Progress in Organic Coatings 111 (2017) 283–293

Contents lists available at ScienceDirect

Progress in Organic Coatings

journal homepage: www.elsevier.com/locate/porgcoat

Preparation of green cardanol-based epoxy and hardener as primer coatings for petroleum and gas steel in marine environment

Ayman M. Atta[a,b,*], Hamad A. Al-Hodan[a], Reda S. Abdel Hameed[c], Abdelrahman O. Ezzat[a]

[a] Chemistry Department, College of Science, King Saud University, Riyadh 11451, Saudi Arabia
[b] Petroleum Application Department, Egyptian Petroleum Research Institute, Nasr City 11727, Cairo, Egypt
[c] Chemistry Department, Faculty of Science, Al-Azhar University, Nasr City 11884, Cairo, Egypt

ARTICLE INFO

Keywords:
Cardanol
Epoxy
Polyamine
Coatings
Steel
Curing exotherms

ABSTRACT

New solvent-free based epoxy and polyamine hardener were prepared from renewable and sustainable materials based on cardanol derived from cashew nut shell liquid as alternative epoxy coats to protect the steel from corrosion. The epoxy resin was prepared from epoxidation of hydroxyl phenol and unsaturated double bonds of cardanol Novolac prepolymer. The polyamine cardanol based hardener was prepared by linking of triethylenetetramine with methyloyl cardanol derivatives. The chemical structures of the prepared cardanol epoxy resin and polyamine hardener were investigated by ^{1}HNMR analysis. The physico-chemical characteristics of the cardanol based epoxy and hardener were investigated. The curing exotherms for different mixing ratios of cardanol based epoxy and hardener were determined at different temperature ranged from 35 to 55 °C. The cured epoxy systems were analyzed for physical, mechanical, and salt spray resistance properties to optimize the best mixing ratio to obtain durable epoxy coat as anticorrosive coatings for steel in marine environments. The salt spray results were compared with those of the commercial cashew coating.

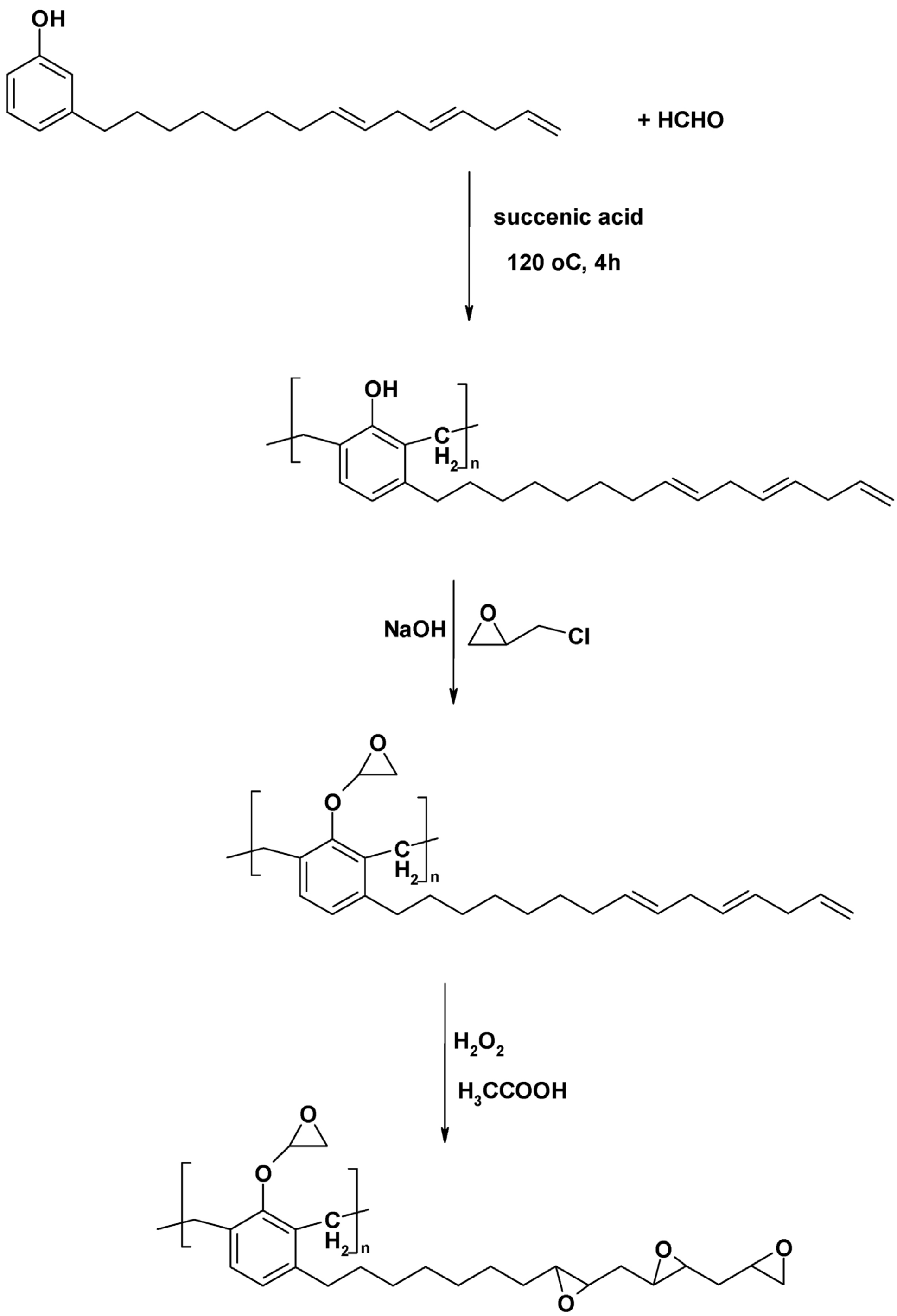
1. Introduction

Cardanol is one of the cashew nut shell liquid oil extracts that attracted great attention as one of the more advanced renewable materials that used to produce new advanced polymeric, thermoset and nanomaterials [1–5]. Its chemical structure based on phenol, benzene rings and unsaturated hydrophobic alkyl groups increased their ability to form more chemicals [3–5]. Their hydrophobic nature directed the attention to produce organic coatings to protect the metals against environmental corrosions such as acids, salts and water [6–10]. Moreover, its chemical structure was modified to produce different types of bio-based surfactants to use as corrosion inhibitors to replace the toxic petroleum based surfactants [11–13]. The cardanol derivatives have been widely used as epoxy organic coatings as modified epoxy blends with diglycidyl ether of bisphenols, anticorrosive additives with epoxy, epoxy curing agents and self-cured epoxy coatings [14–20]. The produced epoxy resins based on cardanol can be prepared either from epoxidation of unsaturated alkyl groups or phenolic hydroxide groups [21–26]. The produced epoxy required high curing temperature ranged from 95 to 165 °C that affect the coating performances beside low impact resistance of epoxy coatings [27]. The curing of epoxy at high temperature produced more problems in the coating surfaces such as cracks, holes and laminations that affect the coating performances and resistances to the environmental conditions. These problems were solved by blending the epoxy with butadiene rubber derivatives during the curing process which act as plasticizer that filled the hole and cracks to enhance the impact resistance and coating durability [28].

The phenolic character of cardanol and the unsaturation in its hydrophobic alkyl side chain attracted attention towards the chemical modifications of cardanol to be an important reactive raw material in the production of epoxy resins. The production of curing agents as polyamides and polyamines, from cardanol, to cure at room temperature is another goal for cardanol chemical modification. The presence of alkyl group in the chemical structure of cardanol introduced chain flexibility to use as polyamides or polyamines based on cardanol as curing agents to modify the epoxy coating performances of epoxy resins [29,30]. There are different polyamides have been produced from cardanol using different complicated synthesis routes such as conversion of cardanol to diacid derivatives [29,30]. The polyamines based on cardanol were prepared using cardanol butyl ethers, formaldehyde and diethylenetriamine by Mannich reaction to obtain epoxy coatings displayed fairly good toughness [31,32]. Moreover, the blending of new epoxy resins based on cardanol with epoxy based on bisphenol and polyamine curing agents achieved good mechanical properties with 40

* Corresponding author at: Chemistry Department, College of Science, King Saud University, Riyadh 11451, Saudi Arabia.
E-mail address: aatta@ksu.edu.sa (A.M. Atta).

http://dx.doi.org/10.1016/j.porgcoat.2017.06.002
Received 21 March 2017; Received in revised form 1 June 2017; Accepted 1 June 2017



Scheme 1. Synthesis of CNE resin.

Wt.% of cardanol epoxy blends [33]. In the present work, utilization of epoxy and curing agent cardanol based chemicals can contribute to produce sustainable coating development and would help in reaching principles of "green chemistry" bio-based organic coatings to replace the petroleum based binders and curing organic coatings. Moreover, the phenolic based epoxy and the presence of alkyl substituents in the chemical structures of the cardanol epoxy and hardener should improve the coating performances and durability. In this respect, new polyamine hardener and epoxy were prepared from modification of cardanol chemical structure to apply as green bio-based organic coatings having excellent mechanical and weathering properties against marine environments as primer for steel coatings. The curing of cardanol epoxy and polyamine hardener at room temperature is another goal of the present work.

2. Experimental

2.1. Materials

Cardanol provided by Shanghai Judong Trading Company Ltd., formaldehyde (37% solution), tiethylenetetramine (TETA), β,β-dichoolorodiethylether (DCDE), epichlorohydrine (ECH), succinic acid, glacial acetic acid anhydrous sodium sulphate, sodium hydroxide, and hydrogen peroxide supplied from Sigma Aldrich chemicals co. were used to prepare epoxy resin and polyamine hardener based on cardanol. Diglycidyl ether of bisphenol A with the epoxy equivalent weight of 196