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A Comparison Between the Influence of Nano-Silica and Silane Coupling Agent on Epoxy Coatings

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Abstract

In order to enhance adhesion and corrosion performance of an epoxy coating, epoxy-Nano silica and epoxy-silane coatings were prepared in 0.5,1,2,3,4 and 5 wt.%, then they were applied to carbon steel substrate. Adhesion test was performed on the prepared coatings using pull off test, furthermore corrosion performance evaluated against salt spray conditions, and it was shown that there is a direct relationship between adhesion and corrosion resistance of both types of coatings. Initial temperature of decomposition (ITD) and temperature of maximum weight loss (T_{max}) which obtained from thermo gravimetric analysis (TGA) of epoxy-silica coating showed a right shift to upper temperatures. Dispersion and distribution evaluation of Nano-silica in epoxy matrix was carried out using SEM images. It was found that an increase in the Nano-silica concentration is resulted in poor dispersion and distribution of nanoparticles, and consequently, the coating formed a non-uniform film with large cracks. DSC thermo grams of epoxy-silica coatings showed that incorporation of Nano-silica in epoxy matrix have several effects on the heat of reaction and kinetic of curing, so that this inorganic filler hindered curing reaction. In total, it is proved that epoxy-silica coating demonstrated better performance as a protective coating for carbon steel substrate in comparison with the epoxy-silane system.

Keywords: Organic/Inorganic Coatings, Epoxy-Silica, Epoxy- GPTMS, Corrosion Resistance, Adhesion.

Introduction

Epoxy / silica composites due to their unique properties, along with relatively low cost and ease of construction, and its application on different levels are welcomed by various industries. This widespread application is due to the unique properties of this type of resin, including chemical resistance and high corrosion, good mechanical and thermal properties, and adhesion to various types of resin. In spite of all useful features, there are also defects in epoxy resin. To enhance the properties of epoxy resin, silane coupling agents have been used to increase the adhesion and corrosion resistance of epoxy resin, which are generated by the sol-gel mechanism [1, 2]. In recent years, various studies have been done to improve the properties of the coating of epoxy resin [3-6]. In spite of the large number of studies on epoxy coatings, the former studies of epoxy / nanosilica and epoxy / GPTMS have not been compared in the same test conditions. In this paper, in order to increase the adhesion and corrosion resistance of epoxy coating, in the first stage nanosilica particles were added to the epoxy resin and its effect on corrosion, adhesion, nanoparticle distribution and thermal resistance of the coating was investigated. Then, in the next step, the epoxy resin (3-glycidoxy propyl) trimethoxysilane (GPTMS) was investigated as before, and finally, two types of coating were compared to select the appropriate method.

Discussion and Results

In order to diffuse silica nanoparticles in the resin bed, weighing 0.5-1.2.3.4.5 by solvent method was added directly to the xylene as a solvent in the resin (for better spreading), the ratio of the epoxy resin and the solvent 2 / 1, and since it was 40 minutes, its rotation speed was 500 rpm. Polyamine HA 620X 80 was used as a cooking agent. It was also used to propagate silane material in the epoxy resin bed to prepare epoxy-silane nanocomposite to compare with epoxy-silica nanocomposite to improve adhesion and anti-corrosion properties. A mixture of toluene and distilled water was prepared in a ratio of 95 to 5. The resulting mixture was then mixed with magnetic stirrer for half an hour. The resulting mixture was added to 50/50 to silane material, and again for subtraction of the mentioned materials, they were placed for two hours; The resulting composition, like silica, was added to the epoxy resin from 0.5% to 5%, and after mixing completely, the mixer was applied to the desired surface. The formation mechanism of this type of epoxy-silane hybrid network differs from epoxy-silica and is carried out according to the sol-gel process.

Scanning Electron Microscope (SEM)

The specimen containing 1% of the weight of the filter and a good uniformity in the fracture surface was observed, which could be a reason for the proper interaction of the organic phase with the mineral by the proper modification of the particles and the proper mixing conditions in the mechanical mixing process. Samples containing 2% by weight of silica nanoparticles were observed in some points of the accumulated hollows of the silica nanoparticles. As the amount of nanoparticles reached, samples containing 4 and 5% by weight of mono unsatutions and hawks increased sharply because of the increase in the concentration of nanoparticles, their tendency to squishing will increase.

TGA Thermal Weight Measurement Analysis

Adding silica to all epoxies causes ITD and Tmax

to be transported at higher temperatures.

This increase in thermal stability results in a high thermal stability of the nanosilica, which causes a delay in the degradation of the organic component of the nanocomposite.

Scanning Difference Thermometry (DSC)

The general behavior of epoxy resin cooking with the HA 620 X 80 is shown in Figure 1. The reduction in the percentage of the nanosilica below the peak area of the cooking reaction has been shown to decrease the negative effect of the silica nanoparticles in the baking reaction.

The corrosion performance test (fog) in Figure 2 shows the corrosion rate of the undercoat covered with two types of coatings made in this study. Both types of coatings show a higher corrosion resistance than pure epoxy coatings, but this test shows that silica nanoparticles can provide resistance to the substrate corrosion resistance to the silicone composition.

Pull off test

The pull-off test was performed to calculate the amount of adhesion of the coating to different levels. The adhesion range is between 2 and 2.4 MPa.

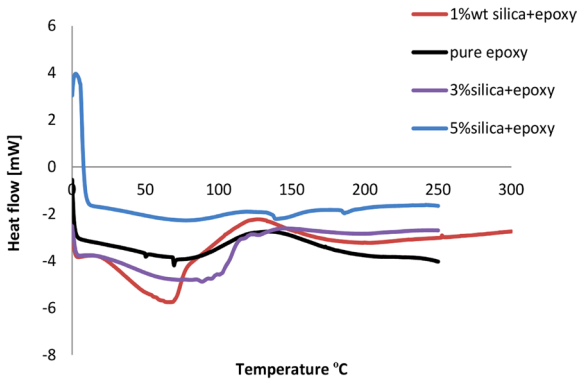

Figure 1: General behavior of baking epoxy resin with amine hardener.

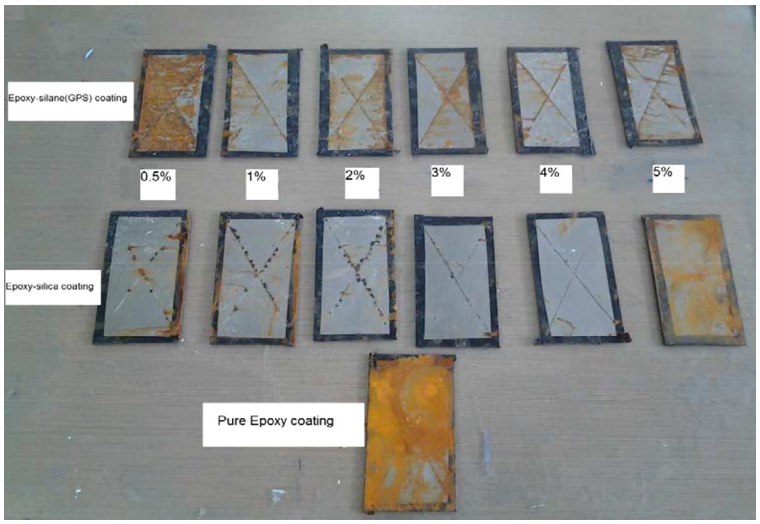

Figure 2: The results of the test of saline fats for the coatings made. The top row refers to epoxy-silane coatings and the lower row for epoxy-silica coatings.

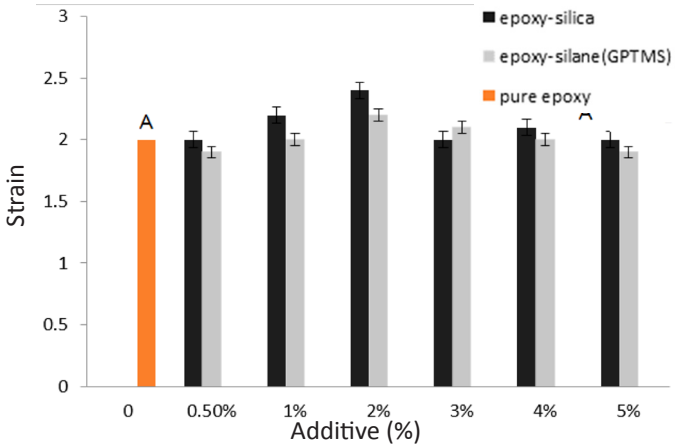

Figure 3: pull off adhesion test.

Conclusions

In this study, the effect of silica nanoparticles and GPTMS silane agent on the properties of epoxy coatings including corrosion performance, adhesion, film quality, curing conditions and thermal resistance were evaluated. The saline test showed a significant effect on the presence of silica nanoparticles in corrosion resistance, and the effect of silicon gTPMS was weaker than that of silica nanoparticles. In the case of adhesion, the effect of silica nanoparticles was higher, but the adhesion range of all specimens was about 2 MPa. DSC deviations showed that silica nanoparticles had a significant effect on the baking mechanism and kinetics, and the heat pump peak was transmitted to higher temperatures. Transfer of ITD and Tmax to higher temperatures by adding nanosilica percent indicates improving thermal resistance cover. The overall conclusion of this study is that the effect of nanosilica up to a "specific loading rate" in all cases, including corrosion and adhesion resistance, is constructive and induces an incremental process, but the properties of the coating will decrease with the passage of the range. One of the reasons for this is the mixing and distribution of non-uniform additives and interactions of the components, the incomplete baking reaction due to the effect of additives on the kinetics of the reaction can be mentioned, and all of this leads to the lack of uniform film formation and the lack of strength and integrity of the three-dimensional resin network; Therefore, the influence of moisture, electrolytes and oxygen does not block the coating layer and cause corrosion of the steel substrate. Considering that the repair of nanoparticles is time-consuming and costly for production at industrial scale, epoxy-silica coating (without surface modification) containing 3% of its made weight in addition to good adhesion to the surface, has showed great corrosive resistance which is one of the most important findings of this study.

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