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NATIONAL EXECUTIVE MANAGEMENT SEMINAR

ON SURFACE FINISHING BY RADIATION CURING

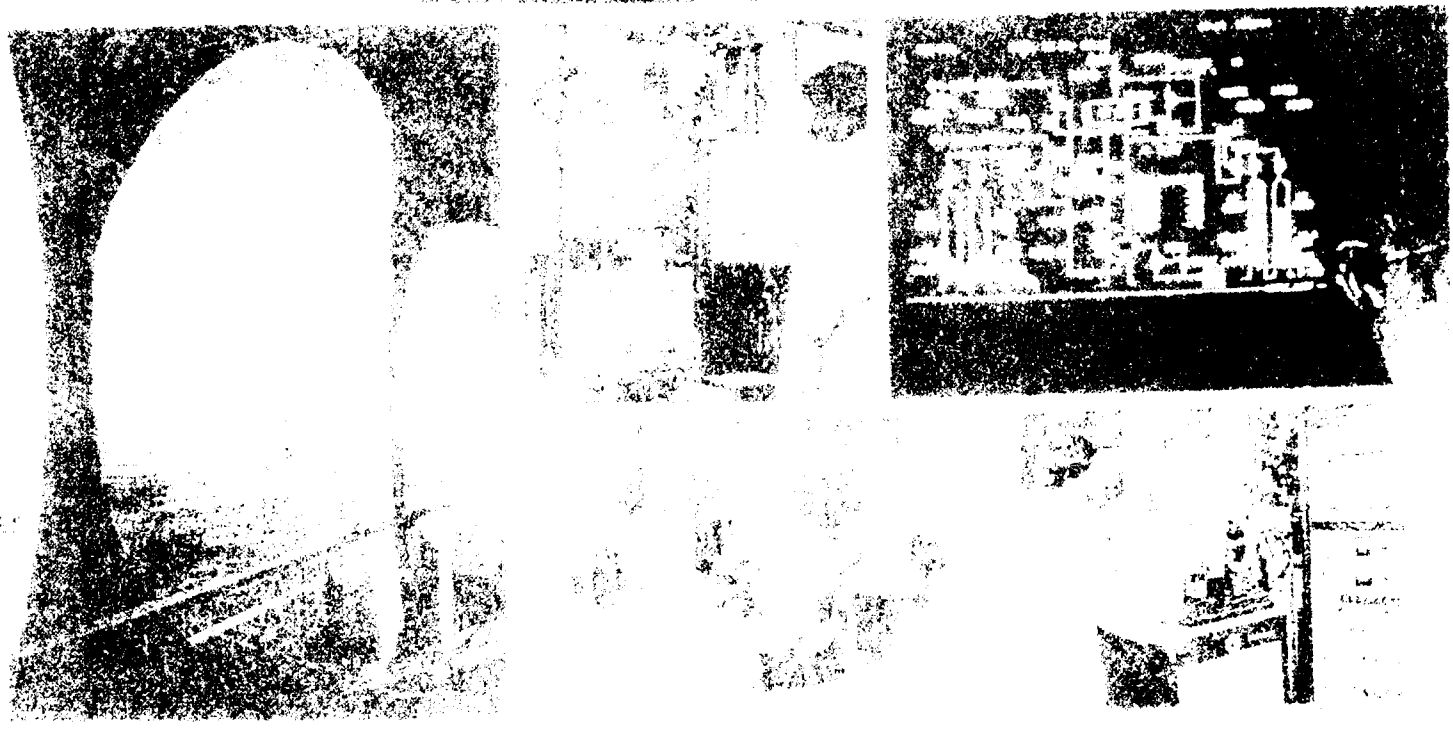
TECHNOLOGY

Chemistry in Radiation Cure Paints

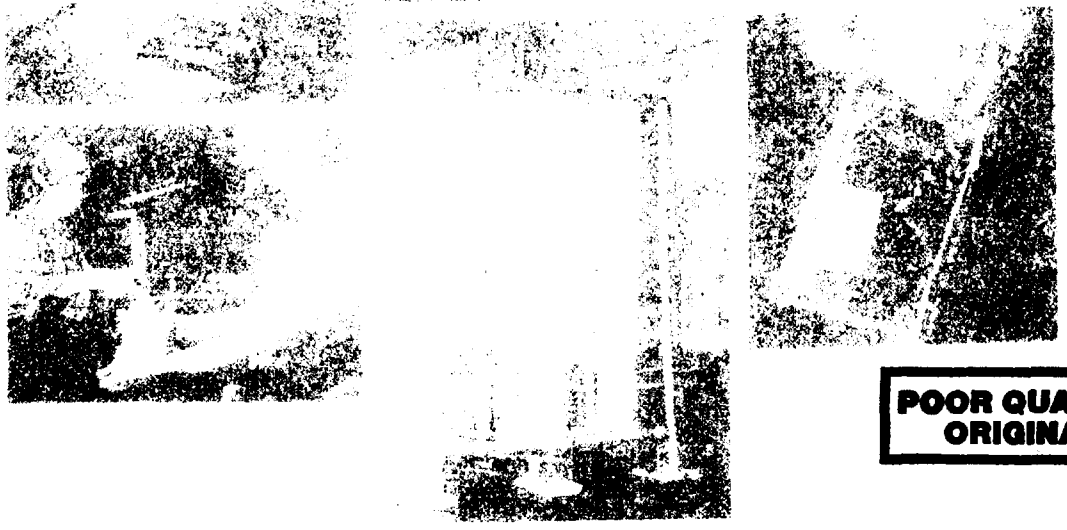
7 September 1993
Equatorial Hotel Kuala Lumpur

Jean-Pierre Ravijst
Business Development Manager
South East Asia

ucb Chemicals
UCB s.a. - Representative Office
Orchard Road 390
Palais Renaissance # 09-03
0923 Singapore
Tel. (65)7350949
Fax (65)7350946



partner
world-wide



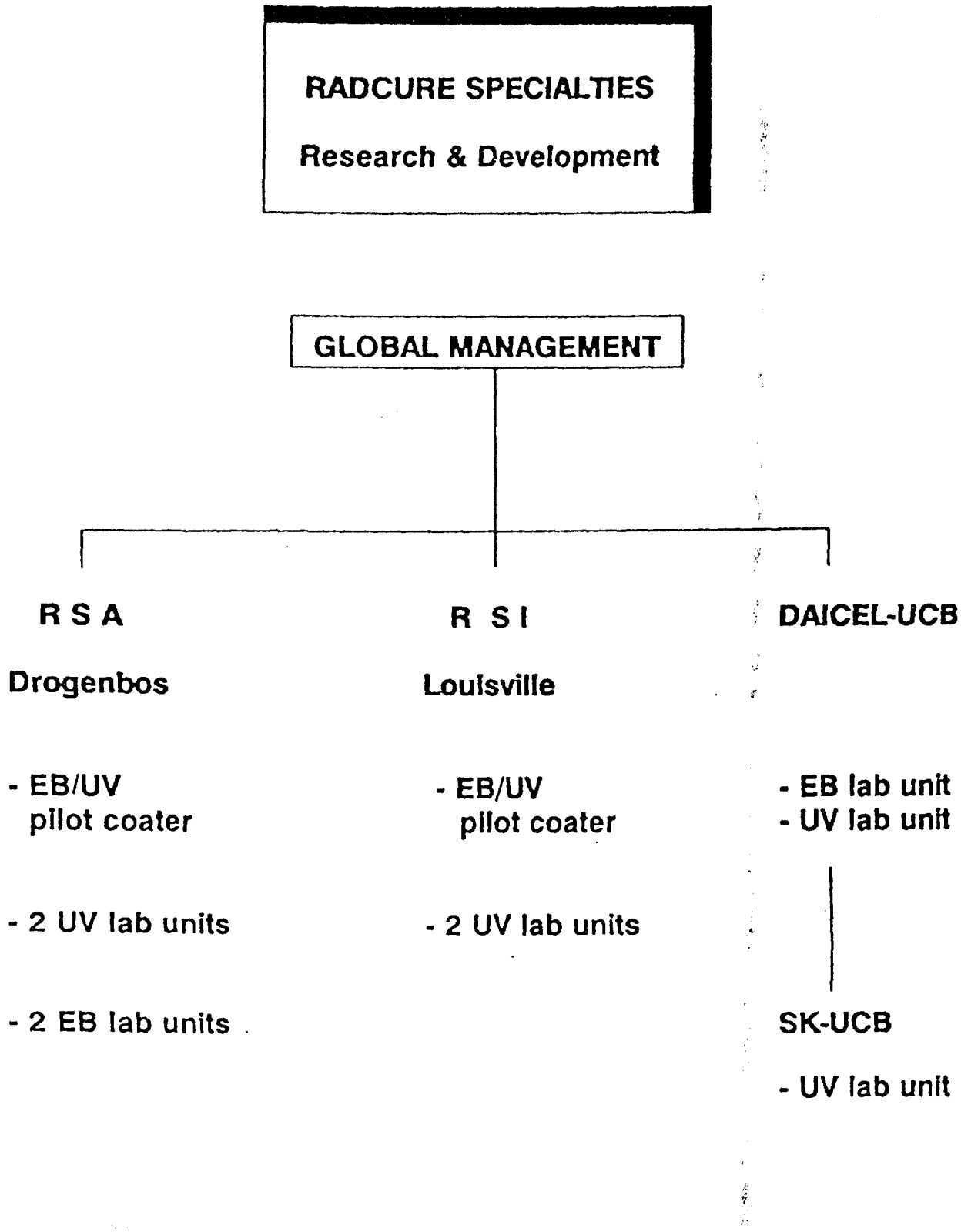
Radcure

RADCURE SPECIALTIES

Production Facilities

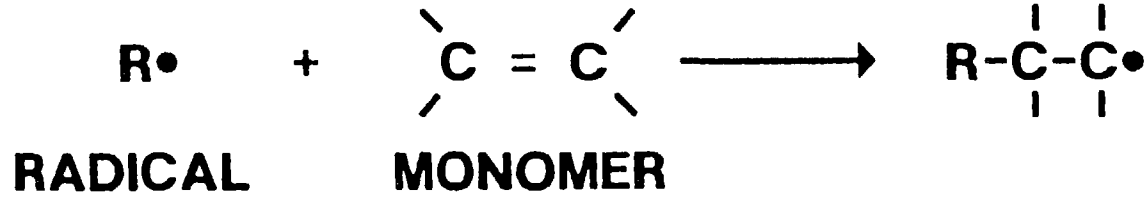
RSA-Europe	RSI-US	J.V. Companies-Far East
Drogenbos (B)	Louisville,KY	Ulsan,South Korea (SK-UCB)
Schoonaarde (B) (Monomers)	Pampa,TX (Monomers)	Otake, Japan (Daicel-UCB)
Madrid (E)	North Augusta,SC (on stream 1993)	

Radcure


RADCURE SPECIALTIES
Research & Development
GLOBAL MANAGEMENT
R S A
Drogenbos
- EB/UV pilot coater
- 2 UV lab units
- 2 EB lab units
R S I
Louisville
- EB/UV pilot coater
- 2 UV lab units
DAICEL-UCB
- EB lab unit
- UV lab unit
SK-UCB
- UV lab unit

RADIATION CURING CHEMISTRY

BASIC FREE RADICAL POLYMERIZATION REACTION

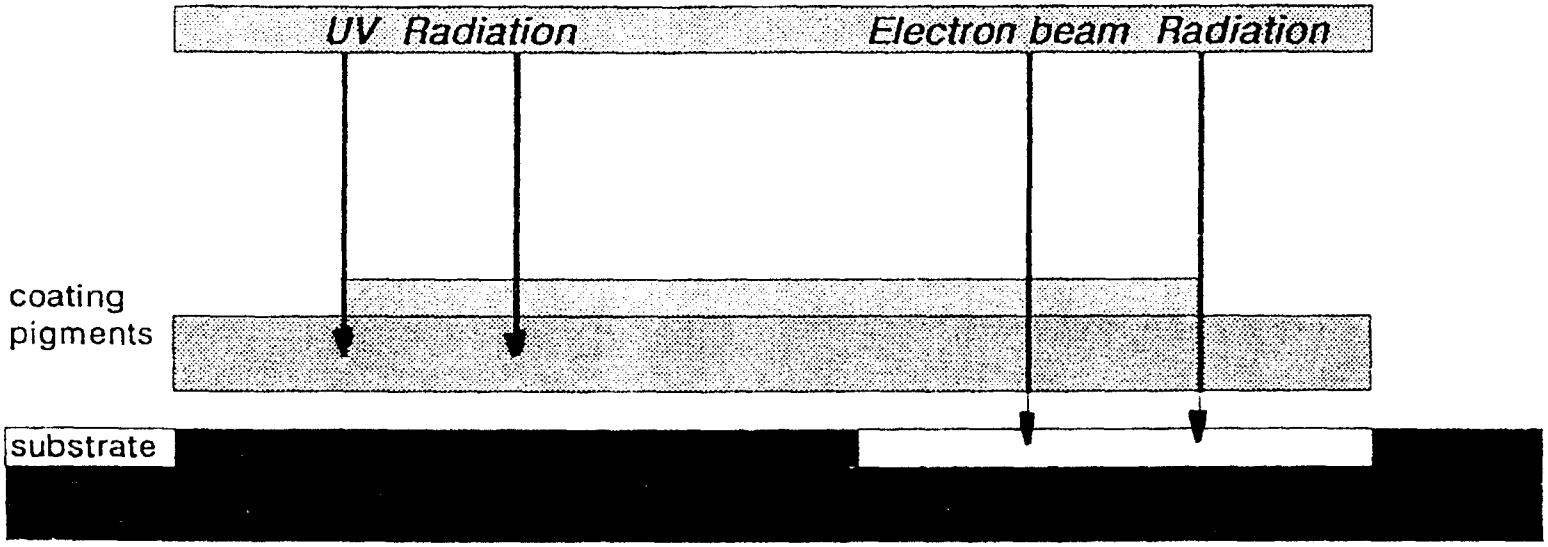


RADICAL MONOMER

POLYMER

Radcure

RADIATION CURING



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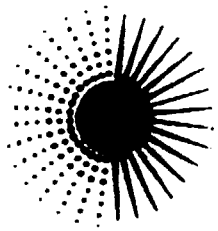
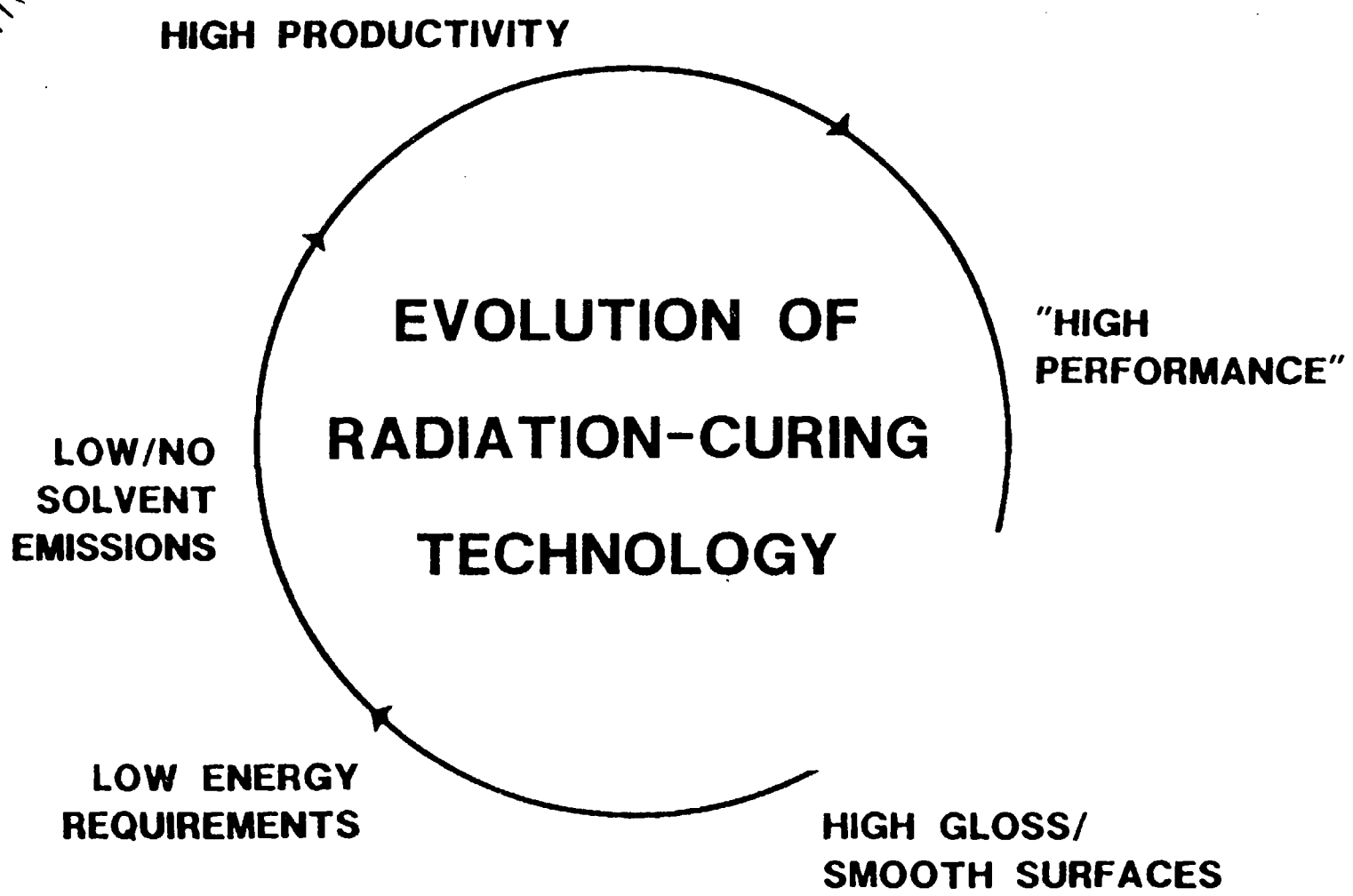
Radcure

DIFFERENCE BETWEEN UV – and EB CURING

	UV-cure	EB-cure
Chemicals	*same*	*same*
Photoinitiators	*present*	*none*
Extractables	*high*	*low*
Residual odor	*high*	*low*
Cure speed	*high*	*high*
Through cure (pigments)	*poor*	*good*
Chemical resistance	*good*	*very good*




HIGH PRODUCTIVITY
EVOLUTION OF
RADIATION-CURING
TECHNOLOGY
"HIGH
PERFORMANCE"
HIGH GLOSS/
SMOOTH SURFACES
LOW ENERGY
REQUIREMENTS
LOW/NO
SOLVENT
EMISSIONS

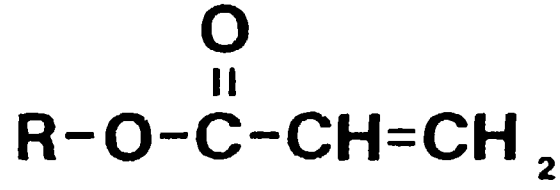
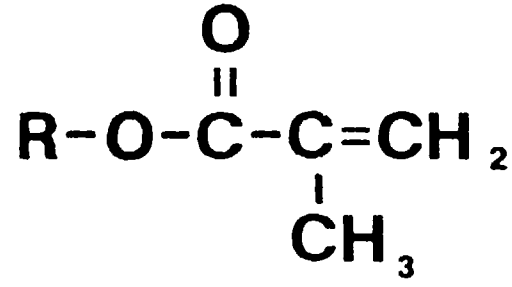
ADVANTAGES

- LOW ENERGY REQUIREMENT
- RAPID THROUGHPUT/HIGH PRODUCTIVITY
- HIGH GLOSS/ULTRA SMOOTH SURFACE
- NO SOLVENT EMISSIONS
- LESS SPACE REQUIREMENTS
- UNIQUE PERFORMANCE -
  ABILITY TO COAT HEAT-SENSITIVE SUBSTRATES

PERCEIVED DISADVANTAGES

- RAW MATERIAL COSTS
- CAPITAL COSTS (EB)
- SKIN AND EYE IRRITATION
- ADHESION PROBLEMS WITH SOME SUBSTRATES
- HANDLING: HIGH RESIN VISCOSITIES
- GLOSS CONTROL

TYPES OF CHEMICAL FUNCTIONALITY

ACRYLATE	
METHACRYLATE	
ALLYL	$R-CH_2-CH=CH_2$
VINYL	$R-CH=CH_2$

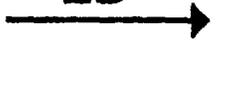
UV CURING

- ACRYLATED RESIN(S)
  BASIC COATING PROPERTIES
- MONOFUNCTIONAL MONOMER(S)
  VISCOSITY REDUCTION, FLEXIBILITY
- MULTIFUNCTIONAL MONOMER(S)
  VISCOSITY REDUCTION, CROSSLINKING
- ADDITIVES
  PERFORMANCE FINE TUNING
- PHOTOINITIATOR PACKAGE
  FREE RADICAL GENERATION

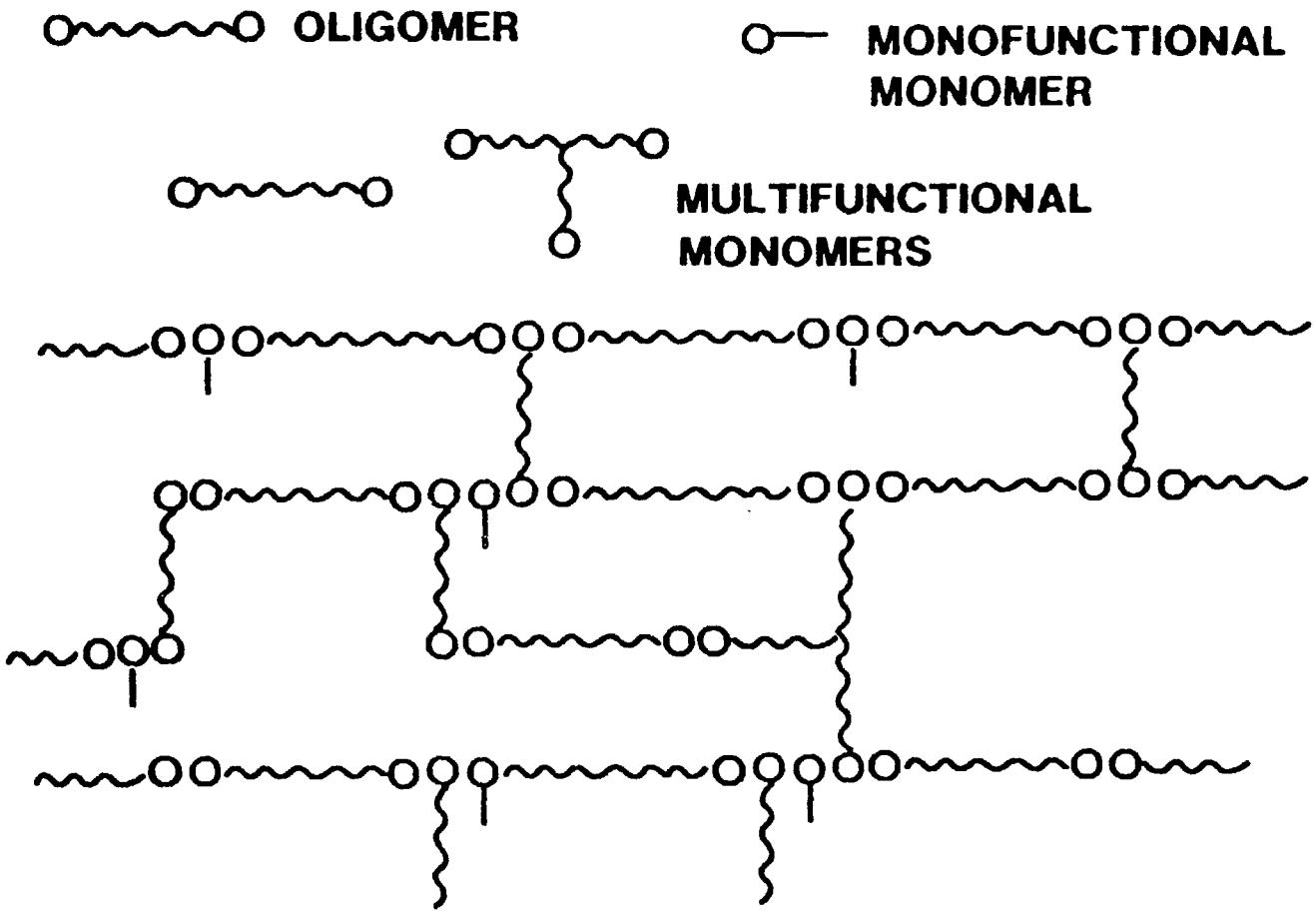
UV LIGHT → CURED PRODUCT

EB CURING

- ACRYLATED RESIN(S)
  BASIC COATING PROPERTIES
- MONOFUNCTIONAL MONOMER(S)
  VISCOSITY REDUCTION, FLEXIBILITY
- MULTIFUNCTIONAL MONOMER(S)
  VISCOSITY REDUCTION, CROSSLINKING
- ADDITIVES
  PERFORMANCE FINE TUNING

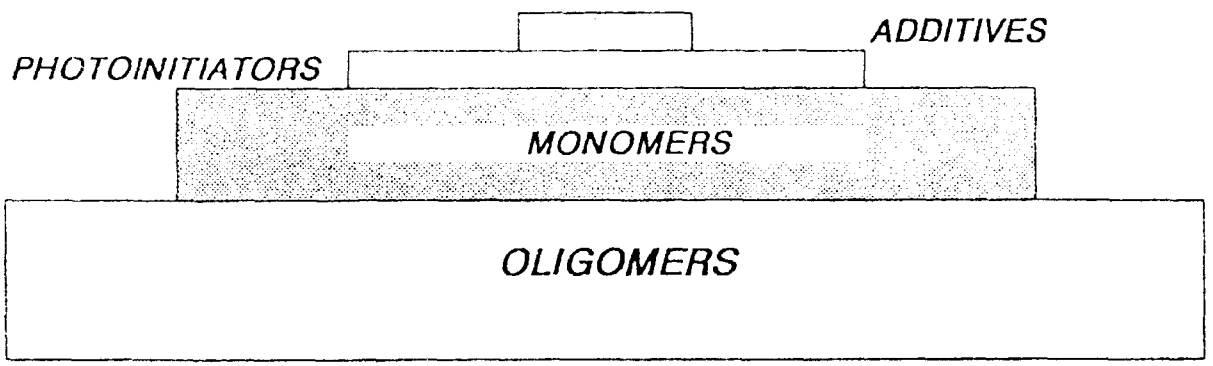


RADIATION CURED POLYMER

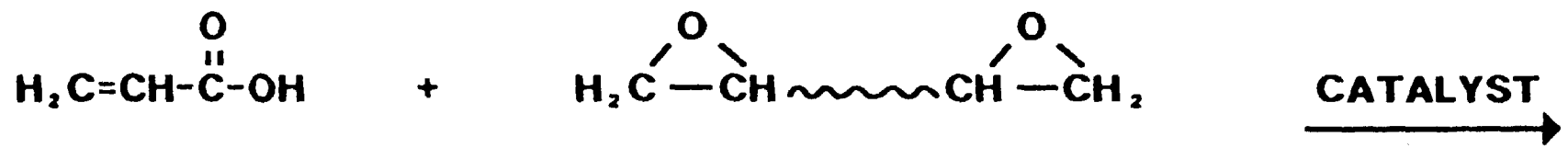


Radcure

FORMULATING A UV - Curable SYSTEM

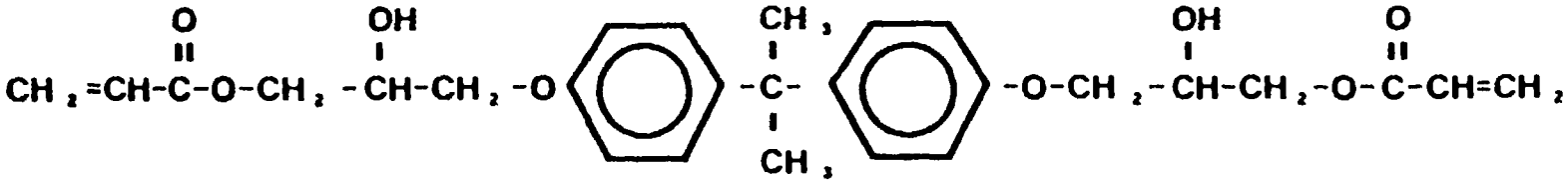


ACRYLATED EPOXY OLIGOMER



ACRYLATED EPOXY OLIGOMER

ACRYLATED EPOXY OLIGOMER
BISPHENOL A BASED



ACRYLATED EPOXY

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ucb Chemicals

UCB s.a. Chemical Sector
Speciality Chemicals Division
Business Unit UCB Radcure
Anderlecht Str. 33
B-1620 Drogenbos (Belgium)
Tel. : (02) 371.46.00
Fax : (02) 378.39.44
Tlx : 22342

Radcure

Ebecryl® 600

Epoxy acrylate oligomer

INTRODUCTION

Ebecryl 600 is the diacrylate ester of bisphenol A epoxy resin. This product is characterized by its light colour and fast cure response. Films of Ebecryl 600 cured by exposure to ultraviolet light (UV) or electron beam (EB) exhibit high surface hardness and gloss, and the excellent solvent resistance typical of an epoxy resin. Ebecryl 600 finds broad use in UV/EB applications, such as inks, coatings, and overprint varnishes.

PERFORMANCE HIGHLIGHTS

Ebecryl 600 is characterized by :
- Light colour
- Fast cure response
- Low irritancy

UV/EB cured products based on Ebecryl 600 are characterized by the following performance properties :
- High surface hardness
- High gloss
- Excellent solvent resistance
- Good water resistance

The actual properties of UV/EB cured products also depend on the selection of the other formulation components, such as reactive diluent(s), additives and photoinitiators.

SUGGESTED APPLICATIONS

Formulated UV/EB curable products containing Ebecryl 600 may be applied by lithographic, screen, gravure, direct or reverse roll, and curtain coating methods. Ebecryl 600 is recommended for use in :
- Overprint varnishes
- Lithographic and screen inks
- Coatings for paper, paperboard, wood chipboard and rigid plastics
- Paper upgrading
- Fast cure coatings
- Laminating adhesives
- Wood sealers and top coats

SPECIFICATIONS

Höppler viscosity at 60°C, mPa.s	2000-4000
Colour, Gardner	2 max.
Acid value, mg KOH/g	2 max.
Draize PII	0.2
Irritation by OECD	0

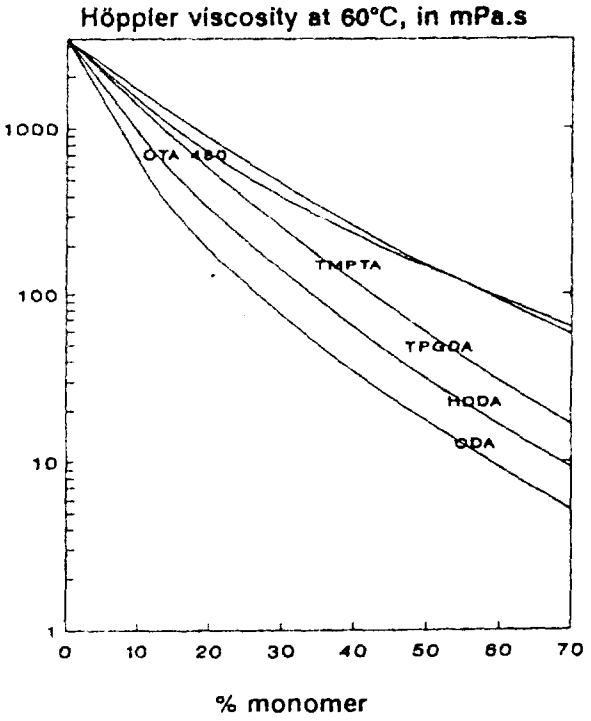
PHYSICAL PROPERTIES

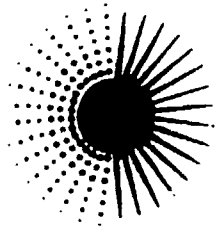
Density, g/cm^3	1.13
Molecular weight, theoretical	500
Functionality, theoretical	2
Polymer solids, % by weight	100

TYPICAL CURED PROPERTIES

Tensile strength, MPa [1]	96
Tensile elongation, % [1]	7
Glass transition temperature, °C	67

The graph shows the viscosity reduction of Ebecryl 600 as a function of the concentration of different monomers.





ACRYLATED URETHANE OLIGOMER

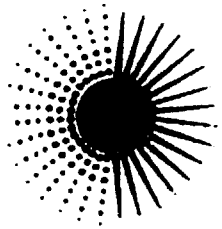
$$H_2C{=}CH{-}R{-}OH \quad + \quad NCO - POLYOL - NCO \xrightarrow[\Delta]{\text{CATALYST}}$$

HYDROXY FUNCTIONAL MONOMER

ISOCYANATE FUNCTIONAL URETHANE PREPOLYMER

$$H_2C{=}CH{-}R{-}O{-}\overset{\overset{O}{\|}}{C}{-}NH{-}POLYOL{-}NH{-}\overset{\overset{O}{\|}}{C}{-}O{-}R{-}CH{=}CH_2$$

ACRYLATED URETHANE OLIGOMER



ACRYLATED URETHANE OLIGOMER

TDI BASED

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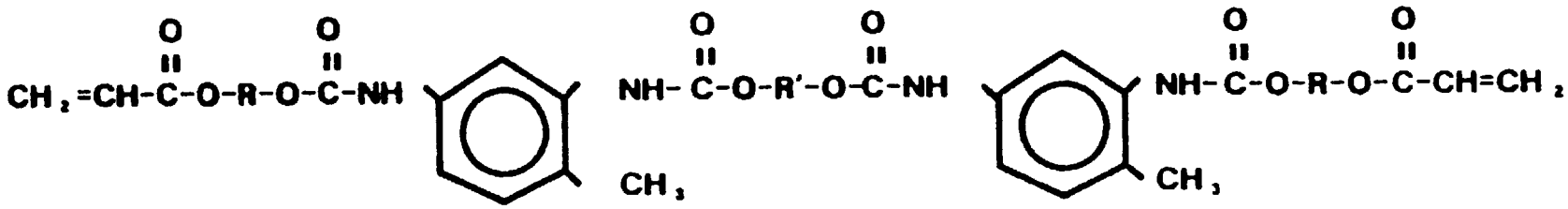

ACRYLATED URETHANE

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ucb Chemicals
UCB s.a. Chemical Sector
Speciality Chemicals Division
Business Unit UCB Radcure
Anderlecht Str. 33
B-1620 Drogenbos (Belgium)
Tel. : (02) 371.46.00
Fax : (02) 378.39.44
Tlx : 22342

Radcure

Ebecryl® 210

Urethane acrylate oligomer

INTRODUCTION

Ebecryl 210 is an aromatic urethane diacrylate oligomer. Films of Ebecryl 210 cured by ultraviolet light (UV) or electron beam (EB) exhibit good flexibility, light colour and good adhesion to various substrates.

PERFORMANCE HIGHLIGHTS

Ebecryl 210 is characterized by :
- Light colour
- Low odour

UV/EB cured products based on Ebecryl 210 are characterized by the following performance properties :
- Adhesion to various surfaces
- Good flexibility

The actual properties of UV/EB cured products also depend on the selection of the other formulation components, such as reactive diluent(s), additives and photo-initiators.

SUGGESTED APPLICATIONS

Formulated UV/EB curable products containing Ebecryl 210 may be applied by lithographic, screen, gravure, direct or reverse roll, and curtain coating methods. Ebecryl 210 is recommended for use in :
- Coatings on rigid and flexible plastics
- Wood coatings
- Screen inks
- Low gloss coatings
- Conformal coatings
- Flexibilizing other UV/EB curable products

SPECIFICATIONS

Höppler viscosity at 60°C, mPa.s	3900
Colour, Gardner	2 max.
Draize PII	2.2
Irritation by OECD	0

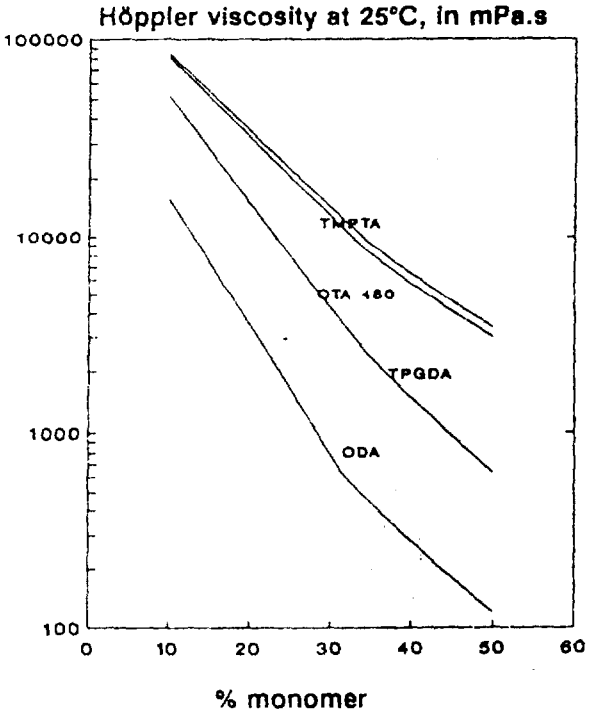
PHYSICAL PROPERTIES

Density, g/cm^3	1.11
Molecular weight, theoretical	1500
Functionality, theoretical	2
Polymer solids, % by weight	100

TYPICAL CURED PROPERTIES

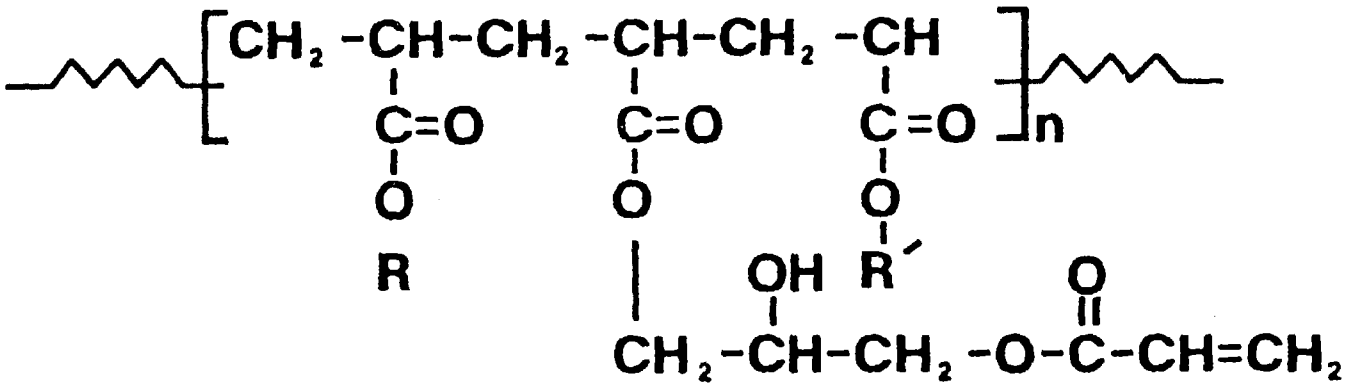
Tensile strength, MPa [1]	5
Tensile elongation, % [1]	26
Glass transition temperature, °C	-6

The graph shows the viscosity reduction of Ebecryl 210 as a function of the concentration of different monomers.



[1] Measured on a 125 µ UV cured film

ACRYLATED ACRYLIC OLIGOMER



ACRYLATED ACRYLIC

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UCB Chemicals
UCB s.a. Chemical Sector
Speciality Chemicals Division
Business Unit UCB Radcure
Anderlecht Str. 33
B-1620 Drogenbos (Belgium)
Tel. : (02) 371.46.00
Fax : (02) 378.39.44
Tlx : 22342

Radcure

Ebecryl® 1701

Full acrylic oligomer

INTRODUCTION

Ebecryl 1701 is an acrylated acrylic copolymer. The product was developed specifically for applications where flexibility and gloss are desired in combination with the other properties as non-yellowing and exterior durability of an acrylic vehicle. It can also be used as an additive to improve flexibility and adhesion.

PERFORMANCE HIGHLIGHTS

Ebecryl 1701 is characterized by :
- Light colour
- Low odour

UV/EB cured products based on Ebecryl 1701 are characterized by the following performance properties :
- High gloss
- Flexibility
- Exterior durability

The actual properties of UV/EB cured products also depend on the selection of the other formulation components, such as reactive diluent(s), additives and photo-initiators.

SUGGESTED APPLICATIONS

Formulated UV/EB curable products containing Ebecryl 1701 may be applied by lithographic, screen, gravure, direct or reverse roll, and curtain coating methods. Ebecryl 1701 is recommended for use in :
- Clear coatings for vinyl, rigid plastics and paper
- Screen ink vehicles
- Top coats for wood
- Metal decorating inks and clear coatings

SPECIFICATIONS

Brookfield viscosity at 65°C, mPa.s	9000-17000
Colour, Gardner	2 max.
Acid value, mg KOH/g	5 max.

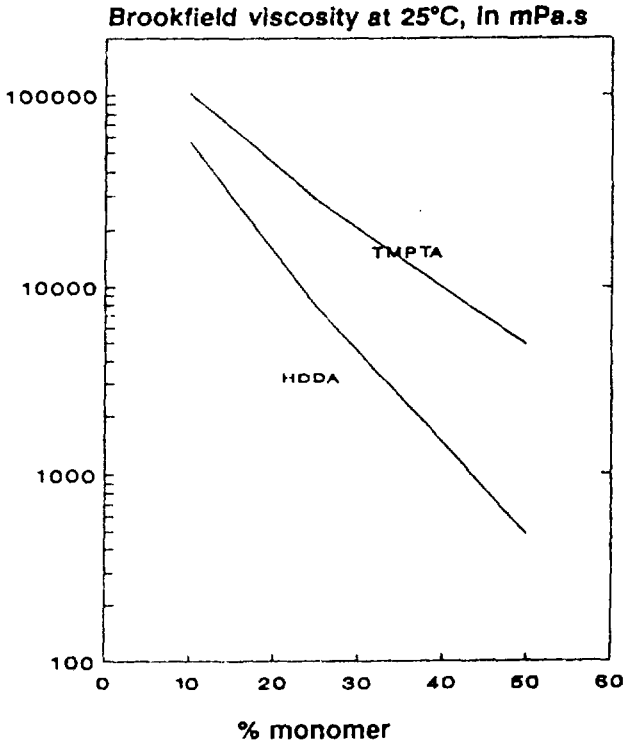
PHYSICAL PROPERTIES

Density, g/cm^3	1.09
Functionality, theoretical	0.12
Polymer solids, % by weight	100

TYPICAL CURED PROPERTIES

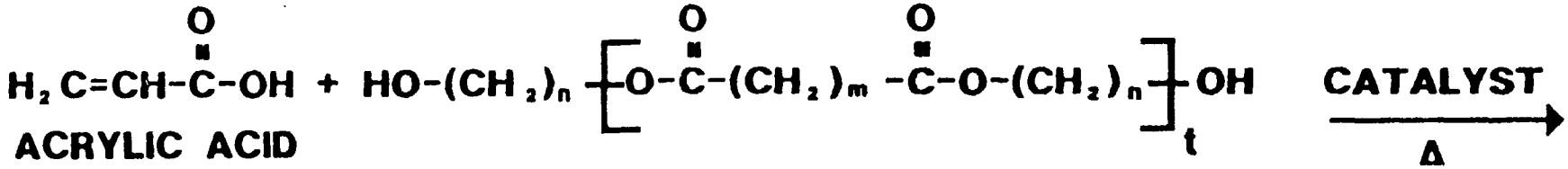
Tensile strength, MPa [1]	5
Tensile elongation, % [1]	17
Glass transition temperature, °C	18

The graph shows the viscosity reduction of Ebecryl 1701 as a function of the concentration of different monomers.

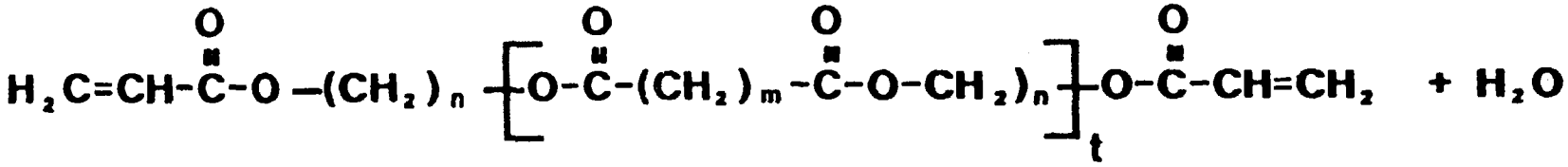


[1] Measured on a 125 µ UV cured film

ACRYLATED POLYESTER OLIGOMER



HYDROXY FUNCTIONAL POLYESTER PREPOLYMER



ACRYLATED POLYESTER OLIGOMER

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ucb Chemicals
UCB s.a. Chemical Sector
Speciality Chemicals Division
Business Unit UCB Radcure
Anderlecht Str. 33
B-1620 Drogenbos (Belgium)
Tel. : (02) 371.46.00
Fax : (02) 378.39.44
Tlx : 22342

Radcure

Ebecryl® 830

Polyester acrylate oligomer

INTRODUCTION

Ebecryl 830 is a 100% solids hexafunctional polyester acrylate oligomer. When cured by ultraviolet light (UV) or electron beam (EB), films of Ebecryl 830 exhibit high abrasion resistance, solvent resistance and hardness. This resin was developed for coatings and inks on wood, paper and plastics.

PERFORMANCE HIGHLIGHTS

Ebecryl 830 is characterized by :
- Light colour
- Fast curing
- Low odour

UV/EB cured products based on Ebecryl 830 are characterized by the following performance properties :
- High abrasion resistance
- Good hardness
- Good solvent resistance

The actual properties of UV/EB cured products also depend on the selection of the other formulation components, such as reactive diluent(s), additives and photo-initiators.

SUGGESTED APPLICATIONS

Formulated UV/EB curable products containing Ebecryl 830 may be applied by lithographic, screen, gravure, direct or reverse roll, and curtain coating methods. Ebecryl 830 is recommended for use in :
- Coatings for paper, wood and plastics
- Paper upgrading
- Scratch and solvent resistant coatings
- Dry lithographic inks
- Fast curing coatings and inks

SPECIFICATIONS

Höppler viscosity at 25°C, mPa.s	45000-55000
Colour, Gardner	3 max.
Acid value, mg KOH/g	30 max.
Draize PII	1.7

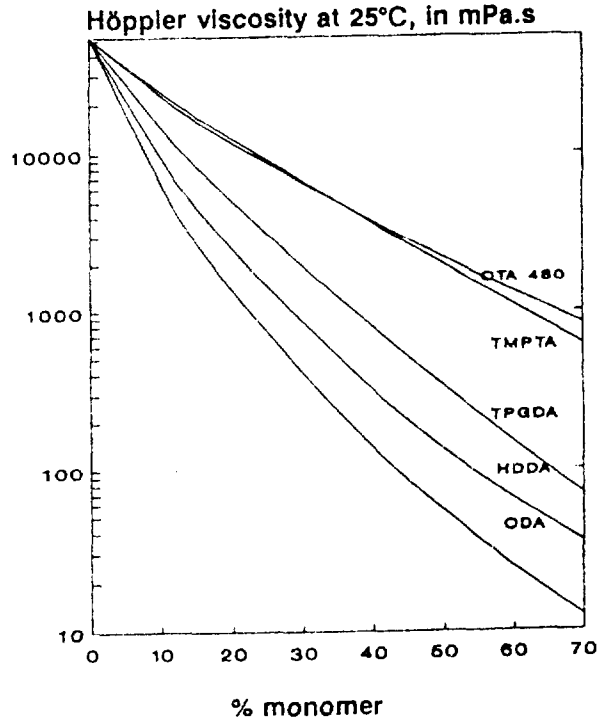
PHYSICAL PROPERTIES

Density, g/cm^3	1.18
Molecular weight, theoretical	1500
Functionality, theoretical	6
Polymer solids, % by weight	100

TYPICAL CURED PROPERTIES

Tensile strength, MPa [1]	77
Tensile elongation, % [1]	4
Glass transition temperature, °C	n.a.

The graph shows the viscosity reduction of Ebecryl 830 as a function of the concentration of different monomers.



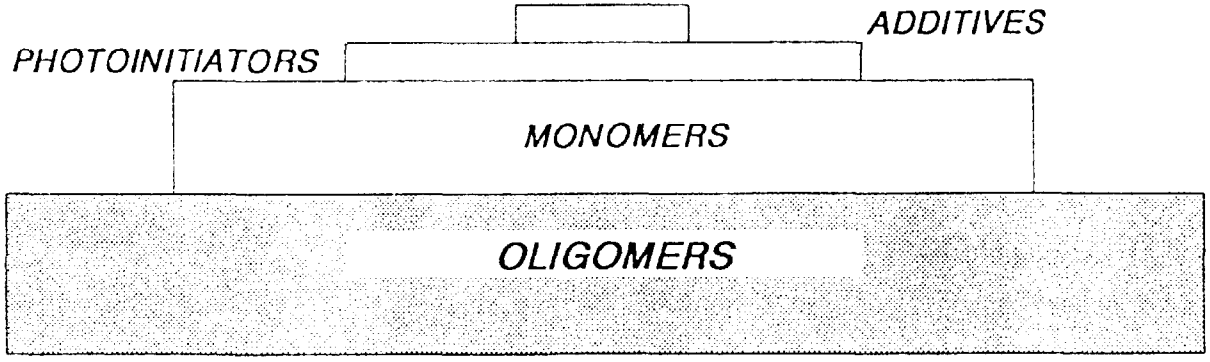
[1] Measured on a 125 µ UV cured film

OLIGOMER SELECTION

ACRYLATED...	
EPOXIES	HARD, SOLVENT RESISTANT, LOWER COST, FAST CURE
ALIPHATIC URETHANES	FLEXIBLE, TOUGH, NON-YELLOWING
AROMATIC URETHANES	FLEXIBLE, LOW VISCOSITY
ACRYLICS	GOOD WEATHERING PROPERTIES, LOW Tg
POLYESTERS	LOW VISCOSITY, FLEXIBLE
AMINES	ACCELERATE CURE, PROMOTE ADHESION

Radcure

FORMULATING A UV - Curable SYSTEM



MONOFUNCTIONAL MONOMERS

2-(2-ETHOXYETHOXY)ETHYL ACRYLATE (EOEOEA)

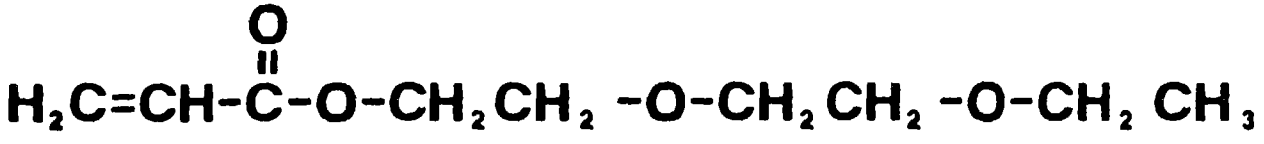
ISOBORNYL ACRYLATE (IBOA)

OCTYL/DECYL ACRYLATE (ODA)

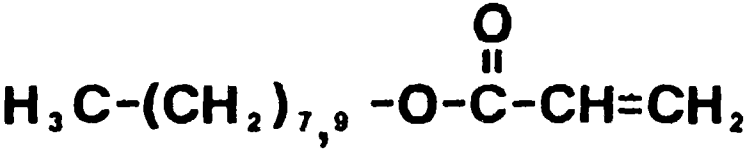
N-VINYL-2-PYRROLIDONE (N-VP)

TETRAHYDROFURFURYL ACRYLATE (THFFA)

MONOFUNCTIONAL MONOMERS



2-(2-ETHOXYETHOXY)ETHYL ACRYLATE



OCTYL/DECYL ACRYLATE

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MONOFUNCTIONAL MONOMER EFFECTS
70/30 ACRYLATED EPOXY/MONOMER BLENDS

	VISCOSITY (CPS)	CURE SPEED (FPMPDL)
STYRENE	1000	12.5
2-ETHYLHEXYL ACRYLATE	1180	60
OCTYL/DECYL ACRYLATE	1204	60
N-VINYL-2-PYRROLIDONE	1400	75
2-PHENOXYETHYL ACRYLATE	5000	110
ISOBORNYL ACRYLATE	13000	75
B-CARBOXYETHYL ACRYLATE	22000	150

MULTIFUNCTIONAL MONOMERS

TRIPROPYLENEGLYCOL DIACRYLATE (TRPGDA)

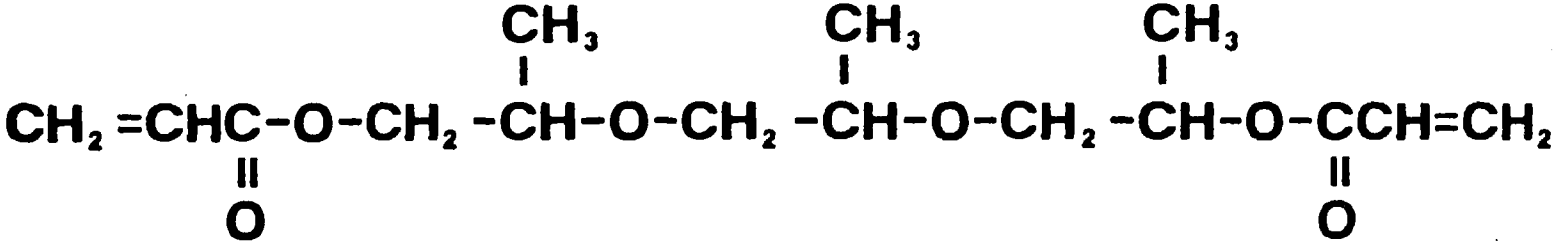
TRIMETHYLOLPROPANE TRIACRYLATE (TMPTA)

TRIMETHYLOLPROPANE TRIMETHACRYLATE (TMPTMA)

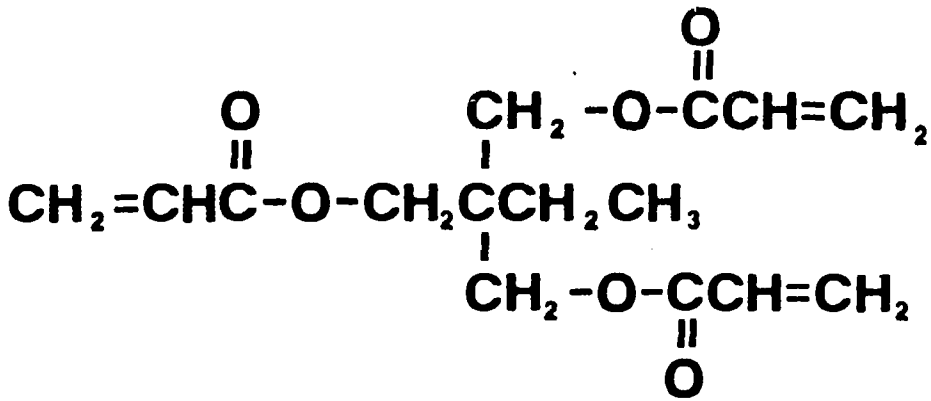
DIFUNCTIONAL MONOMER EFFECTS
70/30 ACRYLATED EPOXY/MONOMER BLENDS

	VISCOSITY (CPS)	CURE SPEED (FPMPDL)
1,6-HEXANEDIOL DIACRYLATE	2088	200
POLYBUTADIENE DIACRYLATE	2300	110
THIODIETHYLENEGLYCOL DIACRYLATE	3200	175
TETRAETHYLENEGLYCOL DIACRYLATE	4050	125
TRIPROPYLENEGLYCOL DIACRYLATE	7550	100

MULTIFUNCTIONAL MONOMERS



TRIPROPYLENE GLYCOL DIACRYLATE



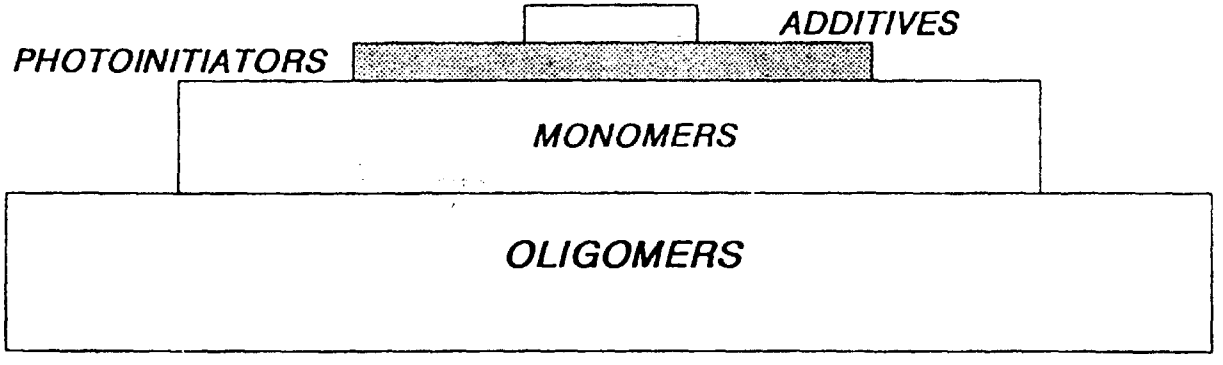
TRIMETHYLOLPROPANE TRIACRYLATE

TRIFUNCTIONAL MONOMER EFFECTS
70/30 ACRYLATED EPOXY/MONOMER BLENDS

	VISCOSITY (CPS)	CURE SPEED (FPMPDL)
TRIMETHYLOLPROPANE TRIMETHACRYLATE	10400	15
PENTAERYTHRITOL TRIACRYLATE	25000	110
TRIMETHYLOLPROPANE TRIACRYLATE	25400	200
GLYCERYLPROPOXY TRIACRYLATE	46250	125

Radcure

FORMULATING A UV - Curable SYSTEM



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PHOTOINITIATORS

- ABSORB LIGHT
- GENERATE FREE RADICALS
- INITIATE POLYMERIZATION

BASIC PHOTOCHEMICAL DEFINITIONS
(Photocleavage)

PHOTOINITIATOR

Absorbs light and is directly involved in the production of radicals which initiate polymerization

BASIC PHOTOCHEMICAL DEFINITIONS
(Photoabstraction)

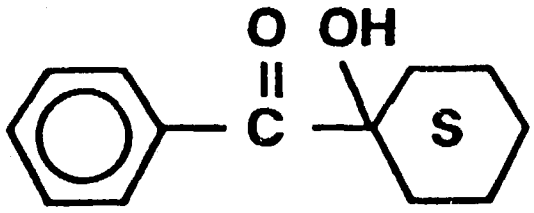
PHOTOSENSITIZER

Absorbs light and transfers energy to another molecule (co-initiator) which actually produces initiator radicals

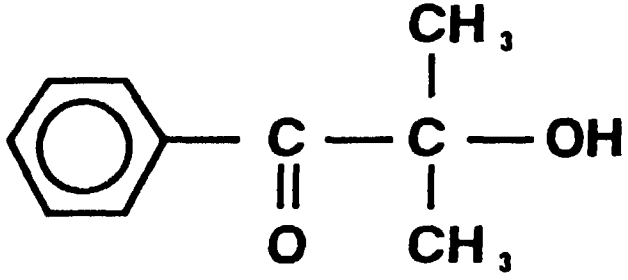
CO-INITIATOR (PHOTOACTIVATOR)

Does not absorb light but is dire ctly involved in the production of radicals which initiate polymerization

COMMON PHOTOINITIATORS
(Photocleavage)

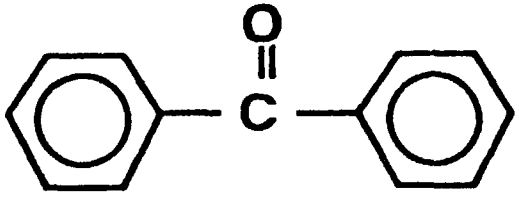


Irgacure ® 184

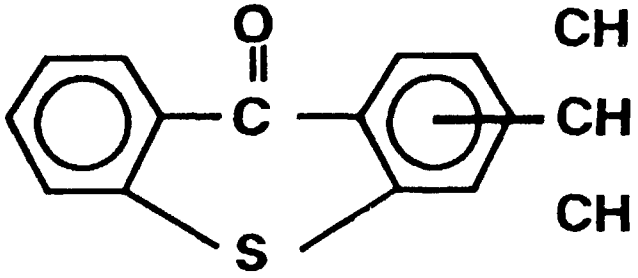


Darocur ® 1173

COMMON PHOTOSENSITIZERS (PHOTOABSTRACTION)

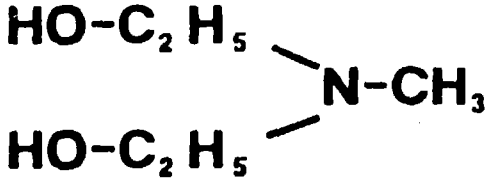


BENZOPHENONE

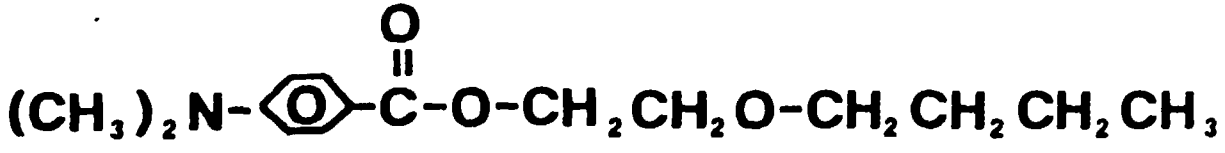


QUANTACURE® ITX

COMMON CO-INITIATORS
(Photoabstraction)



Methyldiethanol Amine



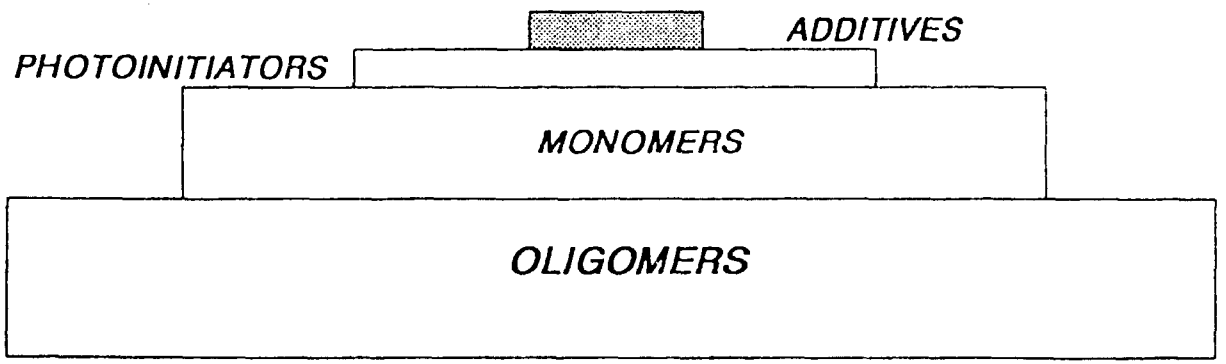
Quantacure ® BEA

PHOTOINITIATOR SELECTION

- ABSORPTION CHARACTERISTICS OF PHOTOINITIATOR AND FORMULATED SYSTEM
- FILM THICKNESS REQUIRED
- PIGMENTATION REQUIREMENTS
- DEPTH OF CURE REQUIREMENTS
- UV EQUIPMENT AVAILABLE
- POTENTIAL FOR CHEMICAL INTERFERENCE
- WEATHERABILITY
- LIQUID VS. SOLID (HANDLING)
- TOXICITY
- COST

Radcure

FORMULATING A UV - Curable SYSTEM



ADDITIVES FOR UV/EB CURABLE SYSTEMS

- PIGMENTS
- FILLERS
- DEFOAMERS
- FLATTING AGENTS
- WETTING AGENTS
- SLIP AIDS

Radcure

TOXICITY AND IRRITANCY OF ACRYLATED BINDERS

IRRITATION INDEX OF RADIATION CURE ACRYLATED PRODUCTS

PRODUCT	DRAIZE METHOD	OECD METHOD
HDDA	5	2-2,4
TMPTA	3,7	0,9-1,8
TPGDA	3,0	0
OTA 480	1,5	0
UV P 115	2,2	-
Eb 600	0,2	-
Eb 860	0,4	-
Eb 810	1,3	0
Eb 870	0,6	-
White spirit	> 6	

0 = no irritant
0-2 = slightly irritant
2-5 = moderately irritant
5-8 = severely irritant

Radcure

TOXICITY AND IRRITANCY OF ACRYLATED BINDERS

TOXICITY

Defined by lethal doses LD 50 - oral
- by skin absorption

LD 50 oral (rats)

5000 mg/kg rat	NON TOXIC
50 mg - 5000 mg/kg	TOXIC
< 50 mg/kg	VERY TOXIC

LD 50 dermal (rabbits)

> 2000 mg/kg rabbit	NON TOXIC
200 mg - 2000 mg	TOXIC
< 200 mg/kg	VERY TOXIC

		ORAL LD 50 (g/kg)	DERMAL LD 50 (g/kg)
HDDA	MONOMER	5.0	3.0
TMPTA	MONOMER	5.2	6.3
TPGDA	MONOMER	6.8	-
OTA 480		10.0	5.0
UV.P 115		> 5	
EB 600		11.5	
EB 860		20	16
EB 810		> 5	
EB 870		> 5	
EB 220		> 5	
EB 280		> 5	
Propanol		3.7	
MEK		4.3	
ASPIRINE		1.7	
NaCl		3.7	

RADIOPOLYMERIZATION

CURING BY POLYMERIZATION , INITIATED BY UV-LIGHT or EB

3 E ADVANTAGES

* ECONOMY
  - HIGH PRODUCTIVITY
  - LOW INVESTMENT COST
  - RAW MATERIALS
  - MAN POWER

* ENERGY
  - NEED FOR ENERGY WHICH INITIATES THE POLYMERIZATION
  - NO NEED FOR TEMPERATURE INCREASE or IR

* ECOLOGY
  - NO POLLUTION (Solvent free)
  - NO CO_2 EMISSION

OTHERS

- IMPROVEMENT OF FINAL PROPERTIES
- CHEMICAL RESISTANCE
- GLOSS CONTROL
- EXTERIOR DURABILITY
- IMPROVED FLEXIBILITY

Radcure

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#5

UV/EB CURING OF COATINGS OF WOOD BASED SUBSTRATES

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UV/EB Curing of Coating of Wood Substrate

MASAO KAWAZOE
CHUGOKU MARINE PAINTS,LTD.
YASU-CHO,SHIGA,520-23. JAPAN

Radiation curing has found many applications in recent years, due to the advantages, mainly high curing speed and good film performances.
The use of UV curing started commercially 20 years ago, but it's in the last 10 years that the application for wood coating was increased in Japan.
Big market of UV wood coating is plywood for flooring. Many manufacturers of plywood in Japan changed conventional coating lines into UV coating lines in this decade.
In the future, 3-dimensional UV coatings for wood substrate, such as joineries, will be common by introducing of vacuum coating.
On the contrary, EB curing for wood substrates is uncommon in Japan.

1. UV Coating

The UV curable coating is mainly made of resin, monomer and photoinitiator.

Resin	: 100 % solid low molecular weight oligomer.
Monomer	: High boiling point reactive diluent which reduce viscosity.
Photoinitiator	: This chemical absorbs the radiation energy and produces reactive species that initiate polymerization of resin and monomers. Photoinitiator is not required in EB curing.

Formulations commonly contain other components such as : fillers, additives, flatting agents.
Fig 1, 2[1] shows the composition of UV coating and the reaction of UV/EB curing schematically.

2. Comparison of Curing Method

One of the advantages of radiation curing is solvent-free.
Conventional coatings are produced by mixing components with a solvent, and this solvent must be evaporated to cure the coating by thermal-heating devices. On the other hand, UV/EB formulations are 100 % solid system, with avoidance of solvent emission and reduction of air pollution.
Although UV/EB coating may cost more than twice compared with conventional coating, costs on a solid basis are usually comparable.
Table 1. shows the comparison of curing methods.

3. Wood Coating

UV coatings are commoly accepted as an efficient and economical method for wood industry in Japan.

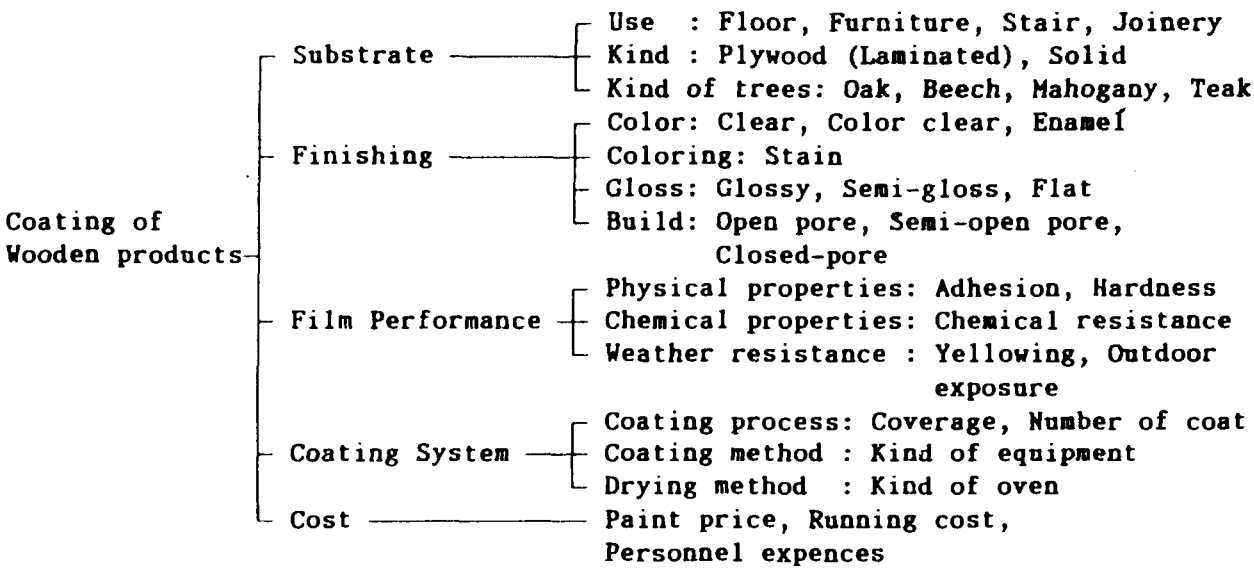
UV systems used for wood coating are based on unsaturated polyesters or acrylic resins. Although acrylic UV coatings provide excellent properties and faster curing speed, they are more expensive than unsaturated polyesters.

Characteristic of unsaturated polyesters and acrylics is shown in Tabe 2.

UV coatings are applied on wood substrates by such coating method :

- Roll Coat (Natural, Reverse)
- Curtain Coat
- Spray
- Vacuum Coat

Coating design for wooden products is shown below.



Sales volume of UV coatings in Japan is shown in Table 3[2].

4. UV Coating System for Color Flooring in Japan

One of the biggest market of wood coating is flooring.

During the last 10 years, greet progress has been achieved in this field by UV curable systems; due to high curing speed, 100 % solid and good film performances.

Finally, a typical UV coating system of color flooring in Japan is shown in Table 4[3].

REFERENCES

1) SASAKI,T., TE2. Radiation Processing of Polymers.
2) YAMAGUCHI,I., Data from Fuji Merchandising Center.
3) YAMAKAWA,M., Toso Gijutsu, November 1991, 83-86.

FIG.1 Composition of UV Curable Coatings

Oligomer

Monomer

Photoinitiator
(Not required in EB)

Fillers, Additives, Flatting Agents

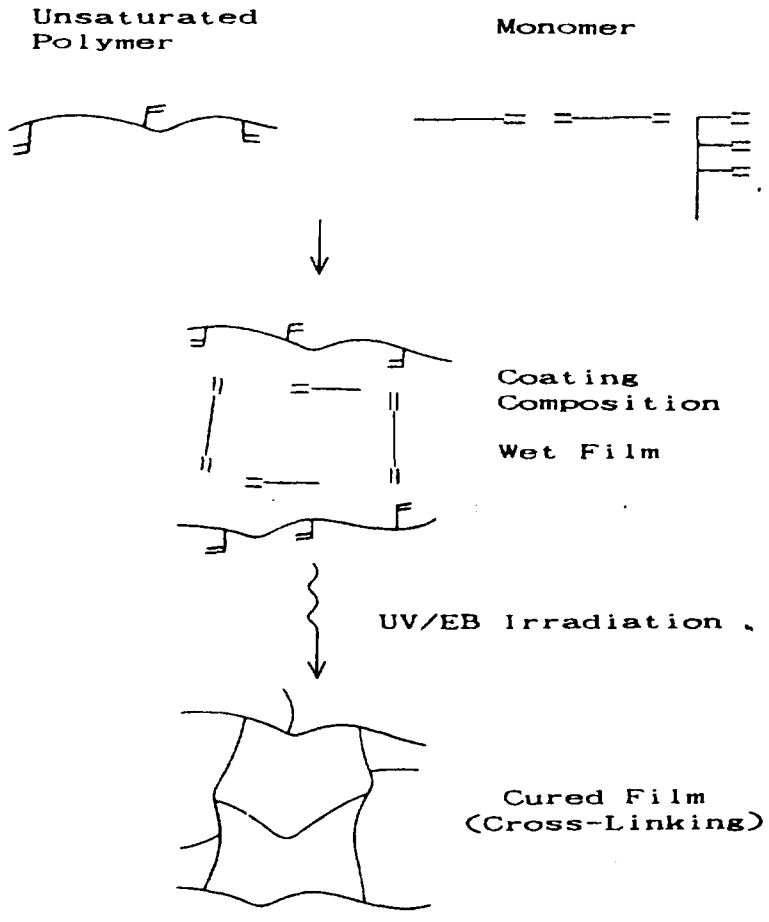


FIG.2 Schematic Diagram of UV/EB Curing

Table 1. Comparison of Curing Methods

Items	UV Curing	EB Curing	Baking (Conventional)
Initial cost for installation	Low	High	Middle
Length of oven (meter)	5	3	30 - 100
On-Off operation	Possible	Possible	Impossible
Special atmosphere	Not necessary	Necessary	Not necessary
Curing time	Several seconds	Less than 1 seconds	Several minutes-several ten minutes
Compatibility to non-heat-resistant substrates	OK	OK	No
Pigmentation	Limited	OK	OK
Catalizer	Necessary	Not necessary	Both necessary & not necessary
Solid content (%)	100	100	35 - 65
Thinning ratio (%)	0 - 30	0	35 - 65
Precautions for worker's health	UV rays Ozone	X rays Ozone	Heat Evaporated solvents
Cost for enviromental problems	Low	Low	High

Table 2. Characteristics of Oligomer

Oligomer	Structure of Oligomer	Characteristic
Unsaturated Polyester	—(C=C-C-O-C=C)— ‖ O	Low-price, Slow curing speed
Urethane Acrylate	C=C-(N-C)-C=C | ‖ H O	High-price, Flexibility
Epoxy Acrylate	C=C-(C-C-O-Ph-C-Ph)-C=C | OH	Chemical resistance Rapid cure
Polyester Acrylate	C=C-(C-O)— C=C ‖ O	Stain resistance Low viscosity

Table 3. Sales Volume of UV Coating in Japan

(tons)

	1988	1989	1990	1991
Hard Coating	600	720	860	1,030
Wood Coating	1,600	2,100	2,700	3,500
PVC Flooring	700	750	830	950
Metal Coating	255	270	280	290
Plastic Film	90	100	110	120
Total	3,245	3,940	4,780	5,890

Table 4. UV Coating System of Color Flooring

Process	Paint(CMP)		Coating Equipment	Coverage (g/ft^2)	Curing (30m/min)
1. Staining	STAIN N		S-R-N Roll Coater	1~2	80℃×90sec
2. Sealer	AULEX NO.800S		N Roll Coater	1	UV 3 lamps
3. Undercoat	AULEX NO.630	100	N-N Roll Coater	2	UV 6 lamps
	WA-500	20			
	GC-500	5			
4. Sanding	-		Wide Belt Sander	-	-
5. Topcoat	① AULEX NO.630		N-N Roll Coater	1.5	UV 8 lamps
	② AULEX NO.655		Curtain Coater	6	80℃×90sec UV 6 lamps
	③ MARBLAC OL		Curtain Coater	6	60℃×15min

WA-500,GC-500: Abrasive. S: Sponge. N: Natural. R: Reverse

MARBLAC: Acid curing amino-alkyd resin paint.