Study of the influence of nano-silica particles on the curing reactions of acrylic-melamine clear-coats

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Abstract

In present study, the influence of presence of nano-silica particles having different surface modifications on curing reaction of a thermosetting acrylic-melamine clear-coat is clarified. Acrylic-silica nano-composites were made by grinding and dispersing of silica nano-particles in a thermosetting acrylic resin via milling. The resulting compositions were characterized in terms of curing reaction and the final film morphology. The cure reaction of the Neat and nano-particle containing clear-coats was monitored by differential scanning calorimetry (DSC). It was found that the presence of nano-silica particles, either hydrophilic or hydrophobic, reduces the activation energy of cure and increases the total heat of reaction. The morphology of the film is also extensively influenced by the presence of nano-particles.

1. Introduction

Mar/scratch resistance of the automotive clear-coatings is one of the most important criteria for many customers [1] and is crucial for coatings/materials in many applications, e.g. the polymer topcoats used in the automotive industry [2–9].

Traditionally the scratch resistance of an organic coating can be improved by the addition of high content of inorganic filler. A wide range of metal-oxide particles can be used as inorganic fillers to enhance the mar/scratch resistance of the clear-coats [10–12].

The incorporation of inorganic nano-particles into coatings and other organic matrices gives rise to hybrid materials (nano-composites) and offers a simple way to modify the properties of the Neat systems. It has been found that the thermal stability of some polymers is affected by the type of nano-additives [13]. The influence of a nano-particle on cure kinetics of the host resin is one of the most important properties determining the suitability of the nanoparticle to modify the properties of a clear-coat. Cure kinetics depends on a large number of variables such as chemical structure, functional groups of the reactants and surface properties of nano-additive.

While curing has a large impact on the final properties of the clear-coats and nano-silica has been used to modify these coatings, there is no report about the effect of these nano-particles on the cure kinetics of such systems.

The goal of this work is to describe the effect of presence of nano-silica particles on cure kinetics of an acrylic-melamine clear-coat through comparison with cure data of the Neat system. The impact of these nano-particles on the morphology of the cured film has also been visualized using scanning electron microscopy (SEM).

2. Experimental

2.1. Materials

The clear-coat was formulated based on an acrylic-polyol and a butylated melamine-formaldehyde resin. Xylene, butanol, ethoxy propyl acetate and butyl glycol acetate were used as solvent. A block copolymer-type dispersing agent was incorporated in the nano-silica grinding vehicle. The UV-absorber and the hindered amine light-stabilizer were Tinuvin 400 and Tinuvin 292, respectively. The clear-coat was formulated according to Table 1.

Different nano-silicas were incorporated into the clear-coat formulation, the properties of which are shown in Table 2. An unmodified hydrophilic silica grade (Neat) and three hydrophobic silica grades were used. The hydrophobic silicas were modified using different silanes, namely methacryl silane (MS), hexamethyl di silane (HMDS) and dimethyl dichlorosilane (DMDCS). These silicas vary in specific surface area and primary particle size. The acidity of the surface of the silicas and some other specifications of these particles are summarized in Table 2.