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Research article

Development of tertiary butyl hydroquinone based polybenzoxazine for effective anti-microbial and anti-corrosion coating applications

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ABSTRACT

The work presents a new type of polybenzoxazines synthesised using tertiary butyl hydroquinone (THQ) with aromatic and fluorinated mono functional amines such as aniline (a), ethynylaniline (ea), cyanoaniline (ca), fluoroaniline (fa), trifluoromethylaniline (tfma) and 4-fluorotrifluoromethylaniline (4ftma). The structure of the benzoxazines were elucidated using spectroscopyic technique. The curing behaviour, thermal stability of the THQ polybenzoxazines were studied in order to assess their performance in high themperature environments. Among the six polybenzoxazines synthesized, the tert-butyl hydroquinone with cyanoaniline based polybenzoxazine shows the exceptional thermal stability with higher residual value of 60 % and higher degradation temperature of 553 °C. The moisture resistance behaviour of the synthesized THQ polybenzoxazines have been studied and all the THQ polybenzoxazines possess excellent hydrophobicity. The synthesized THQ polybenzoxazines were tested for their surface protection efficiency as anti-corrosive coatings on mild steel surfaces. The poly(THQ-4ftma) polybenzoxazine coating exhibits excellent corrosion resistant behaviour with efficiency of 99.99 %. All the six THQ polybenzoxazine coated mild steel specimen shows better corrosion resistant behaviour than that of the uncoated mild steel. In addition to the above, THQ benzoxazines were checked for their antibacterial activity (against *S. aureus* and *E.coli*) was checked and inhibition zone was observed at greater than 25 mm. The results obtained from different studies indicate that the tert-butyl hydroquinone based benzoxazines can be effectively used as a multifunctional coatings under high thermal environment and protection against microbes including adverse corrosive environment.

1. Introduction

Protection of mild steel surfaces from corrosion is one of the important practices used in wide range of industries to safeguard mild steel structures and machineries. Various types of materials have been used as coating material to protect the metallic surfaces from corrosion [1,2], however, the stability and efficiency of the coatings were still a permanent challenge for researchers, and the industries. The coating of materials principally consist of a polymeric binder capable of forming adherent film over the metallic substrates. Varied nature of polymeric materials have been utilized as the binder such as epoxy resins, polyurethane resins, alkyd resins, inorganic resins, vinyl resins for the preparation of coatings to protect the surfaces from corrosion [3,4]. Some of these thermosetting binders require external thermal energy for the polymerization process. In addition to the binder, the anti-corrosive pigments such as salts of zinc, aluminium, titanium, etc are added to the coating formulation, which plays the major role in acting as a barrier [5,6]. Hence, researchers are interested to develop a polymeric material which can perform both as binder as well as anticorrosive material.

One such material is polybenzoxazines, which is a versatile material possessing excellent thermal stability along with good hydrophobicity [7,8]. The benzoxazine monomers does not require an external curing chemical agents, but it requires thermal energy to gets cured/polymerized. Nowadays, several reports have been found on using the polybenzoxazines as an effective anti-corrosion coating [9–11]. For instance, Deng et al., synthesized curcumin based benzoxazine for anti-corrosion and anti-fouling applications. Their results showed that the polybenzoxazine coated substrates showed excellent corrosion

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Table 5
Inhibition zones of THQ-BZ.

THQ-BZ Sample (1 mg/ml)	Zone of inhibition (mm)	
	Staphylococcus aureus	*Escherichia coli*
THQ-a	23	12
THQ-ea	25	15
THQ-ca	32	20
THQ-fa	25	18
THQ-tfma	20	12
THQ−4ftma	25	18

ca) benzoxazines was studied using DSC technique. From the TGA analysis, the poly(THQ-ca) posessess higher value of char yield (60 %) and the value of higher degradation temperature (553 °C) than other polybenzoxazines. From the water contact angle studies, the poly(THQ-4ftma) possess better water resisting behavior (WCA 152°) than that of other polybenzoxazines.The THQ-PBZ were coated on the surfaces of mild steel and the corrosion resistance property of the coated MS specimens were studied. The potentiostatic dynamic polarization results of the THQ-PBZ coated MS specimens show 99.99 % corrosion protection efficiency than that of the uncoated MS specimen. The poly(THQ-4ftma) shows better corrosion protection than that of other THQ-PBZ because of its higher hydrophobicity. The THQ-BZ were tested for their activity against the growth of *S.aureus* and *E.coli* bacteria. The THQ-ca shows effective inhibition towards the growth of both the bacteria with inhibition zone of 32 mm and 20 mm respectively. Data obtained from thermal, hydrophobic, corrosion and microbial studies suggest that the THQ based polyenzoxazines can be efficiently utilized as high performance corrosion resistant and anti-bacterial coatings under moist and thermal environments.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.nxmate.2025.100723.

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