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ORIGINAL PAPER

# Effect of processing conditions on the microencapsulation of 1-methylimidazole curing agent using solid epoxy resins

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**Abstract** Among various methods for preparation of the non-reactive or latent curing agents for epoxy resins, encapsulation offers a promising and cost-effective method. This system has been used in one-part thermosetting adhesives or prepregs for developing advanced composite materials. In this study, 1-methylimidazole (1-MI) was microencapsulated using solid epoxy resins via solvent evaporation method. The effect of various types of shell materials or solid epoxy resins, different core-to-shell ratios of 30/70, 50/50, and 70/30, and a variety of mixing rates (500, 1000, and 1500 rpm) on the preparation of microcapsules were evaluated. The 1-MI content and microencapsulation efficiency were calculated using thermal gravimetric analysis (TGA). The shape and surface morphology of the prepared microcapsules were evaluated using scanning electron microscopy (SEM) technique. Gel time of the microcapsules mixed with liquid epoxy resin was also investigated. Results showed that by decreasing the core-to-shell ratio at different stirring rates, the encapsulation efficiency increased. The microencapsulation efficiency of 34.8% was obtained at shell-to-core (1-MI) ratio of 70/30 at stirring rate of 500 rpm. The results also showed that at higher mixing rates, 1-MI content in microcapsules was controlled by high shearing force. It has been found that the gel time of the epoxy resin/microcapsule samples was proportional to the imidazole content and it was in agreement with the data obtained by TGA analysis, as well.

**Keywords** 1-Methylimidazole · Microencapsulation · Solid epoxy · Curing agent · Solvent evaporation method

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## Introduction

Epoxy resins are widely used in different applications such as molded products, electric insulating materials, adhesives, coatings, and electronics due to their promising properties. They are cured with different curing agents to obtain products with high tensile and compressive strengths, appropriate solvent and chemical resistance, and high heat distortion temperatures [1–3]. Epoxy resins are useful for producing of different types of prepreg products, which are applicable in preparation of aircraft interiors, aerospace components, and automotive parts [4, 5]. The curing process of epoxy resins can be carried out using a wide range of curing agents such as anhydrides, amines, polyamides, phenol formaldehyde resins, and polysulfides. Although epoxy resins are cured with primary and secondary amines through a step growth polymerization, tertiary amines undergo a chain growth polymerization. Imidazoles are heterocyclic compounds that are often used as hardeners or accelerators in a variety of epoxy resin systems to initiate the homopolymerization of epoxy compounds [6, 7].

Imidazoles as anionic curing agents are known for their relatively long shelf life. Epoxy resins can be cured with imidazoles at medium temperatures (80–120 °C) and short-time duration to achieve a material with high heat distortion temperature. Various imidazole derivatives that have different reactivities with epoxy group can prolong storage time of resin/hardener system [8, 9]. The imidazole derivatives include imidazole carboxylate, epoxy-imidazole adducts, metal salt-imidazole complex compounds, and imidazole reacted with acidic substances. All these types of curing agents are intended to improve workability by having high pot life and rapid curing rate at elevated temperatures (100–180 °C). Therefore, they have been used in compound resin