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EVALUATION OF THE THERMAL PROPERTIES OF EPOXY-AGRO WASTE (EGG SHELL AND PALM KERNEL SHELL) NANOPARTICLE COATING FOR MILD STEEL

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Abstract: Epoxy has been widely used as a coating material to protect the steel reinforcement in concrete structures, because of its outstanding processability, excellent chemical resistance, good electrical insulating properties, and strong adhesion/affinity. The major disadvantage raised from exothermic curing reaction of highly crosslinked epoxy matrix is brittleness and microcracks that change the epoxy coating performances. The barrier performance of epoxy coatings can be enhanced by the incorporation of inorganic filler particles at nanometer scale which can be dispersed within the epoxy resin matrix to form an epoxy nanocomposite. The parametric addition of eggshell ash nanoparticles (ESAnp) and palm kernel shell ash nanoparticle (PKSAnp) in epoxy for the coating of mild steel was studied. Thermal decomposition was observed in terms of global mass loss by using a TGA Q50 thermogravimetric analyzer. Improvement of 78.05% and 82.56% thermal properties were obtained for the epoxy-4wt%ESAnp and epoxy-5wt%PKSAnp at 1000°C. This work showed that epoxy-4wt%ESAnp and epoxy-5wt%PKSAnp have best properties for thermal applications.

Keywords: Mild steel, Epoxy, Nanoparticles, Palm kernel shell ash, Egg shell ash, Thermal properties

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1. Introduction

Steels are vital construction materials in our modern society; the corrosion protection of steel is of great importance, both to ensure safety and to reduce costs associated to corrosion. High thermal-resistant coatings are required for a wide variety of metallic substrates that we encounter in everyday life, including nonstick cookware, barbecues and boilers. Several processes have been employed in the past to protect metallic substances from corrosion attack. Polymeric coatings are among the processes that are used to protect metals from corroding. The effectiveness of the coating is typically reliant on the fundamental properties of the sacrificial pigments, barrier effect, organic film, presence of inhibitors and the interface interaction as regards observance (Ayman et al, 2007).

Epoxy coatings generally reduce the corrosion of a metallic substrate subject to an electrolyte in two ways. First, they act as a physical barrier layer to control the ingress of deleterious species. Second, they can serve as a reservoir for corrosion inhibitors to aid the steel surface in resisting attack by aggressive species such as chloride anions (Ehsan et al, 2014).

Although other binders such as phenolic or epoxy are used to prepare high thermal-resistant coatings, at present silicon containing coatings dominate the market. Silicon-containing polymers offer better thermal resistance due to the high energy required to cleave silicon bonds compared to carbon bonds in analogous molecules (Chanadee and Chaiyarat, 2016).

Nanoparticles are being incorporated into epoxy matrices as filler to improve the mechanical, rheological, anticorrosive, and light-resistance properties. Especially nano metal oxides such as TiO_2, Fe_2O_3, ZnO, SiO_2, Al_2O_3, $CaCO_3$ and zirconia have been used as nano filler for corrosion protection on mild steel for more than a decade. The anticorrosive property of these coatings provides a barrier protection against the penetration of aggressive environmental constituents and prevents the cathodic reaction ($2H_2O + O_2 + 4e^- \rightarrow 4OH^-$) occurring on the substrate/coating interface (Bagherzadeh and Mahdavi 2007). Industries all over the world, produce wastes in large amounts from their various manufacturing and production operations. The use of biomaterials in general and agro-waste in particular is a subject of great interest nowadays not only from the technological and scientific points of view, but also socially, and economically, in terms of employment, cost and environmental issues (Dagwa et al, 2012). Bio-wastes are produced from a large variety of sources and agro-wastes are a class of these wastes.

Agro-wastes are gotten from animal and plant sources. Some of the animal wastes include feathers, shells (egg, snail, periwinkle, and etcetera), horns, hides and skin, hoofs, bones, etcetera. Plant wastes include palm kernel shells and empty fruit bunches coconut husks, walnut shells, and etcetera. These wastes contribute to the problem of environmental pollution and the growing cost of handling the problems of environmental pollution is a world problem being tackled by various organizations around the world. Nwaobakata and Agunwamba (2014) suggested that a wise alternative is to utilize these wastes and extract useful substances from them and therefore reduce the cost of disposing of the wastes and also the environmental damages imposed on our environment by these wastes. Palm kernel shells are waste products of oil palm and previous researches have shown that palm kernel ash contains hard silica while egg shell ash is mostly made up of calcium carbonate.

Thus, this work evaluates the thermal properties of developed epoxy-agro waste nanoparticle coating for mild steel.

2. Material and Methods

2.1. Material

Mild Steel (ASTM/SAE 1013) obtained from Warri, Nigeria, the palm kernel shell was obtained from Nigeria Institute for Oil Research near Benin City, Nigeria and the egg shell was obtained from the local tea seller in Benin City Nigeria. The epoxy (LY 556), chemically belonging to the epoxide family was used in the present work. Its common name is Bisphenol-A-Diglycidyl-Ether. Epoxy provides a solvent free room temperature curing system when it is combined with the hardener tri-ethylene-tetramine (TETA) which is an aliphatic primary amine with commercial designation (HY 951) was purchased from Chemical shop in Warri Delta State Nigeria, TGA Q50 thermogravimetric analyzer.

2.2. Method

The sol gel method was used in the production of Palm kernel shell ash nanoparticles and egg shell ash nanoparticles used in this work.

2.2.1. Thermal analysis of the sample

Thermal decomposition (TA) was observed in terms of global mass loss by using a TA Instrument TGA Q50 thermogravimetric analyzer (Figure 1). The apparatus detects the mass loss with a resolution of 0.1 as a function of temperature. The samples were evenly and loosely distributed in an open sample pan of 6.4 mm diameter and 3.2 mm deep with an initial sample weight of 8-10 mg. The temperature change was controlled from room temperature (25±3°C) to 1000°C with a heating rate of 10°C/min. High purity Argon was continuously passed into the furnace at a flow rate of 60 ml/min at room temperature and atmospheric pressure. Before starting of each run, the Argon was used to purge the furnace for 30 min to establish an inert environment in order to prevent any unwanted oxidative decomposition. The TG and DTA curves were obtained from TGA runs using universal analysis 2000 software from TA Instruments.

Figure 1. Photograph of TGA Q50 thermogravimetric analyzer used.

3. Results and Discussion

3.1. DTA/TGA Thermal Analysis of the PKSAnp and ESAnp

The temperature of destruction (Tdes) of the nanoparticle was determined from DTA curves. DTA data were recorded on "Derivatograph OD 102", at heating rate of 5°C/min in argon. The results of the DTA/TGA scan of the nanoparticles are shown in Figures 2-3. TGA curve of the PKSAnp indicate that the PKSAnp show less percentage of decomposition than ESAnp. At temperature above 1000°C, the residual weight stabilized agrees with the silica and CaO content in PKSAnp this is in par with the earlier reported in literature (Akash et al., 2017; Hussain et al, 2019).

From the thermal analysis results it was clear that the PKSAnp still retailed above 50% of its weight at temperature around 1000°C (Figure 2).

From Figure 3 the ESAnp shows the onset decomposition temperature (T=5%) is at 200°C, and the thermal decomposition process only has one stage with a Tmax at 800°C. ESAnp leaves 45% char residue at 1000°C.

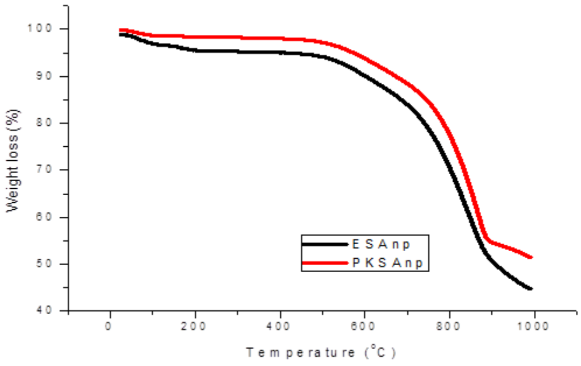

Figure 2. TGA curves of the nanoparticles.

3. 2. Thermal Analysis of the Coated Samples

The composite coating was produced by mixing the uncured epoxy with its corresponding hardener in a ratio of 2:1 by weight and the eggshell ash nanoparticles and palm kernel shell ash nanoparticles were added in a percentage of 1 to 5 by weight after being sonicated in ethanol solvent by ultrasonic waves using sonicator equipped with a titanium probe with a diameter =13 mm) for 15 minutes, thereafter the mixture was stirred up to a speed of 1200 rpm for 15 minutes, then the coating mixture was applied to the mild steel by using spray gun and then kept in a dry place at room temperature for 7 days to allow full curing as per recommendation from Lu and Jagannathan (2002).

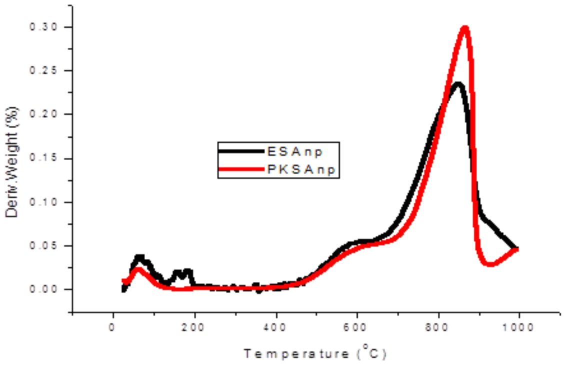

Figure 3. DTA curves of the nanoparticles.

The TGA/DTA was used in the study of the thermal analysis. Figures 4-6 displayed the results. It was observed that the coating had an appreciable effect on the thermal analysis of the mild steel. As the samples were heated close to 1000°C, the samples started to decompose and the decomposed byproducts including silica and calcium oxide were formed. The silica and calcium oxide delays the degradation process and makes the PKSAnp more thermally stable. As the TGA curve shifted to a higher temperature from 400 to 1000°C, the weight loss and weight retained had values of 95.053, 98.06, 99.14, 99.75 and 44.73, 51.49, 79.64, 81.66% (Figure 4) for the mild steel, epoxy coated, epoxy-4wt%ESAnp and epoxy-5wt%PKSAnp respectively.

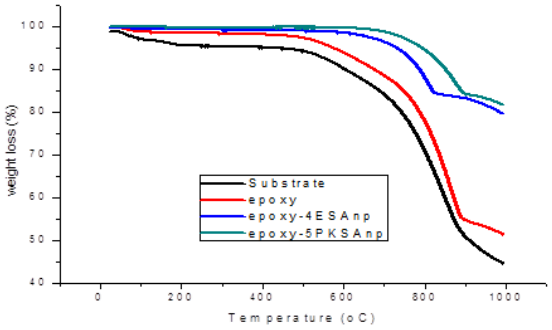

Figure 4. Variation of weight loss with temperature.

Improvement of 78.05% and 82.56% thermal properties were obtained for the epoxy-4wt%ESAnp and epoxy-5wt%PKSAnp at 1000°C. The low weight retained for the mild steel at 1000°C could be attributed to that fact that scaling of the mild steel occurs at higher temperature due to decarburization of the mild steel. The higher thermal properties obtained for the epoxy-4wt%ESAnp and epoxy-5wt%PKSAnp could be attributed to the chemical makeup of the ESAnp (CaO) and PKSAnp (SiO_2). The low peak obtained for the coated samples at temperatures between 100 and 200°C in Figure 5 was attributed to evaporation of moisture from the samples at low temperature. The high peak obtained for the mild steel as compared with the coated samples supports the fact that the mild steel undergone high rate of decomposition due to decarburization (Figure 6).

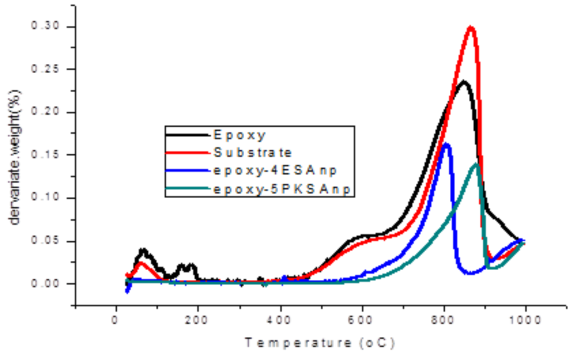

Figure 5. Variation of deviation of weight with temperature.

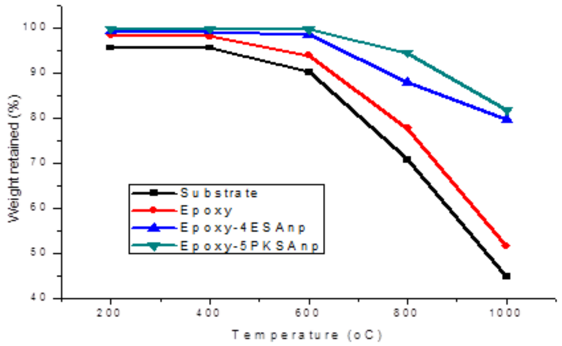

Figure 6. Variation of weight retained with temperature.

4. Conclusion

From the above results, the following conclusion was made: Improvement of 78.05% and 82.56% thermal properties were obtained for the epoxy-4wt%ESAnp and epoxy-5wt%PKSAnp at 1000oC. This work shows that at epoxy-4wt%ESAnp and epoxy-5wt%PKSAnp have best properties for thermal applications.

Author Contributions

All task was done by the single author. The author reviewed and approved the manuscript.

Conflict of Interest

The author declared that there is no conflict of interest.

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