



PRODUCTION OF PRESSURE SENSITIVE ADHESIVES (PSA) FROM PALM OIL BASED RESIN-A PREPOLYMER METHOD

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SUMMARY

Various low T_g acrylate and methacrylate monomers were mixed with epoxidised palm oil acrylate (EPOLA) with the ratio of 50/50 prior to curing with an electron beam (EB) irradiation. Methacrylate monomers such as dicyclopentenloxyethyl methacrylate (DCPOEMA) and isobornyl methacrylate (ISBMA), although displayed relatively high adhesive properties but were finally excluded from being further utilised as monomers for PSA because of a very slow curing speed. Literally, it is suggested that poorer adhesive performances of the cured films made from 50/50:EPOLA/monomer mixture as compared to that of 100% monomer was attributed to the lack of compatibility between EPOLA and that particular monomers. Further compatibility investigations were continued using formulations prepared via prepolymer route cured by an ultraviolet (UV) irradiation and the results showed that several monoacrylate monomers with polar and non-polar-groups exhibited high curing speed as well as good compatibility with EPOLA as shown by their cured film properties such as; surface tackiness, peel adhesion and creep resistance. It is also suggested that these monomers were acting as surfactants for EPOLA which consequently enhance their compatibility upon mixing.

1.0 INTRODUCTION

Previous works (Mohd. Hilmi *et al.* 1997; Mohd. Hilmi *et al.* 1998) carried out at the Malaysian Institute for Nuclear Technology Research (MINT), on the studies to investigate the potential use of palm oil based acrylated resins namely EPOLA and palm oil based urethane acrylate (POBUA) for the production of radiation (UV/EB) curable

PSA were mainly focused on the use of ISBMA as a monomer. However, the requirements of around 200 to 300 kGy and 2.25×10^{13} to 4.125×10^{13} MeV/cm² (6 to 11 times of UV light exposures from a 200 watt/cm, 20 cm UV machine with the condition of 7.5 A current and 4m/min conveyor speed) dose or energy for curing using EB and UV respectively were considered rather high and might lead to overcuring and subsequently the risk of degradation to the irradiated films, especially when using EB irradiation, where, dose variations are less flexible when compared to UV. Employment of N-vinyl-2-pyrrolidone (NVP) into formulations to some extent increased the curing speed but at the expense of adhesive properties. The poor creep resistance results showed by UV/EB curable PSA made of 60/40:EPOLA/ISBMA mixture (Mohd. Hilmi *et al.* 1998) could be considered a setback in determining the properties of PSA. The introduction of tackifying agents such as; poly(vinylmethylether) (PVME), hydrogenated rosin (HR) and aliphatic hydrocarbon resin (AHR) into formulations did little in improving these properties.

The present study is conducted with the aims of searching for monomers which are most compatible with EPOLA as well as possessing high curing speed without compromising the properties of PSA such as; tackiness, peel adhesion and creep resistance. Also, in this study, we will examine the efficiency of a new procedure, i.e., the prepolymer method in preparing PSA formulations to enhance viscosities which will subsequently produce cured films with desired thickness of around 30-50 μm .

2.0 EXPERIMENTAL

2.1 Materials

2.11 Oligomers/resins

EPOLA oligomer used in the present work was prepared in MINT Laboratory through acrylation of the epoxidised palm oil products (EPOP). The acid number (AN), molecular weights (MW) (measured using Tosoh made GPC, model HLC-8020) and T_g (measured using Shimadzu Thermal Analyser, Model DSC-50) of EPOLA are around 29.81, 3200 and -5.0°C respectively. The viscosity of EPOLA, measured using a Brookfield Viscometre Model RVTDV-IIICP was about 1200 Cps at 25°C .

Poly(vinylmethylether) (PVME) having MW and T_g (data supplied by manufacturer) around 99,000 and -31°C (242 K) respectively, supplied as 50 wt. % solution in water by Aldrich Chemical Co., USA and liquid epoxidised natural rubber (LENR) having MW and T_g around 38,000 and app. -60°C respectively, supplied as 48 wt. % in toluene by MINT Laboratory were used as tackifiers. Prior to use, PVME and LENR need to be dried (e.g. vacuum oven at 60°C for 24 hours).

2.12 Monomers/diluents

Most monomers i.e., dicyclopentenylxyethyl methacrylate (DCPOEMA), isodecyl acrylate (i-DA), isodecyl methacrylate (i-DMA), lauryl methacrylate (LMA), acrylic acid (AA), isobornyl acrylate (ISBOA), isobornyl methacrylate (ISBMA), isooctyl acrylate (i-OA), isononyl acrylate (i-NA), 2-ethylhexyl acrylate (2-EHA), n-butyl acrylate (n-BA), isobutyl acrylate (i-BA), N-vinyl-2-pyrrolidone (NVP) and 1,6-hexanediol diacrylate (1,6-HDDA) employed in this work were supplied by Aldrich Chemical Co., USA, while, phenol diethoxylate acrylate (M-101), phenol tetraethoxylate acrylate (M-102), nonylphenol monoethoxylate acrylate (M-111), nonylphenol tetraethoxylate acrylate (M-113), nonylphenol poly(n=2.5)propoxylate acrylate (M-117), 2-ethylhexyl carbitol acrylate (M-120), 2-hydroxy-3-phenoxy-propyl acrylate (M-5700) and 2(2-ethoxyethoxy)ethyl acrylate (IRR-184) were supplied by Toagosei Chemical Industry Co., Ltd., Japan and UCB Chemicals (M) Sdn. Bhd., Malaysia respectively. Lastly, dimethylaminopropyl acrylamide (DMPAA) was supplied by Kohjin Co., Ltd., Japan.

2.13 Other additives

Photoinitiator namely Darocure® 1173 (D-1173) product used in UV curing applications was supplied by CIBA-GEIGY Corporation, USA and used as received.

2.2 Application and Irradiation

The PSA formulation recipes of EPOLA:monomer/ISBOA/AA/D-1173=50:50(85)/10/5/0.1, prepared either through normal mixing method or prepolymer method, i.e., purging with N₂ gas while intermittently exposed to a 400 watt, Mercury Lamp UV Irradiation Source of Photochemical Reactors Ltd., U.K., uniformly along the flanks of the transparent vessel when finally a prepolymer formation was marked with the gradual increased in viscosity, were coated onto polyethylene terephthalate (PET) films having thickness around 30-40 µm with a baker type applicator marked # 2 (50 µm) thickness (this parametre is used throughout experiments) giving around 20-50 µm thickness of dried films (vary with formulation viscosities). The coated resins were covered with transparent silicone treated PET films prior to irradiation curing using a 200 watt/cm, medium pressure mercury vapour lamp of IST®-UV Dryer (Switzerland) at 10m/minute giving app. 1.31×10^{12} MeV/cm² energy per pass to reduce O₂ inhibition effects, while, the uncovered resins were subjected to a 15 cm wide Curetron® (NHV, Japan) at an acceleration voltage of 200 kV, a beam current of 2 mA and a conveyor speed of 22.5 m/min under nitrogen atmosphere giving app. 10 kGy (1 Mrad) per pass.

2.3 Measurements and Testing

The viscosity of the PSA formulations are measured using a Brookfield Viscometre Model RVTDV-IICP at 25°C. The 180° peel strength was evaluated following Pressure Sensitive Tape Council Test Method Number 1 (PSTC-1) (Perkins 1980) test in which a strips of 1 inch width adhesive tape was pasted onto a stainless steel panel (SUS 304) and

peeling off at a crosshead speed of 300 mm/min by using a Strograph-RI (Toyoseiki Co., Ltd.) 24 hours after pasting and pressing with a 1.8 kg roller. The surface tackiness was measured by using a Probe-Type Tackiness Tester (Rhesca Co., Ltd., Japan) which followed the "IPC-SP-819 IIW SUB-COMMISSION 1A" standard (specified by the supplier), where a 5 mm diameter stainless steel probe being contacted with a specimen for 1 second followed by being peeled off at a speed of 30 mm/sec. The creep resistance was conducted via the Pressure Sensitive Tape Council Test Method Number 7 (PSTC-7) (Perkins 1980) test procedure in which one inch square tape sample is applied to a stainless steel surface mounted in a vertical position after which a 500 gram weight is attached to the tape and the time to failure is measured.

3.0 RESULTS AND DISCUSSION

3.1 Choice of Monomers-Fox Equation

Various low T_g monomers, most of them with T_g below -30°C such as listed in Tables 1(a) and 1(b) were mixed with EPOLA (with $T_g \sim -5.0^\circ\text{C}$) at 50/50:EPOLA/monomer ratio following the Fox equation (Billmeyer 1984) to produce mixed materials with an expected cured film's T_g around $< -20^\circ\text{C}$. The Fox equation is described below:

$$1/T_g = W_1/T_{g1} + W_2/T_{g2} \dots \dots \dots$$

and $W_1 + W_2 = 1$ (weight fraction)

where, W_1, W_2 ; weight fraction of each content

T_g ; glass transition of a compound (mixture)

T_{g1}, T_{g2} ; glass transitions for each component (content)

(T_g is in unit of Kelvin, not in Celcius)

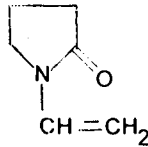
3.2 EB Irradiation-Search For Monomers

Table 2 shows the properties of PSA formulations prepared via normal mixing method cured by EB. Most of the monomers used exhibited high curing speed except for the methacrylates, i.e., DCPOEMA, ISBMA, i-DMA and LMA. Among the acrylate monomers, ISBOA shows the fastest curing rate and highest tackiness which qualifies it to be further utilised as a speed enhancer in other formulations together with acrylic acid (AA) which was later introduced as a hardener (might copolymerises with other monomers in the present of photoinitiator and UV light). Although, the adhesive properties shown by DCPOEMA and ISBMA were reasonably high but their slow curing speed hinders them from being considered for further use in PSA formulations.

Table 1 (a): List of Monomers Used In PSA Formulations

Chemical names (Abbreviations)	Chemical Structures	MW	Viscosity (Cps/25°C)	T _g (°C) (Homopolymers)
DCPOEMA	$\text{H}_2\text{C}=\overset{\text{CH}_3}{\text{C}}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{CH}_2-\text{CH}_2-\text{O}-\text{[Bicyclic Ring]}$	262	17	25 - 35
i-DA	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{C}_{10}\text{H}_{23}$	212	2	-55
i-DMA	$\text{CH}_2=\overset{\text{CH}_3}{\text{C}}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{C}_{10}\text{H}_{23}$	226	20	-70
LMA	$\text{CH}_2=\overset{\text{CH}_3}{\text{C}}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-(\text{CH}_2)_n\text{CH}_3 \quad n = 11 - 13$	254	-	-65
ISBOA/ *ISBMA	$\text{CH}_2=\overset{\text{H}^*/\text{CH}_3}{\text{C}}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{[Bicyclic Ring]}$	208/ *222	7.5	* - 144
i-OA	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{C}_8\text{H}_{17} \text{ (iso)}$	184	14	-45
i-NA	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{C}_9\text{H}_{19} \text{ (iso)}$	-	-	-
2-EHA	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\underset{\text{C}_2\text{H}_5}{\text{CH}_2\text{CH}-\text{C}_4\text{H}_{11}}$	184	1-54	-85
n-BA	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$	-	-	-54
i-BA	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\underset{\text{CH}_3}{\overset{\text{CH}_3}{\text{CH}_2\text{CH}}}$	-	-	-40

Table 1(b): List of Monomers Used In PSA Formulations

Chemical Names/ Trade Names (Abbreviations)	Chemicals Structures	MW	Viscosity Cps (25°C)	Tg (°C)
AA	$\text{H}_2\text{C}=\text{CH}-\overset{\text{OH}}{\underset{\text{O}}{\parallel}}{\text{C}}$	72.06		
DMAPAA	$\text{H}_2\text{C}=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{NH}-\text{CH}_2\text{CH}_2\text{CH}_2-\text{N}(\text{CH}_3)_2$	156.11		
IRR - 184	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-(\text{CH}_2\text{CH}_2-\text{O})_2-\text{CH}_2\text{CH}_3$	188	4.7	-70
M - 101	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-(\text{OCH}_2\text{H}_4)_2-\text{O}-\langle\rangle$		16	-8
M - 102	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-(\text{OCH}_2\text{H}_4)_4-\text{O}-\langle\rangle$		30	
M - 111	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-(\text{OCH}_2\text{H}_4)_2-\text{O}-\langle\rangle-\text{C}_9\text{H}_{19}$		70	17
M - 113	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-(\text{OCH}_2\text{H}_4)_4-\text{O}-\langle\rangle-\text{C}_9\text{H}_{19}$		90	-20
M - 117	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-(\text{OCH}_2\text{H}_6)_{2.5}-\text{O}-\langle\rangle-\text{C}_9\text{H}_{19}$		110	-3
M - 120	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-(\text{OCH}_2\text{H}_4)_n-\text{O}-\text{CH}_2-\underset{\text{C}_4\text{H}_9}{\overset{\text{C}_2\text{H}_5}{\text{CH}}}$		5	-65
M - 5700	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{CH}_2-\underset{\text{OH}}{\text{CH}}-\text{CH}_2\text{O}-\langle\rangle$		140	17
NVP		111	2.07	175
1,6 - HDDA	$\text{CH}_2=\text{CH}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-(\text{CH}_2)_6-\text{O}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}=\text{CH}_2$	226.3	20 - 35	

3.3 UV Curing-Prepolymer Method

Further search for good compatibility monomers was conducted by using UV irradiation since its machine is less complicated to handle as compared to that of EB and the dose or light intensity is easier to control, i.e., by merely changing the conveyor speed or varying the # of passes, giving only small variations in intensity (measured by using UV Curing Radiometre) and hence reduces the risk of overcuring and consequently degradation to

Table 2: Properties of PSA Formulations By EB Curing-Baker Type Bar Coater # 2 (50 µm)
(Following Ordinary Mixing Method)

Components	Composition % By Weight										
	AD 1	AD 2	AD 3	AD 4	AD 5	AD 6	AD 7	AD 8	AD 9	AD 10	AD 11
EPOLA	50	50	50	50	50	50	50	50	50	50	50
DCPOEMA	50										
2 - EHA		50									
n - BA			50								
i - BA				50							
ISBMA					50						
ISBOA						50					
i - DA							50				
i - DMA								50			
i - OA									50		
i - NA										50	
LMA											50
Properties											
Dose (# Passes)	9	2	2	1	10	1	3	> 20 not cure	2	2	> 11 not cure
Viscosity (Cps/25°C)	179.5	-	-	-	134.4	-	-	57.2	36.8	44.1	-
Tackiness (gf)	126.7	30.4	25.0	14.9	33.3	181.6	30.5	-	23.8	24.2	-
Peel Adhesion (g/in)	15	1	2	2	100	8	3	-	3	3	-
Mode of Failure	CRF	CRF	CRF	CRF	BF	BF	CRF	-	CRF	CRF	-

Note : CRF (Clean Release Failure) Dose : 30 kGy/ Pass
BF (Backing Failure)

the cured films as compared to the bigger intensity differences in case of EB irradiation, which otherwise might cause the adverse effects.

The prepolymer method as described in sec. 2.2 was employed on all formulations. The behaviour of formulations AD12 to AD14 shown in Table 3 indicates that the adhesion properties were superior when using baker-type applicator with thickness indicator # 2 (50 µm). Thus this parametre was used throughout experiments. Table 3 also displayed the effect of EPOLA/monomer ratio on adhesive properties as shown by formulations AD15 to AD20; where PSA formulations made of 100% monomers although showed rather slow curing speed but their adhesive properties i.e., tackiness and peel strenght were superior. Sudden decline in adhesive properties when adding 25% to 50% EPOLA illustrated that these monomers are incompatible (hardly miscible) with EPOLA oligomer.

Table 4 further explains that the prepolymer method was more superior than that of normal mixing since it produces PSA formulations with higher viscosities, better curing

speed and better adhesive performances. The most notable one is that when using baker-type applicator marked # 2 (50 µm) for coating, the PSA formulations made from prepolymer route produced cured films with favourable thickness of 42-48 µm as compared to only 25-30 µm for normal mixing method. It is suggested that the increased viscosities of the formulations made by prepolymer method minimised the flow of wet resins on the substrates after coating and thus maintaining the predetermined coating thickness. Also, the formation of prepolymers as marked by the increased in viscosities will similarly enhance adhesive properties such as; surface tackiness and peel adhesion.

Table 3: Properties of PSA Formulations By UV Curing (Following Prepolymer Method)

Components	Composition % By Weight								
	AD 12	AD 13	AD 14	AD 15	AD 16	AD 17	AD 18	AD 19	AD 20
EPOLA					50	25	50	25	
i- NA	100	100	100						
n - BA				100	50	75	50	75	100
NVP							15	15	15
ISBOA	10	10	10	10	10	10			
AA	5	5	5	5	5	5			
D - 1173	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Properties									
Coat. Thickness (µm)	25	37.5	50	50	50	50	50	50	50
Dose (# Passes)	3	3	3	13	6	4	2	6	25
Viscosity (Cps/25°C)	948.0	948.0	948.0	184.0	152.0	38.0	-	-	-
Tackiness (gf)	298.9	402.3	441.7	413.2	128.2	168.5	32.0	81.5	277.8
Peel Adhesion (g/in)	80	150	210	2500	10	20	5	4	600
Mode of Failure	CRF	CRF	CRF	BF	CRF	CRF	CRF	AF	CRF

Note : CRF (Clean Release Failure) Dose : 1.31×10^{12} MeV/cm² per pass
BF (Backing Failure)
AF (Adhesive Failure)

Table 4: Properties of PSA Formulations By UV Curing - A Comparison Between Normal Mixing and Prepolymer Methods

Components	Composition % By Weight								
	AD 21	AD 22	AD 23	AD 24	AD 25	AD 26			
EPOLA		50	25		50	25			
M - 101	100	50	75	100	50	75			
ISBOA	10	10	10	10	10	10			
AA	5	5	5	5	5	5			
D - 1173	0.1	0.1	0.1	0.1	0.1	0.1			
Properties									
Dried film Thickness (µm)		Prepolymer	Method		Normal	Mixing	Method		
Dose (# Passes)	48	43	42	25	30	28			
Viscosity (Cps/25°C)	4	5	5	5	6	6			
Tackiness (gf)	281.0	166.4	118.8	13.1	99.5	35.1			
Peel Adhesion (g/in)	268.5	88.8	82.1	74.4	77.0	78.3			
Mode of Failure	100	5	8	10	5	5			
	CRF	CRF	CRF	CRF	CRF	CRF	CRF		

Note : CRF (Clean Release Failure) ; Dose : 1.31×10^{12} MeV/cm² per pass

3.4 Surfactants Like Monomers

Current experimental results displayed that common monomers [Table 1(a)] commercially employed in PSA formulations such as; 2-EHA, n-BA, i-BA, i-DA, i-OA and i-NA showed very poor compatibility with EPOLA as shown by the sudden drop in adhesive properties when 25 to 50% EPOLA was added to the formulations (see Table 3). So, it is necessary to continue searching for monomers with better compatibility without compromising the essential requirements of PSA properties such as; high curing speed and reasonably high adhesive performances.

Incompatibility results from the existence of high surface tension between two immiscible media (Zahariah *et al.* 1997). In order to promote the miscibility, this surface tension must be removed or reduced and this can only be done by the so called surface active agents or surfactants which are amphiphilic compounds consisting of a hydrophobic (hates water) and a hydrophilic (loves water) moieties. The presence of this two moieties within a molecule causes it to partition preferentially at the interface between fluids of different polarity and hydrogen bonding and thus lowers the interfacial energy or surface tension (Thambirajah 1998) which later improves miscibility or compatibility.

Table 5: Properties of PSA Formulations By UV Curing-Baker Type Bar Coater # 2 (50 µm)
(Following Prepolymer Method)

Components	Composition % By Weight									
	AD 27	AD 28	AD 29	AD 30	AD 31	AD 32	AD 33	AD 34	AD 35	AD 36
EPOLA	50	50	50	50	50	50	50	50	50	50
M - 101	50									
M - 102		50								
M - 111			50							
M - 113				50						
M - 117					50					
M - 120						50				
M - 5700							50			
IRR - 184								50		
DMAPAA									50	45
PVME										5
ISBOA	10	10	10	10	10	10	10	10	10	10
AA	5	5	5	5	5	5	5	5	5	5
D - 1173	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Properties										
Dose (# Passes)	5	5	5	6	6	7	3	3	4	8
Viscosity (Cps/25°C)	166.4	138.4	217.1	249.0	330.9	139.5	290.5	114.3	3,570	10,670
Tackiness (gf)	88.8	54.6	196.3	125.0	199.4	122.0	140.6	59.3	404.3	448.1
Peel Adhesion (g/in)	5	5	190	15	40	8	75	5	175	280
Creep Resistance (hr) ^a 25°C	> 72	> 72	> 72	> 72	> 72	> 72	> 72	< 1	> 72	> 72
	Intact	Intact	Intact	Intact	Intact	Intact	Intact	min.	Intact	Intact
^b 60°C	> 72	> 72	> 72	> 72	> 72	> 72	> 72	> 72	> 72	> 72
^b 25°C	Intact	Intact	Intact	Intact	Intact	Intact	Intact	-	Intact	Intact
	-	-	-	-	-	-	-	-	-	Int.> 72
Mode of failure	CRF	CRF	CRF	CRF	CRF	CRF	CRF	CRF	CRF	CRF

Note : CRF (Clean Release Failure); Dose : 1.31×10^{12} MeV/cm² Per pass; a: 500g load; b: 1 kg load

Ethoxylated/propoxylated nonyl phenol acrylates and other monomers having polar and non-polar groups as listed in Table 1(b) were later chosen as monomers for PSA not only because of their low T_g but it was also thought that they are capable of functioning like surfactants (Glotfelter 1997) and thus promote compatibility. In general, most of these monomers have shown reasonably high curing speed (see Table 5) with the exception of long chain 2-(ethyl)hexylcarbitol acrylate, M-120, (formulation AD32) and formulation AD36 which could be due to the addition of 5% PVME into DMAPAA monomer. As for the adhesive performances four monomers namely; nonylphenol monoethoxylate acrylate (M-111), nonylphenol tetraethoxylate acrylate (M-113), nonylphenol poly(n=2.5)propoxylate acrylate (M-117), 2-hydroxy-3-phenoxy-propyl acrylate (M-5700) and dimethylaminopropyl acrylamide (DMAPAA) exhibited a reasonably high adhesive properties i.e., tackiness and peel adhesion, where the most outstanding performances were shown by DMAPAA (also known for its readily copolymerises with most common monomers through the reactive amino group) and secondly by M-111 monomers. All of them also displayed a clean release mode of failure during peel tests. When samples were subjected to creep resistance or holding tests at 25°C (room temperature) and 60°C, all the films were remained intact to the steel panel after 72 hours.

3.5 Effect of Multifunctional (MF) Monomer and Tackifier On Properties of PSA

Brief studies on the effect of MF monomer has been performed and the initial results shown in figures 1 and 2 indicated that the addition of MF monomer i.e., 1,6-HDDA, into formulations improves the adhesive properties. Further studies will be conducted in detail to investigate the effect of employing various other common MF monomers such as; tetraethyleneglycol diacrylate (TEGDA), polyethyleneglycol diacrylate-400 (PEGDA-400), trimethylolpropane triacrylate (TMPTA) and pentaerythritol triacrylate (PETA) at different concentrations on the adhesive properties.

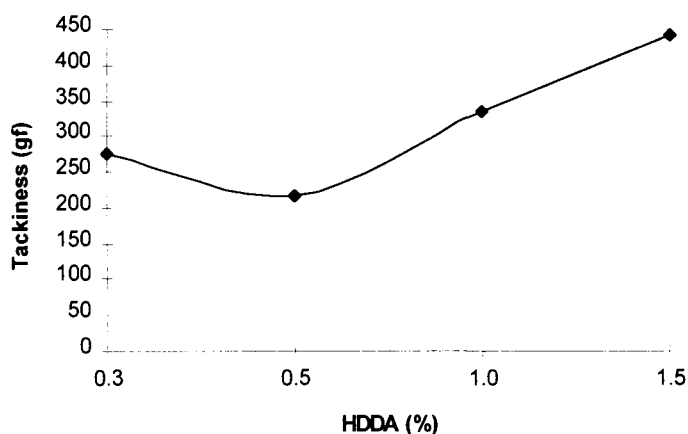


Figure 1 : Crosslinker (HDDA) Concentration of PSA Formulation (AD 14) vs Tackiness

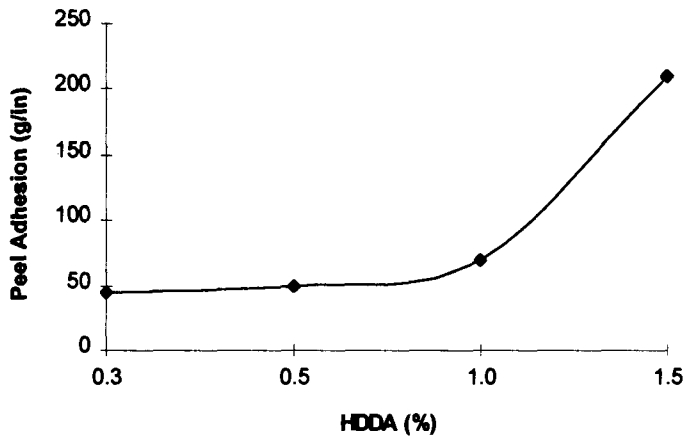


Figure 2 : Crosslinker (HDDA) Concentration of PSA Formulation (AD 14) vs Peel Adhesion

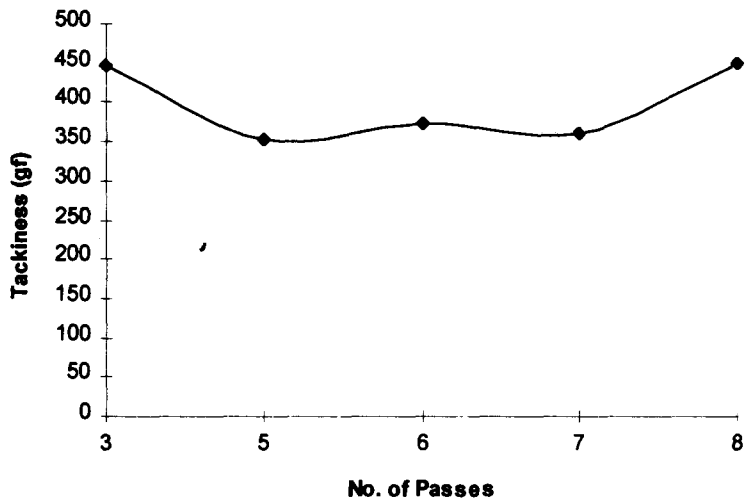


Figure 3 : Effect of Dose (# passes) On Tackiness of PSA Formulation (AD 35) Blended with 5% Tackifier (PVME)

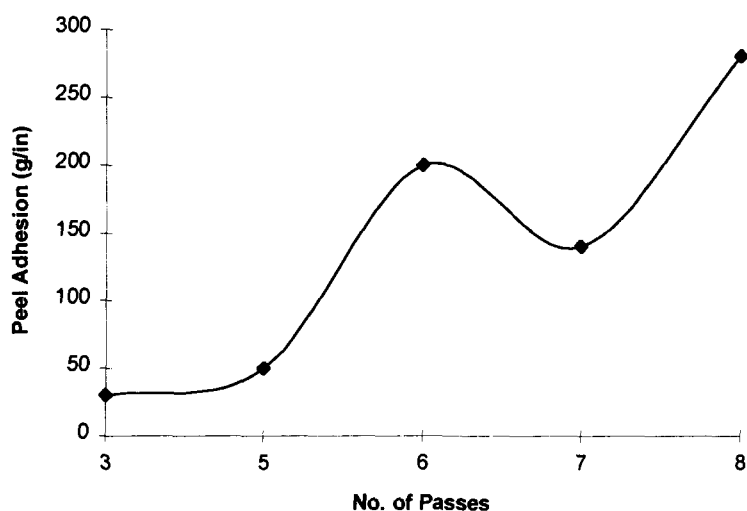


Figure 4 : Effect of Dose (# passes) On Peel Adhesion of PSA Formulation (AD 35) Blended with 5% Tackifier (PVME)

Similarly, addition of 5% PVME tackifier to the PSA formulation such as shown in Table 5 (formulation AD36) and figures 3 and 4 significantly enhanced its adhesive performances, but, at a higher irradiation dose as compared to that of without tackifier. Further studies will be performed to investigate the effect of varying PVME contents on the adhesive properties.

On the other hand, the use of LENR, prepared in MINT Laboratory (Dahlan 1998) as tackifier (see figures 5, 6 & 7) increased both the viscosities and tackiness but decreased the peel adhesion. Figure 6 shows that the use of 5-7% LENR in PSA formulations was sufficient in obtaining the maximum tackiness value. In the future studies an attempt will be made to improve the peel adhesion of LENR containing formulations by incorporating up to 1.5% MF monomers such as 1,6-HDDA, the task which is considered worthwhile since LENR, similar to EPOLA is one of Malaysian indigenous product.

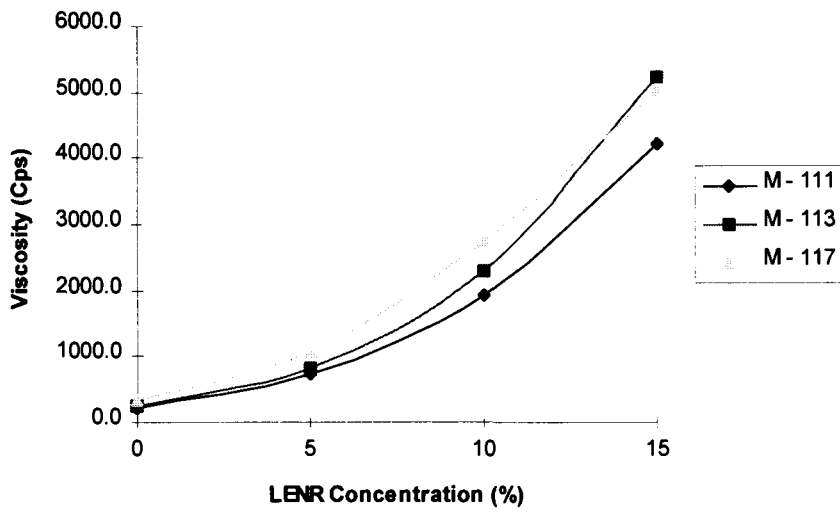


Figure 5 : LENR Concentration vs Viscosity

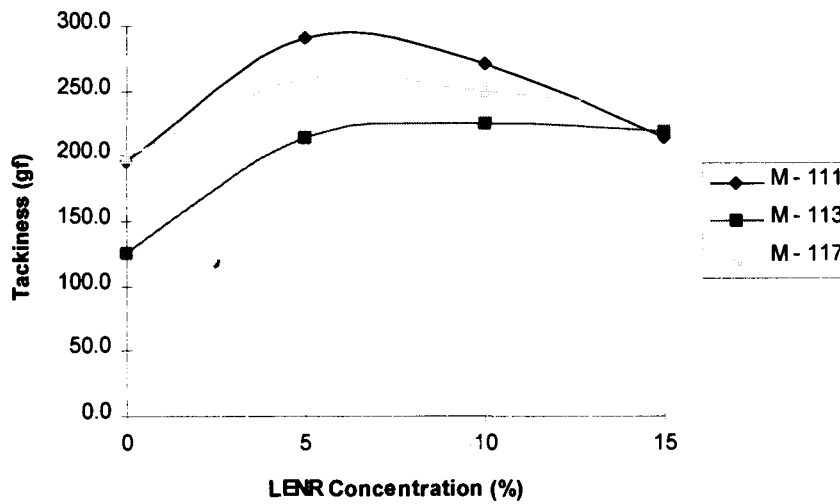


Figure 6 : LENR Concentration vs Tackiness

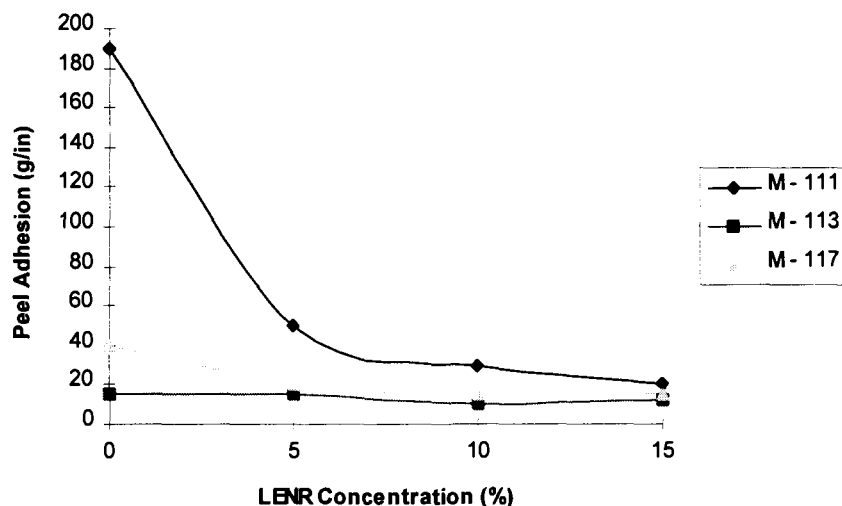


Figure 7 : LENR Concentration vs Peel Adhesion

4.0 CONCLUSIONS

From this study it was found that the use of prepolymer method in PSA formulations produced better coating, curing and adhesive performances compared to the normal mixing method as has previously been practiced.

So far, two monomers namely nonylphenol monoethoxylate acrylate (M-111) and dimethylaminopropyl acrylamide (DMPAA) were found to be most compatible with EPOLA as shown by the outstanding adhesive properties of their cured films based on 50/50:EPOLA/monomer formulation ratios.

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