CHAPTER

6

SUSTAINABLE EPOXY MATERIALS FOR LOW-CARBON INDUSTRIAL APPLICATION

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6.1 INTRODUCTION

Epoxy coatings play a crucial role in providing corrosion protection within marine environments. Their superior durability and film-forming properties enable them to effectively shield metallic structures from the corrosive effects of saltwater and prolonged environmental exposure (Saman et al., 2022). Various types of epoxy coatings have been developed for marine corrosion protection, including solid-based, water-based, solvent-based, and high-solid formulations. Each type offers distinct advantages and limitations. Among these, high-solid epoxy coatings are generally preferred for corrosion protection in harsh environmental conditions due to their enhanced performance and reduced volatile organic compound (VOC) emissions (Sofian & Noda, 2013).

Nevertheless, this extensive utilization incurs a substantial ecological toll, the emission of VOCs during the process. Xylene, a prevalent solvent found in traditional epoxy coatings, is a significant source of VOC emissions, which contribute to air pollution and pose possible health hazards. The urgent requirement to find a practical and enduring

substitute for high-solid epoxy coatings used in marine settings has arisen (Niaz et al., 2015).

Replacing xylene with eco-friendly solvents can greatly decrease volatile organic VOC emissions. However, difficulties arise when integrating them with high-solid epoxy compositions. An environmentally compliant and sustainable solution is required to address the issue of xylene exposure. Existing solutions generally face challenges in simultaneously providing corrosion protection and minimizing environmental impact (Inoue et al., 1991).

Although several studies have proposed eco-friendly solvents, limited research has focused specifically on evaluating their effects within high-solid epoxy systems used in marine applications. Most available data lack comprehensive comparison in terms of performance indicators such as VOC content, viscosity, and drying time.

Recognizing this gap, the present study aims to assess the potential of propylene glycol monomethyl ether (PM) as a complete replacement for xylene in high-solid epoxy coatings. By investigating its influence on physicochemical properties particularly VOC emissions, viscosity, and touch-dry characteristics—This work seeks to determine whether PM can offer a practical, sustainable, and effective alternative for use in corrosion-prone environments, thereby supporting Malaysia's commitment toward a net zero 2050 transition.

6.2 EPOXY COATING

Epoxy coatings are widely used for their strong adhesion, chemical resistance, and durability, especially in marine applications. With growing emphasis on sustainability, the development of sustainable epoxy materials for low-carbon industrial applications is becoming essential. The performance of these coatings depends on the balance of resin, curing agents, solvents, pigments, and additives, which together provide effective corrosion protection.

6.2.1 Components of Solvent-based Epoxy Coating

Solvent-based epoxy coatings are widely recognized for their remarkable adhesion and durability. These coatings are created by dissolving epoxy resins in organic solvents like xylene, resulting in a strong and chemically resistant film after curing. Their exceptional mechanical strength and endurance make them ideal for protecting metal structures from corrosion in industrial and marine settings. However, the ecological and health concerns associated with the release of VOCs from solvents have prompted the search for more environmentally friendly alternatives (Kim et al., 2003).

Solvents play a crucial role in reducing the viscosity of epoxy coatings, facilitating easier application. Alcohols or glycol ethers are often used due to their volatility and influence on film formation. Additives enhance specific properties of the coating, varying based on formulation needs (Chen et al., 2020).

Xylene, a common solvent in high-solid epoxy coatings, helps achieve the necessary viscosity for application. It ensures consistent coverage across substrates and aids in the blending of epoxy resin and other components. Xylene's evaporation during application leads to the deposition of a thicker epoxy layer, enhancing mechanical strength and corrosion resistance. It also promotes cross-linking between the epoxy resin and curing agent, resulting in a strongly adhering cured film. Despite its benefits, the environmental and health concerns linked to xylene necessitate the exploration of alternative solvents.

Propylene glycol monomethyl ether (PM) is gaining popularity as a substitute solvent in high-solid epoxy coatings. PM is chosen for its favorable environmental and health properties. It has a low evaporation rate, resulting in reduced VOC emissions and lower health risks for workers. PM's compatibility with high-solid epoxy formulations enhances the uniformity and consistency of the coating mixture. Its ability to dissolve resins and adjust viscosity makes it an effective solvent for achieving optimal application properties (Zhang et al., 2013).