber (b) EDX for the nickel coated glass fiber

3.3 Mechanical Properties

3.3.1 Tensile strength

Fig. 5 shows the tensile strength of three samples conducted in UTM with ASTM standard D412. The Fig. revel that the bare glass fiber reinforced PMC has low tensile strength and the strength furthered increased with when the electroless Ni-P coated glass fiber [16]. The maximum strength is obtained when the reinforcement is coated into Ni-P and with the addition of 0.5 weight % of nano iron oxide. The higher strength arises principally from nano iron oxide particles strengthening [17].

3.3.2 Compressive strength

The Fig. 6 shows the comparison of compressive tests results conducted in UTM with ASTM standard D695. Compare to conventional glass fiber reinforced polymer matrix composites the samples of coated reinforcement and nano filler material exhibits increased compressive strength. Sample B showed increase in strength over bare sample A. The sample C exhibits the maximum compressive strength than the other two samples due to presence of nano iron oxide particles of the matrix [17].

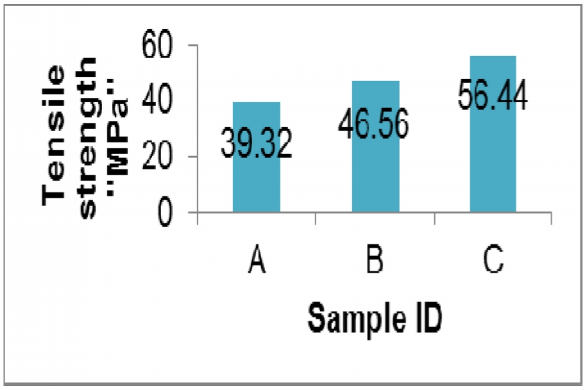

Fig. 5. Graph for variation of tensile strength

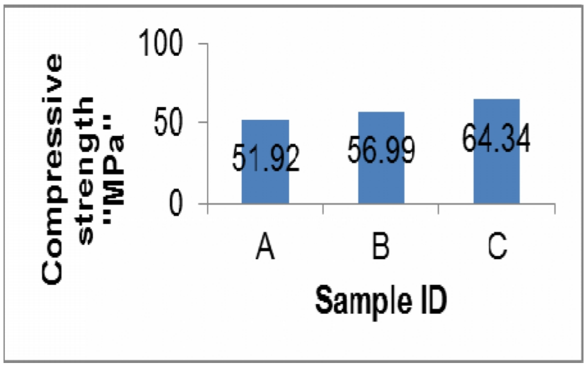

Fig. 6. Graph for compressive strength

3.3.3 Flexural strength

The flexural strength is measured by means of three point bend test. Both tensile and compression will occur to the same specimen. The test is conducted as per ASTM standard D790. The Fig. 7 revels that the sample B has improved strength than sample A and sample C has maximum strength compared to the other two.

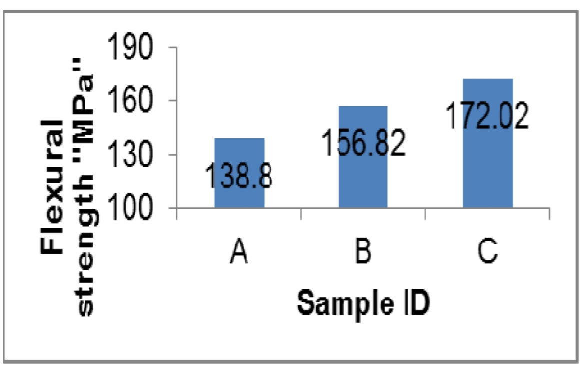

Fig. 7. Graph for flexural strength

3.3.4 Impact strength

The impact strength was measured with the help of charpy impact tester with ASTM standard D256. Fig. 8 showed the sample A has low impact strength. The strength increases when we coat the glass fiber with Ni-P. The maximum impact strength is obtained in sample C. The reason for increased impact strength for sample C is due to presence of nano iron oxide particles [17].

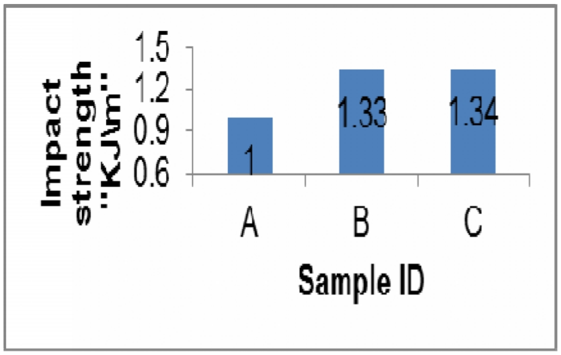

Fig. 8. Graph for variation of impact strength

3.3.5 Abrasion/wear loss

Din abrader is used to measure the abrasive wear. The specimen is prepared for ASTM standard D5963. Fig. 9 revel that the sample A has less wears resistance. The wear resistance increases considerably when we coat the glass fiber with Ni-P. The maximum wear resistance is found when the reinforcement is coated with Ni-P with the addition of 0.5 weight % of nano iron oxide [18].

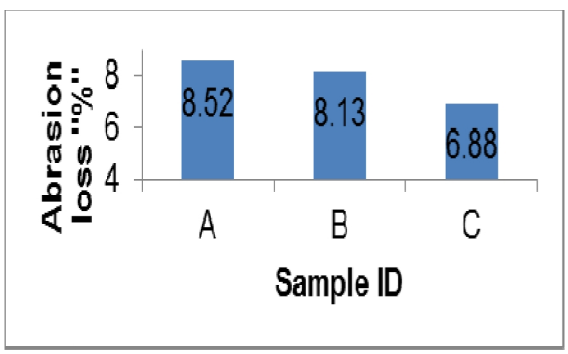

Fig. 9. Graph for variation of wear loss

4. CONCLUSION

Based on the experimental results and discussion the following conclusions have been drawn: For the first time, investigation on electroless Ni-P coated glass fibers reinforced polymer is carried out.

- Electroless Ni-P was successfully deposited on the glass fibers, after many trials and error.
- The nano iron oxide added Ni-P coated glass fiber polymer composites was compared with polymer composites made with bare glass fibers and Ni-P coated glass fiber as reinforcement.
- The experimental result shows that after coating the glass fiber reinforcement with electroless Ni-P, the ultimate tensile strength, compressive strength, flexural strength, impact strength and wear resistance is improved by 17.90%, 9%, 12.98%, 33% and 4.58%.
- After adding nano iron oxide as filler material at 0.5 weight % concentration of Ni-P coated glass fibers reinforced polymer matrix composites, the properties such as ultimate tensile strength, compressive strength, flexural strength, impact strength and wear resistance are improved by 43.54%, 23.9%, 23.93, 34% and 19.25% respectively. Hence this proposed Nanopolymer composite may be used in the engineering applications where the strength to weight ratios required is high.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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