

Effect of ZnO-SiO₂ Nanoparticles on the Morphology of Nanocoating

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Abstract:

The objective of this research is to investigate the interfacial compatibility of metal oxide nanoparticles and epoxy as the nanocoating. The sol is synthesized by the copolymerization of epoxy resin and hardener with the incorporation of metal oxide nanoparticles, which is Zinc Oxide (ZnO) and Silica (SiO₂). Epoxy and hardener acted as a host while the metal oxide nanoparticles acted as guest components. Nanoparticles are uniformly distributed throughout the coating on the silicon wafer. Nanoparticles provide the resin or coating with a continuous, solid and protective network layer. SEM and FESEM images showed that the nanoparticles form a unique elastomeric structure within the coating. Nanoparticles improved the quality of the cured epoxy coating, reduced the porosity of the coating matrix, leading to the improved barrier performance of the epoxy coating.

Keywords: ZnO, SiO₂, Nanocoating

I. INTRODUCTION

According to the research study by Thomas [1], the nanocoatings market is envisaged to grow over the next 5 to 10 years across all market segments. This is attributed to growing need for better facilities and advances in nanocoating technology. This industry is segmented by type of future markets that includes anti-bacterial, anti-fouling, anti-fingerprint, easy to maintain and self-cleaning nanocoatings [2]. In addition, the anti-corrosive nanocoatings market is expected to grow on the strength of demand from oil and gas industries for protection of pipeline surfaces. Epoxy (organic) coating is a type of common organic coatings used to protect metals against corrosion. Research by Armelin [3] reported that epoxy characteristics such as resistance to chemicals, good mechanical properties, thermal stability and good adhesion make it is widely used for protective coatings. An epoxy coating is suitable to use under all different conditions [3] such as for internal lining as well as for external coatings such as on pipelines. ZnO offers better corrosion protection to

carbon steel and SiO₂ giving better adhesion to substrate [4].

II. EXPERIMENTAL

The morphology study of nanoparticles in epoxy matrix and thickness of the applied nanocoating were studied using Field Emission Scanning Electron Microscopy (FESEM) model JSM-5600 (JEOL) and Scanning Electron Microscopy (SEM). The nanocoating were applied on silicon wafer p type 101 as substrate prior to FESEM analysis. Then, the substrate were sputter-coated with 0.1 μm of platinum to avoid charging effect and nonconductive nature of epoxy coating.

III. RESULT AND DISCUSSION

A. Scanning Electron Microscopy (SEM)

SEM micrograph of plain/neat coating and coating with incorporated nanoparticles are shown in Fig. 1a-e. The nanocoating with incorporation of SiO₂ nanoparticles was observed to be much homogeneous than the plain epoxy coating (Fig. 1b). The

nanocoating with addition of ZnO nanoparticles was also denser than the plain epoxy coating, but had some agglomeration of nanoparticles (Fig.1c). The coating had a thickness of approximately 12-13 μ m as in Fig.1d.

In case of the addition nanoparticles into epoxy coatings, the nanoparticles with higher specific surface area not only served as better nano-fillers for the epoxy matrix, but also more actively participated in the epoxy-curing process which possibly acts as nuclei for the growth of cross-linking epoxy-amine networks [4]. As the addition of nanoparticles increased in Fig.1e, the nanoparticles give higher specific surface area and served as better nano-fillers in coating for the epoxy matrix. It also actively participated in the epoxy-curing process (possibly acts as nuclei for the growth of cross-linking epoxy-amine networks). The small size of the nanoparticles is also advantageous since it enables their penetration into ultra-small holes, in the coating matrix itself and at the metallic substrate, leading to the improved barrier performance of the epoxy coating. However addition of 5wt% of nanoparticles leads to agglomeration.

More agglomeration of nanoparticles was observed in Fig.1c. When having too much agglomeration in coating base the coating would not be functionalize as smart coating yet to contribute for side effect on the strength of the coating, where it initiate the weak point of cracking effect.No crack was observed across the entire thickness of the coating layer or near the coating-steel interfaces. Nanoparticles improved the quality of the cured epoxy coating, reduced the porosity of the coating matrix, leading to the improved barrier performance of the epoxy coating. Nanoparticles improved the adherence of the cured epoxy coating to the underlying substrate and altered the physiochemical properties of the coating-steel interface [5].

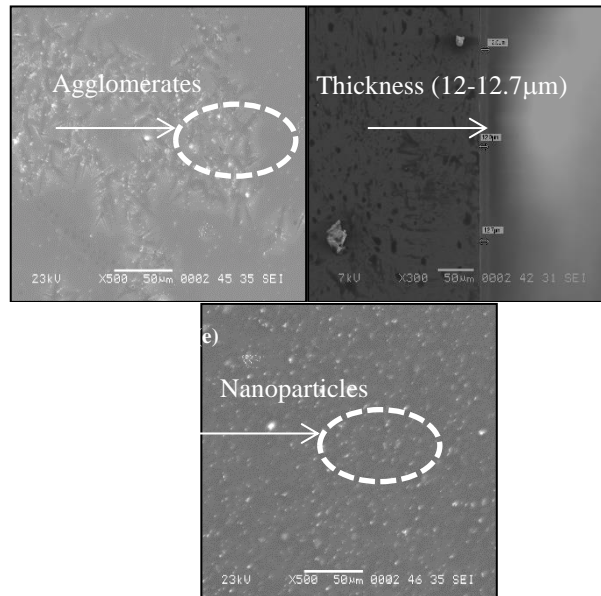
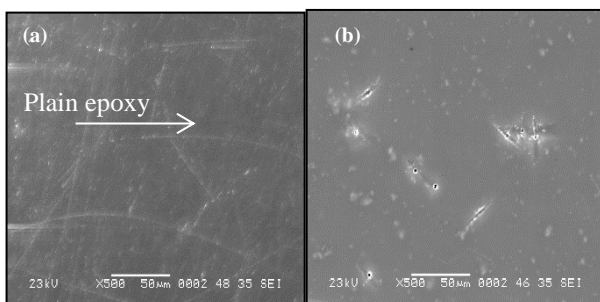


Fig. 1 SEM images of nanocoatings. a):plain epoxy; b)with SiO₂ nanoparticles; c)with ZnO nanoparticles; d) thickness of coating; e) hybrid nanoparticles

B. Field Emission Scanning Electron Microscopy (FESEM)

A typical FE-SEM image of plain epoxy and hybrid nanocoatings (SiO₂-ZnO) was shown in Fig. 3. It was observed that the plain epoxy coating having no network layer and having relatively homogeneous morphology. The epoxy coating consists of nanoparticles showed no sign of nanoparticle agglomeration. The nanoparticles that occupied surface area served as best nano fillers for the epoxy matrix and actively participated in the curing epoxy process. Nanoparticles acting as nuclei for the growth of cross-linking epoxy-amine networks. FESEM images of hybrid nanocoatings SiO₂-ZnO epoxy with different magnification at X30000-100000 showed in Fig.2.

It was importantly to increase the magnification gradually in order to observe the nanoparticles within the matrix. The small size of nanoparticles gives advantageous to epoxy matrix since it enables to penetrate into ultra small holes within network layer in the coating matrix itself and the substrate. Magnification at X100000 showed the most clearly images of nanoparticles within the matrix. The nanoparticles of hybrid between SiO₂-ZnO were found to significantly improve the microstructure of the coating matrix. The nanoparticles dispersed in epoxy resin to fill cavities, hole and prevent epoxy



disaggregation during curing, resulting in more homogeneous coating [6].

Nanoparticles occupied small hole defects formed as a result of local shrinkage during curing of epoxy resin that acted as a bridge interconnecting molecules and an increased in the cross-linking density. Epoxy coating containing nanoparticles offered network layer of significant barrier properties in preventing delamination. FE-SEM images showed that nanoparticles of SiO₂-ZnO uniformly distributed within the epoxy matrix and provide the resin with continuous, protective network layer of SiO₂-ZnO as shown in proposed mechanism.

The unique advantage of SiO₂-ZnO nanoparticles was, if the coating worn away, the additional layer of nanoparticles remains. The nanoparticles form a unique elastomeric structure within the epoxy. The structure resists the object from entering the surface of the coating, thus preventing the damage of the coating [7]. Nanoparticles giving large surface area, create a denser and more compact structure [8].

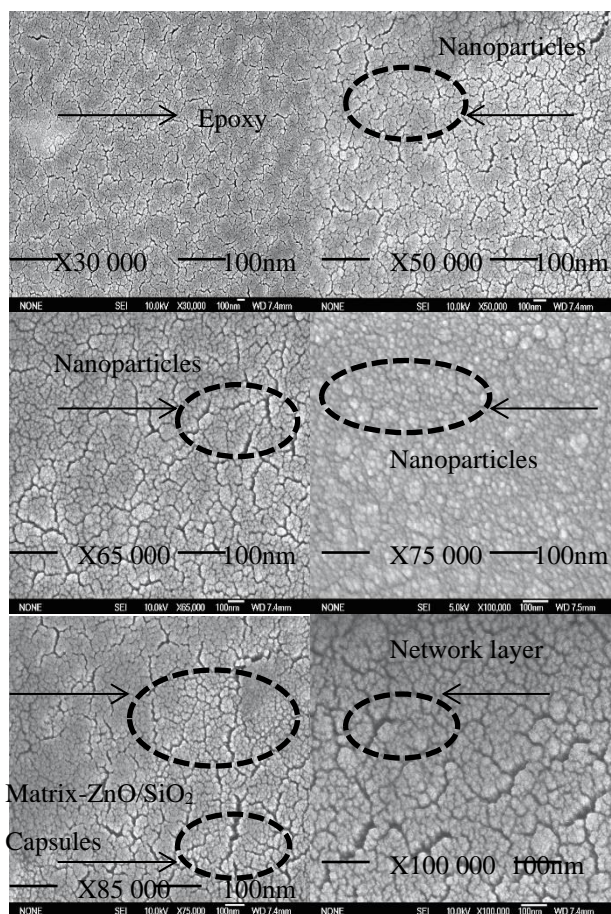


Fig.2 FESEM images of hybrid nanocoatings (SiO₂-ZnO) epoxy with different magnification X30000-100000

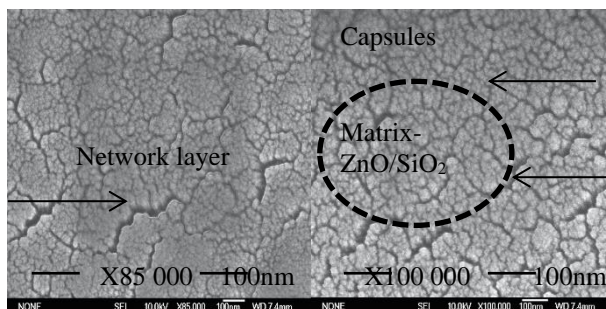


Fig.3 FESEM images of plain epoxy and hybrid nanocoatings (SiO₂-ZnO)

IV. CONCLUSION

Nanoparticles improved the quality of the cured epoxy coating, reduced the porosity of the coating matrix, leading to the improved barrier performance of the epoxy coating. Nanoparticles of SiO₂-ZnO also uniformly distributed within the epoxy matrix and provide the resin with continuous, protective network layer of SiO₂-ZnO. The unique advantage of SiO₂-ZnO nanoparticles was, if the coating worn away, the additional layer of nanoparticles remains.

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