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Development of Radiation Curable Nanocomposites for Coating Applications

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ABSTRACT

Radiation curing is one of the most effective processes to produce rapidly composite materials at ambient temperature. Silica nanoparticles can be introduced into radiation curable resins to produce scratch and abrasion resistant materials, which can be used as coating materials. In preparation of radiation cured polymeric composites for wood based products, we synthesized radiation curable silico-organic nanoparticles from silica/ acrylates system. These nano-sized silica particles were used as fillers. Epoxy acrylate was used as prepolymer while pentaerythritol triacrylate and tetraacrylate (PETIA) was used as monomer. The surface of the silica was chemically modified to improve the embedding of the filler within the acrylate matrix. Modification of the silica surface was done to overcome the problem of incompatibility with acrylates at high silica contents. The nature of the nanoparticles changed from hydrophilic to organophilic. These polymerization active nanoparticles were obtained by heterogeneous hydrolytic condensation of the silane to the silanol groups of the silica particles. Formulations useful for technical coating processes could be prepared and cured by electron beam (EB) or ultraviolet (UV) light. These composite materials showed highly improved mechanical properties and provided a high network density whilst the coatings remain transparent. These polymeric nanocomposites show excellent resistances toward scratch and abrasion properties compared to pure acrylates.

I. INTRODUCTION

Recently, there has been a strong and increasing demand for scratch and abrasion resistance composite materials that can be applied to various substrates such as plastic and wood based products. For example, plastics have been widely used as motor vehicle parts, optical lenses etc. due to their characteristic features such as lightness, toughness, easy processing and low production costs. However, they are vulnerable to scratch and abrasion resistance. Another application is in the construction industry where the industry needs high scratch and abrasion resistant coating materials especially for wood polymer composite materials.

Kencana Fibercomposite is a manufacturer producing high performance fiber composites derived from a revolutionary green technology. These composites are alternative to wood and used in building construction. However, they are vulnerable to scratch and abrasion during handling and transportation. Therefore, Kencana Fibercomposite and Nuclear Malaysia have collaborated to develop scratch and abrasion resistant nanocomposite coatings. The most appropriate process to cure the materials is using radiation curing technology [1,2]. The technology offers several advantages such as high speed fast cure [3,4], improve productivity and product performance, curing at room temperature, energy efficient and elimination of volatile organic compound (VOC). The objective of the project is to develop and produce highly scratch and abrasion resistant coating materials by radiation curing technology.

II. METHODOLOGY

Preparation of silico-organic nanoparticles was carried out in a reactor and the percentages of materials in the formulations were shown in Table 1. Maleic anhydride, dissolved in water, was introduced in a mixture of several acrylates and 4-methoxyphenol. The coupling agent such as VTMOS was added within 30 minutes. Finally, nano-sized silica particles were dispersed under intensive stirring during 1-2 hours using a high speed dissolver at 60°C. The coating materials were cured using electron beam (EB) or ultraviolet (UV) light and characterized by several methods such as scratch test and Taber abrasion test.

Table 1 The amount of materials in the formulations.

Formulations	Materials (%)			
	PETIA	VTMOS	SiO_2	EB600
SF-1	30	25	-	45
SF-2	30	25	10	35
SF-3	30	25	20	25
SF-4	30	25	30	15

III. RESULT AND DISCUSSION

Silico-organic nanoparticles have relatively large surface areas than microparticles, therefore modification effects from the polymerization activity should have a great influence to the properties of the composites. In these investigations, we use radiation such as ultraviolet and electron beam to initiate polymerization and interaction at the interface between the nanoparticles and the monomeric materials. These polymerization active nanoparticles were obtained by heterogeneous hydrolytic condensation of the silane to the silanol groups of the AEROSIL particles.

The above reaction could be verified by the application of FT-Raman spectroscopy (intensity measurements of the C=C vibration band at 1640 cm^{-1}) and gel permeation chromatography to show that the polymerization activity of the nanoparticles imparts to the silico/acrylate dispersion [5]. In the curing process, the nanoparticles form crosslinkages to produce radiation cured polymeric composites with improved scratch and abrasion resistance.

Table 2 Gel content and pendulum hardness measurement.

Formulations	Gel Content (%)	Pendulum Hardness (%)	
		EB	UV
SF-1	96.4	74.0	70.1
SF-2	97.3	73.7	73.6
SF-3	98.3	73.1	73.7
SF-4	98.6	65.1	72.9

Table 3 Abrasion resistant properties.

Formulations	Weight Loss (mg)	
	EB	UV
SF-1	44.1	44.4
SF-2	22.0	19.9
SF-3	13.2	12.0
SF-4	8.5	6.7

After soxhlet extraction, all the coated materials show very high gel content. These coating materials also show high pendulum hardness property as shown in Table 2. In Table 3, the weight loss of the UV/EB cured materials significantly reduced when the amount of silica particles increases i.e. up to 30% of SiO_2. These nanoparticles improve the abrasion property of the coating materials.

Table 4 Scratch resistant properties (steel ball tip).

Formulations	Resistant to scratch (N)	
	EB	UV
SF-1	9	0.7
SF-2	1.5	1.0
SF-3	3.5	2.0
SF-4	4.5	2.5

Table 5 Scratch resistant properties (diamond tip).

Formulations	Resistant to scratch (N)	
	EB	UV
SF-1	9	>10
SF-2	>10	>10
SF-3	>10	>10
SF-4	>10	>10

Finally, the performance of these composites is also related to other factor such as resistance to scratch. Two types of needles were used for determining the resistance of a single coat system of the composites to penetration by scratching i.e. using diamond tip and steel ball (spherically tipped needle). The method used was by applying increasing loads to the needle to determine the minimum load at which the coating was penetrated. The nanoparticles added into the coating materials improve the scratch property of the composite materials as shown in Table 4 whereas in Table 5, most of the composites exhibit excellent resistance to scratch property including SF-1.

IV. SUMMARY

Polymerization active silico-organic nanoparticles could be prepared by heterogeneous condensation (in situ reaction) and formed crosslinking in the polymeric substrates. With a relatively high nanopowder content of the nanodispersions, these coating materials could still be cured by UV light and electron beam (EB) to produce excellent polymeric composites. These nanocomposite coatings showed highly improved mechanical properties and excellent resistances toward scratch and abrasion properties when compared to pure materials without nanoparticles.

V. REFERENCES

[1] N. S. Allen, M. Edge, J. Oil Colour Chem. Assoc., 11, 438, 1990.

[2] N. G. Salleh, H. J. Gläsel, R. Mehnert, Radiat. Phys. Chem., 63, 475-479, 2002.

[3] C. Decker, Prog. Polym. Sci., 21, 593, 1996.

[4] C. Decker, L. Keller, K. Zahouily, S. Benfarhi, Polymer, 46, 6640-6648, 2005.

[5] H. J. Gläsel, E. Hartmann, R. Mehnert, D. Hirsch, R. Böttcher, J. Hormes, Nucl. Instrum. Meth. Phys. Res., B 151, 200, 1999.