CYTEC

Surface Specialties

Evaluation of resins in UV OFFSET inks

EBECRYL® resins

and ADDITOL® additives

for Graphic Arts

Cytec Industries Inc.

Cytec Industries is a specialty chemicals and materials technology company with sales of $ 3 billion. Its growth strategies are based on developing technologically advanced customer solutions for global markets including: aerospace, coatings, mining, plastics and water treatment.

Cytec Surface Specialties

Cytec Surface Specialties manufactures and markets a broad range of technically innovative products for applications in key coating markets such as industrial, graphic arts, wood and paper, adhesives and opto-electronics.

A leader in environmentally-friendly coatings technologies, we are a total solution provider – offering an extensive range of high-performance products, supported by a deep level of technical expertise.

Product Range

Cytec Surface Specialties offers a comprehensive product range, including many world-class technologies that have earned leading positions in their target markets. These are divided into three main groups:

- Liquid Coating Resins.
- RADCURE® and Powder Resins.
- Adhesives, Bonding and Formulation Resins.

Cytec Surface Specialties leads in:

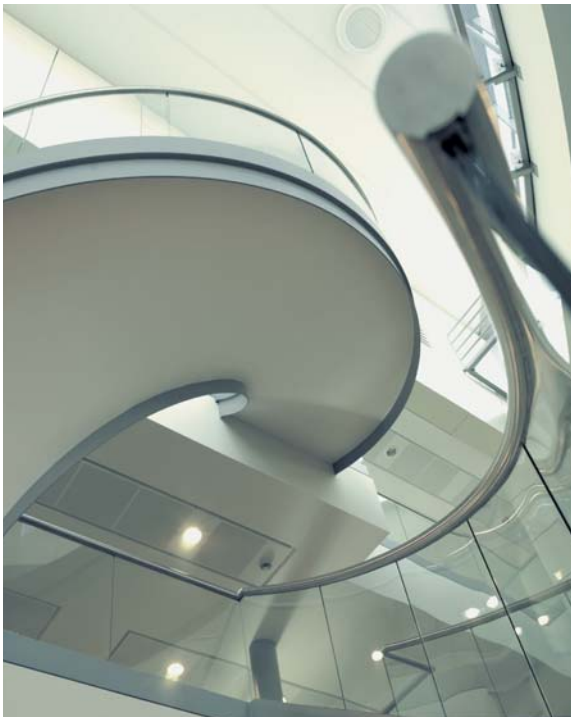
- UV/EB curable systems.
- Powder coating resins.
- Waterborne alkyds.
- Waterborne epoxies.
- Waterborne resin systems in primer base coat for automotive OEMs.

Global Presence

Headquartered in Brussels (Belgium), **Cytec Surface Specialties** operates ISO-certified manufacturing facilities.

Our ten technology centers – located in Europe, Asia and North America – offer customers ready access to world-class technical support and applications research.

We also have sales offices in more than 30 countries, enabling us to provide responsive service around the globe, and to help our customers identify and profit from emerging opportunities.



Provider of innovative solutions to the graphics industry

We are committed to consolidating our leadership position as the preferred supplier to the global energy-curable graphics industry. We shall continue to deliver added value to our customers through innovative market-driven solutions based on technological and operational excellence.

To fulfill our objective of delivering superior value to our customers, we have a dedicated technical service team investigating inks and varnishes requirements for all printing processes. Based on this, we have designed a full range of UV/EB vehicles, binders and resins that address the most stringent needs of the energy-curing graphics market.

With numerous plants, research and technical service centres around the world, we are in a strong position to satisfy the multidimensional requirements of our customers with unrivalled world-class levels of service.

Introduction to UV Offset

Products for UV Offset inks

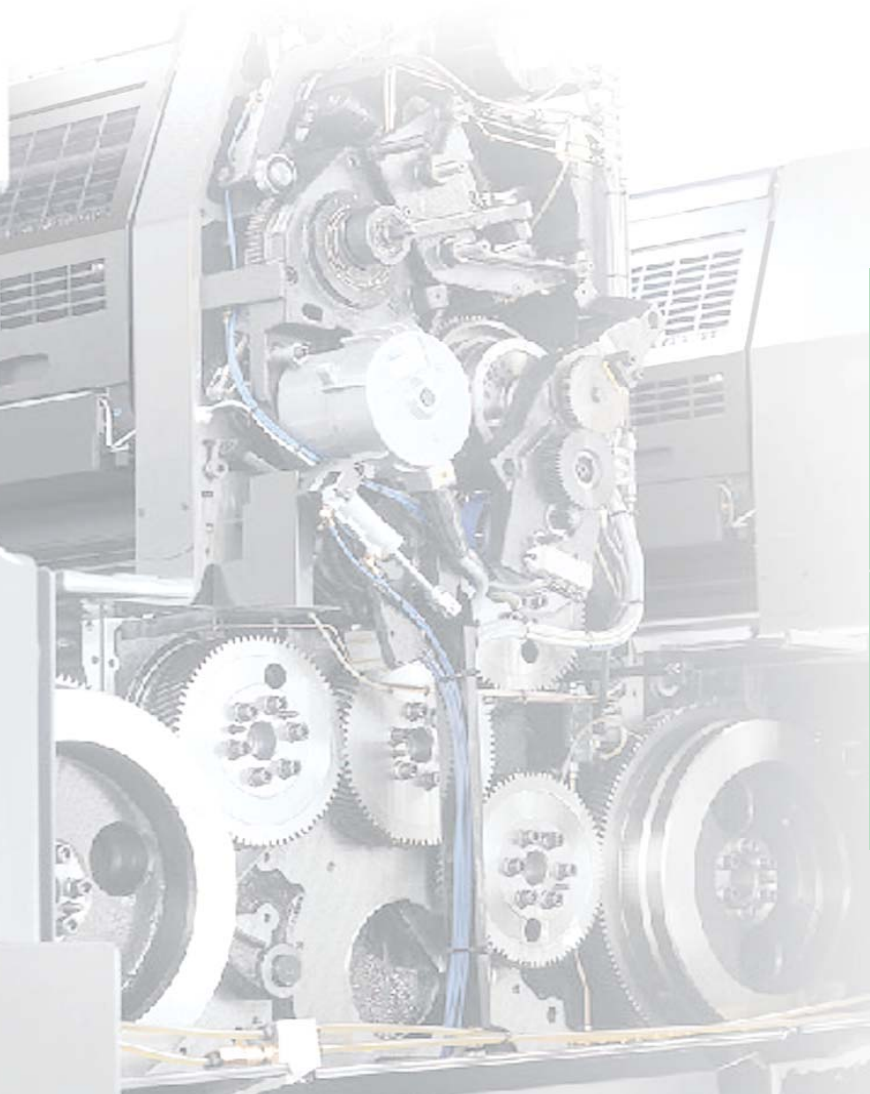
Standard ink formulations for evaluations of binders for UV Offset inks

4 Introduction to UV Offset

General principles of the lithographic process

Lithography is a planographic process, in that the ink-carrying image is in the same plane as the non-image areas. On the plate, areas of different surface energy are created by chemical treatment. This process leads to the formation of image areas that are ink accepting and water repellent, and non-image areas that are water accepting.

Usually, the plate is damped before it is inked. The fountain solution - consisting of water, buffer salts, surface active agents, and other additives and possibly isopropanol - forms a film on the non-image areas (water accepting), but contracts into tiny droplets on the image areas (water-repellent).(See Fig.1).



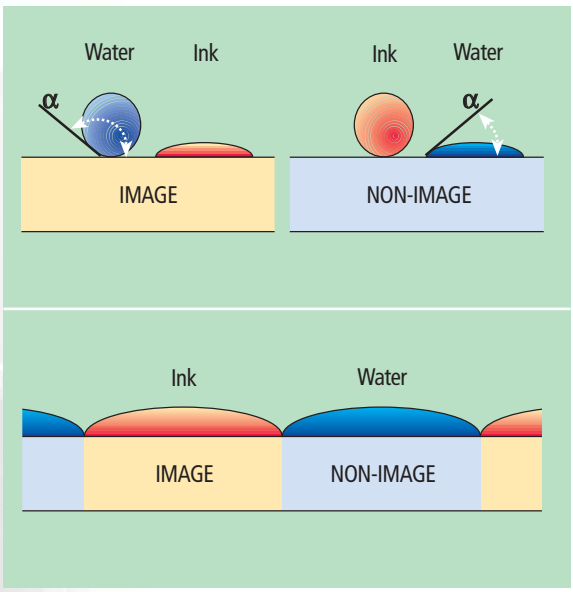
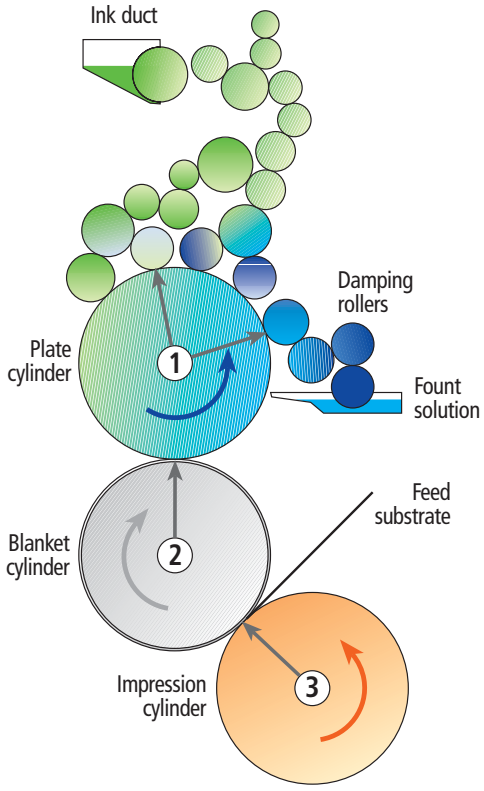


Fig. 1: Lithographic principle.



When an inked roller passes over the damped plate, the water film on the non-image areas prevents these being inked up and pushes the ink towards the image areas. The water droplets present on the image areas are either removed or emulsified into the ink. If the ink is too water repellent and this emulsification does not take place, an uneven "mottled" print will result. Emulsifcation of too much water in the ink may lead to a loss of transfer and hence a loss of optical density of the print.

A proper "water window" is necessary to be able to print with varying levels of fountain solution emulsified. It is important that when water is emulsified in the ink, the ink rheology undergoes a minor change. This is necessary to obtain a constant ink transfer and thus stable press behaviour.

To print correctly in lithography, the right balance between ink and fountain solution must be achieved, thus comes the term "ink water balance".

The process is called offset lithography because the ink is not transferred directly from the plate to the substrate, but is first "offset" onto a rubber blanket cylinder and is then transferred to the substrate.

The offset lithographic process dominates the graphic industry in a wide range of formats: from single colour A4 sheets (Sheet-fed printing, see Fig. 2), to printing magazines and newspapers on a continuous web of paper (web offset). This process is particularly suited to the production of lightweight packaging, books, magazines, newspapers, brochures, maps, promotional posters and literature, business stationery, to name some examples.

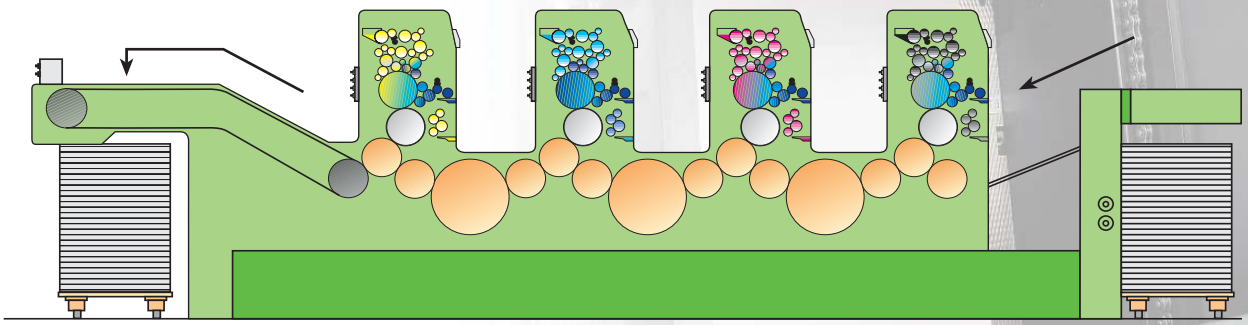


Fig. 2: Schematic presentation of a Sheet-fed Offset printing machine.

Introduction to UV Offset

Types of Offset lithographic inks:

Offset lithographic inks are often characterised according their drying method:
- Absorption: cold-set inks (eg. newspaper inks).
- Evaporation: heat-set inks.
- Oxidation: conventional sheet-fed inks.
- Radiation curing (UV/EB).

UV Offset inks are used in sheet-fed and web-fed applications. The setting and the drying of the ink occur in approximately 0,1 second by transforming the wet binder into an insoluble dry ink film through a polymerisation reaction.
The polymerisation is induced by UV light (or electron beam).

UV inks mainly consist of:
- Acrylated resins (oligomers): basic coating properties.
- Monomers (di- to hexa acrylates): viscosity reduction, flexibility (monofunctional); crosslinking (multifunctional).
- Pigments and fillers.
- Additives: performance fine tuning.
- Photoinitiator package: free radical generation to initiate polymerisation.

Typical properties of UV Offset inks:

- Immediate drying (surface and in-depth).
- On-line processing.
- No spray powder needed in sheet-fed offset.
- Increased productivity.
- No solvents used.
- No drying of ink on the printing press (less cleaning).
- Low energy level required (vs heat drying).
- Ability to print on a wide variety of substrates with the same ink.
- Printing on heat-sensitive substrates.
- Reduced space required (vs heat drying).
- High gloss.
- High chemical resistance.

Offset ink parameters and test methods

Ink parameters

Inks used for the lithographic industry must fulfil a number of requirements:
- Suitable viscosity (expressed in Pa.s or poise).
- Low shortness index.
- Low tack (at 350 m/min – 30 °C).
- Low misting (at 350 m/min – 50 °C).
- High strength / mileage (density ~ g/m^2 ink).
- High gloss.
- Good ink-water balance.
- Good reactivity.

During the last decades, a number of methods have been developed to evaluate properties of wet inks and printed (dried) inks. We have chosen the following laboratory methods to assess the above characteristics.

Test methods used at Cytec Surface Specialties:

a) Viscosity:

- **Measuring equipment:**
  Physica MCR 100 viscosimeter.
- **Measurements:**
  - Flowcurve / viscosity curve (viscosity expressed in Pa.s at 25°C),
  - Shortness index (see Fig. 4),
  - Recovery of ink structure in time,
  - Visco-elasticity.

Fig. 3: Physica Viscosimeter.

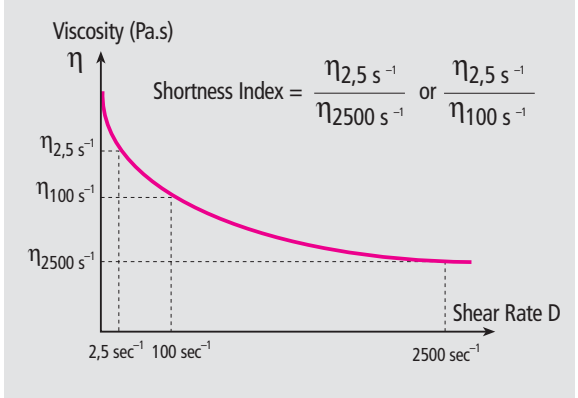


Fig. 4: Viscosity curve.

b) Tack - measuring equipment:

- **Definition:**
  The tack is the force required to split an ink film between two rollers. The more tacky the ink is, the higher the force pulling the rider roller. Tack is given in arbitrary units, which depend on the instrument and the method used.
- **Measuring equipment:**
  Tack-O-Scope measuring equipement(Testprint).
- **Method:**
  - 0.3 cc ink,
  - Temperature = 30°C,
  - Speed: 50 m/min. up to 350 m/min.

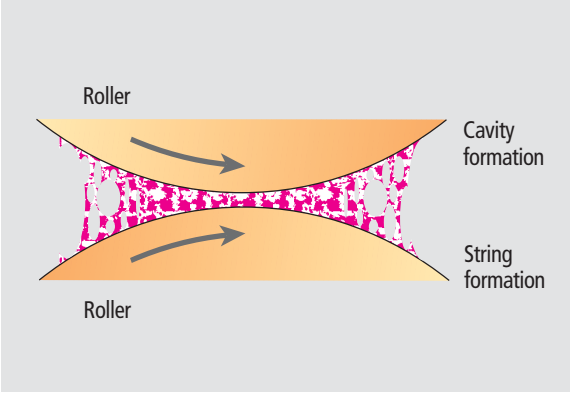


Fig. 5: Ink film splitting.

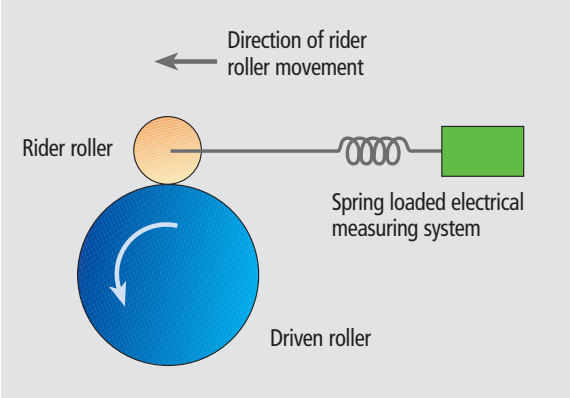


Fig. 6: Tack measuring principle.

Test methods used at Cytec Surface Specialties (continued):

c) Misting:

- **Measuring equipment:**
  Tack-O-Scope.
- **Method:**
  - Temperature is set at 50°C.
  - 1 cc ink is applied to ink rollers and distributed for 30 seconds at 50 m/min.
  - A white paper is placed under and over the rollers to collect ejected ink particles.
  - Inks are subjected to a speed of 350 m/min for 1 min.
  - Misting is expressed as average optical density (3 points measurement): higher optical density means more misting.

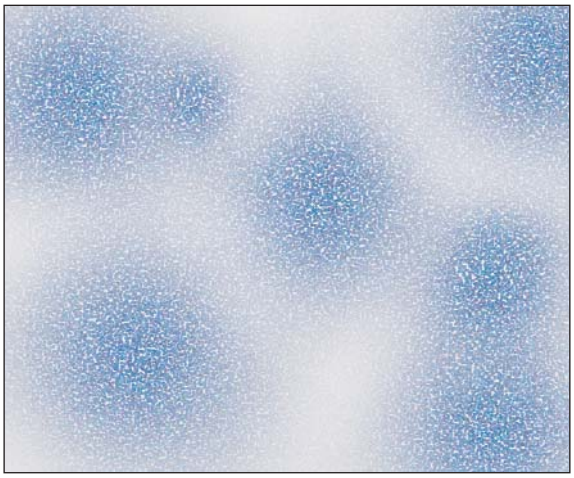


Fig. 7: Example of misting result.

d) Mileage (ink consumption) and gloss:

- **Substrate:**
  Silico Ultraflat , 135 g/m² coated paper (Cham paper group).
- **Printing device:**
  Mickle Proofer printing device.
- **Method:**
  Print form is weighed before and after printing to determine ink weight transferred to the substrate. Ink film weight in g/m² is calculated. Optical density and gloss of prints at different ink film weight are measured. From the curve obtained, optical density and gloss at 1,5 g/m² ink is determined.

e) Cure speed and adhesion on film:

- **Measuring equipment:**
  UV lamp 120 W/cm.
- **Substrate:**
  Polypropylene.
- **Cure speed:**
  Graphite test. Speed (m/min) at which no graphite stain is observed is determined.
- **Adhesion:**
  Tape and/or cross hatch test.

f) Ink water balance:

LITHOTRONIC torque measurement machine

- **Measuring equipment:**
  (see Fig.8 & Fig.9).

- **Principle:**
  Basically, the Lithotronic (Fig.8) measures the torque required for a certain speed (rpm). The torque is a measure of viscosity. With the Lithotronic, the change in viscosity of an ink with water emulsified in it is measured. Maximum emulsion capacity (EC max: see Fig.9) is determined. This is the point where the ink is "saturated" with water.

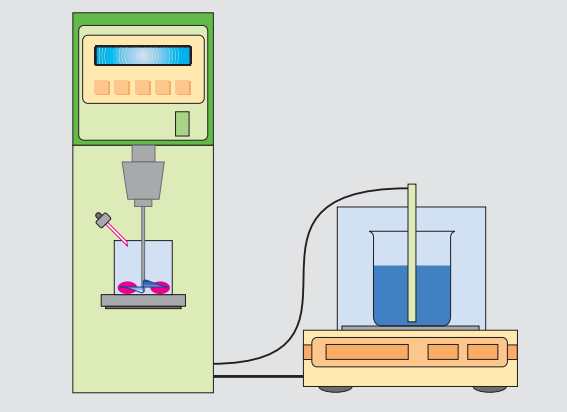


Fig. 8: Schematic representation of Lithotronic (Novocontrol).

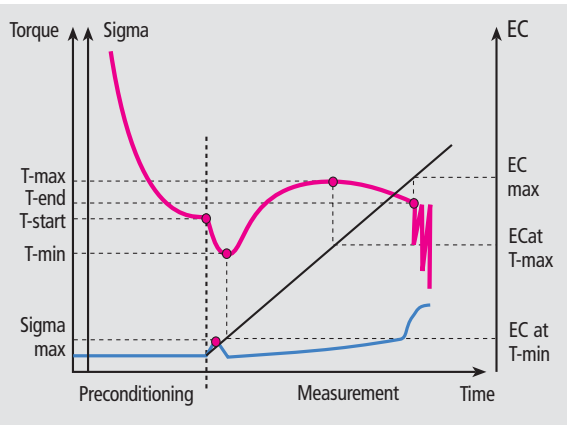


Fig. 9: Principle of Lithotronic (Novocontrol).

HYDROSCOPE torque measurement machine

- **Measuring equipment:**
  (see Fig.10).

- **Principle:**
  The device consists of three rollers. The smallest roller (1) is rubber coated and is used to measure the tack of the ink film. The principle of tack measurement is identical to that used with the Tack-O-Scope. (see page 8).
  The two larger metal rollers (2 & 3) both have driving mechanisms, and their temperature is controlled at 25°C. The direction of rotation of the rollers is shown in the Fig.11. Above the two metal rollers there is a space (ink reservoir) where the test sample of ink can be inserted. The sides of the ink bath have been sealed, so that all ink and water are enclosed therein. Fountain solution is dripped into the ink at a speed of 1.3 ml/min, using an accurate pumping system, located at two points above the ink bath. Ink and fountain solution are jointly forced through the opening between the rollers, so that they undergo a joint shear stress (Testprint).

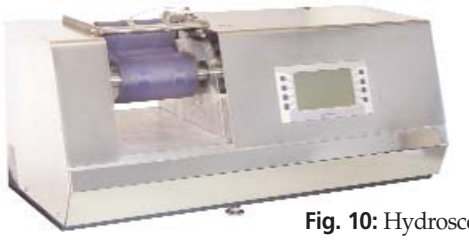


Fig. 10: Hydroscope.

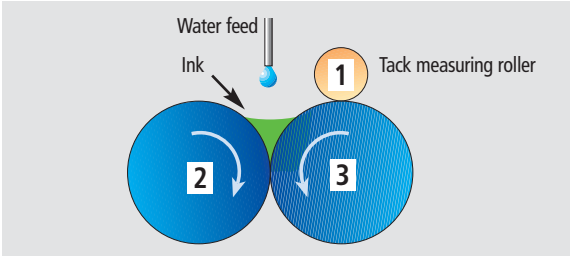


Fig. 11: Principle of Hydroscope (Testprint).

10 Product for UV Offset inks

This section describes products recommended for UV Offset inks. General recommendations are given on the use of the different types of acrylates in UV Offset inks. Features and benefits of each product are also mentioned.

General recommendations

Product type	*Benefits*
Polyester acrylates	Pigment wetting Ink water balance
Diluted polyesters	Adhesion to plastics and metals
Epoxy acrylates	Reactivity Hardness; scratch resistance Solvent resistancy
Modified epoxy acrylates	Improved ink water balance
Urethane acrylates	Reactivity (dark colours) Hardness; scratch resistance Solvent resistancy
Monomers	Viscosity/tack adjustment

Raw materials recommended for UV Offset inks:

Polyester acrylates

Products	*Type*	*Features and benefits*	*Suggested use*
EBECRYL® 450 (*)	Hexa functional	Low viscosity, low misting. Good ink water balance.	Paper and board. Improve pigment wetting and ink water balance for offset inks for plastics.
EBECRYL 657	Tetra functional	Very good pigment wetting and lithographic behaviour. Low misting.	Paper and board. High speed presses.
EBECRYL 811	Tetra functional	Low tack, low misting. Good adhesion.	Adhesion to plastics. Suited for waterless.
EBECRYL 812	Tetra functional	High reactivity. Good adhesion.	Adhesion to plastics.
EBECRYL 845	Tetra functional	Medium viscosity. Very good pigment wetting and lithographic behaviour.	Paper and board. High speed presses. Pigment concentrates.
EBECRYL 846	Hexa functional	High reactivity. Good misting.	High speed presses.
EBECRYL 870	Hexa functional	Very good pigment wetting and lithographic behaviour.	Paper and board. Improve pigment wetting and ink water balance for offset inks for plastics. High reactivity in EB.
EBECRYL 1657	Tetra functional	Low odour version of EBECRYL 657.	See EBECRYL 657.
EBECRYL 1870	Hexa functional	Low odour version of EBECRYL 870.	See EBECRYL 870.

Diluted polyesters

Products	*Type*	*Features and benefits*	*Suggested use*
EBECRYL 436 (*)	Chlorinated polyester resin diluted in 40 % TMPTA.	Very good adhesion. High photoreactivity.	Plastics and metals.
EBECRYL 438	Chlorinated polyester resin diluted in 40 % OTA 480.	Very good adhesion. High photoreactivity.	Plastics and metals.
EBECRYL 446	Modified Chlorinated polyester resin diluted in 32 % TMPTA.	Very good adhesion. High photoreactivity. Improved lithographic behaviour.	Plastics and metals.
EBECRYL 525	Chlorinated polyester resin diluted in 40 % TPGDA.	Excellent adhesion.	Improve adhesion on difficult substrates.

(*) : EBECRYL UV curable resin

Product for UV Offset inks (continued)

Epoxy acrylates

Products	Type	Features and benefits	Suggested use
EBECRYL® 648 (*)	Modified diacrylate of bisphenol A epoxy diluted with 25% OTA480.	Improved pigment wetting.	White inks.
EBECRYL 860	Epoxidised soja bean oil acrylate.	Good compatibility with rubber compound ink rollers.	Hybrid. Hot foil stamping.
EBECRYL 1606	Standard bisphenol A epoxy acrylate diluted with 25% TMPTA.	Fast cure, high gloss. Excellent solvent and water resistance. Good adhesion.	Improve reactivity, scratch and solvent resistance of offset inks for plastics and metal.
EBECRYL 1608	Standard bisphenol A epoxy acrylate diluted with 15% OTA480.	Fast cure, high gloss. Excellent solvent and water resistance. High tack.	Improve reactivity, scratch and solvent resistance of offset inks for paper and board.
EBECRYL 3420	Low viscosity, modified epoxy acrylate.	Good pigment wetting Improved flexibility.	Improve reactivity, scratch and solvent resistance of offset inks for paper/board and plastics.
EBECRYL 3608	Fatty acid modified epoxy acrylate.	Improved pigment wetting and ink water balance. Lower cure speed.	Paper and board.
EBECRYL 3700/25OT	Standard bisphenol A epoxy acrylate diluted with 25% OTA480.	Fast cure, high gloss. Excellent solvent and water resistance. Better pigment wetting than EBECRYL 600 type resin.	Improve reactivity, scratch and solvent resistance of offset inks for paper and board.
EBECRYL 3701	Flexibilised bisphenol A epoxy acrylate.	Improved flexibility and adhesion.	Plastics.
EBECRYL 3702	Fatty acid modified epoxy acrylate.	Improved pigment wetting and ink water balance. Lower cure speed.	Paper and board.
EBECRYL 6040	Modified diacrylate of bisphenol A epoxy.	Fast cure, high gloss. Excellent solvent and water resistance. High tack.	Improve reactivity, scratch and solvent resistance of offset inks for paper and board.

Urethane acrylates

Products	Type	Features and benefits	Suggested use
EBECRYL 220 (*)	Aromatic undiluted hexa functional.	Fast cure, high hardness and solvent resistance.	Improve cure speed darker colours. Improve scratch resistance of offset inks for plastics.
EBECRYL 1290	Aliphatic undiluted hexa functional.	Fast cure, high hardness and solvent resistance.	Improve scratch resistance of offset inks for plastics (better than EBECRYL 220).

(*) : EBECRYL UV curable resin

Diluting acrylates

Products	Type	Features and benefits	Suggested use
EBECRYL® 40 (*)	Polyether tetra acrylate.	Good flexibility and high reactivity. Low irritancy.	Plastics.
EBECRYL 140	Ditrimethylol propane tetra acrylate.	High reactivity and good hardness. Very low irritancy.	Paper and board.
EBECRYL 150	Diacrylated bisphenol A derivative.	High reactivity. Low tack and low misting. Good scratch resistance.	Paper and board. High speed presses.
EBECRYL 160	Ethoxylated trimethylol propane triacrylate.	Low viscosity. More flexible than TMPTA.	Paper and board. Plastics.
OTA 480	Propoxylated glycerol triacrylate.	Low viscosity.	Paper and board.
TMPTA	Trimethylol propane triacrylate.	High cure speed, chemical and abrasion resistance. Good adhesion.	Plastics.
DPHA	Dipentaerythritol hexa acrylate.	High reactivity, hardness and scratch resistance.	Increase reactivity of offset inks for paper and board.

Additives

	Products	Type	Features and benefits	Suggested use
Photoinitiators	***ADDITOL® BDK (**)***	α-cleavage	Good solubility. Balanced surface and through cure.	1 - 5% ADDITOL BDK in combination with other photoinitiators.
	ADDITOL BP	H-abstraction	Excellent surface cure. Good solubility.	To be used in combination with amine co-initiators.
	ADDITOL CPK	α-cleavage	Good solubility. Good surface and through cure. Low yellow.	1 - 5% ADDITOL CPK in combination with other photoinitiators.
	ADDITOL EHA	Amine co-initiator.	Liquid. Low odour. Good surface and depth cure.	2 - 6% in combination with 1 - 3% ADDITOL ITX.
	ADDITOL EPD	Amine co-initiator.	Good solubility. Low odour. Good surface and depth cure.	2 - 6% in combination with 1 - 3% ADDITOL ITX.
	ADDITOL ITX	H-abstraction	Good solubility. Good through cure. Low odour.	To be used in combination with amine co-initiators.
	ADDITOL HDMAP	α-cleavage	Liquid. Balanced surface and through cure.	1 - 5% **ADDITOL** HDMAP in combination with other photoinitiators.
	ADDITOL PBZ	H-abstraction	Low odour. More reactive than ADDITOL BP.	1 - 4%
	ADDITOL TPO	α-cleavage	Low odour. Low volatility. Increased depth cure.	0.5 - 2% on reactive components for white inks.
Miscellaneous	***EBECRYL 350***	Silicone diacrylate.	Good substrate and slip without migration problems.	Improve slip of offset inks for plastic substrates.
	EBECRYL 373	Anti-misting additive.	Reduces misting on high speed offset presses.	3 - 5% in an offset ink formulation.
	EBECRYL 1360	Silicone hexaacrylate.	Good substrate and slip without migration problems.	Improve slip of offset inks for plastic substrates.

(*) : EBECRYL UV curable resin - (**) : ADDITOL photoinitiator.

Product for UV Offset inks (continued)

General properties of raw materials for UV Offset inks

Products	Pigment wetting	Tack 350 m/min	Misting	Ink water balance	Reactivity
DPHA	●●●●	●●●●	●●	●	●●●●
OTA 480	●●	●●●	●	●●	●●●
TMPTA	●●	●●●	●	●●	●●●●
EBECRYL® 40 (*)	●●	●●●	●●	●●	●●●
EBECRYL 140	●●●	●●●●	●●	●●	●●●●
EBECRYL 150	●●●●	●●●●●	●●●	●●●	●●●
EBECRYL 160	●●●	●●●	●	●●	●●●
EBECRYL 220	●●	●●	●●	●	●●●●●
EBECRYL 436	●	●	●●	●●	●●
EBECRYL 438	●	●	●●	●●	●●
EBECRYL 446	●	●	●●	●●●	●●
EBECRYL 450	●●●●	●●●	●●	●●●●	●●●●
EBECRYL 525	●	●	●●	●	●
EBECRYL 648	●●●	●●●●	●●●	●	●●●●
EBECRYL 657 EBECRYL 1657	●●●●	●	●●●	●●●●	●●●
EBECRYL 811	●●	●●●●	●●●●	●●●	●●
EBECRYL 845	●●●●	●	●●●	●●●	●●
EBECRYL 846	●●	●●	●●●	●●	●●●●
EBECRYL 860	●●	●●●	●●●	●	●
EBECRYL 870 EBECRYL 1870	●●●●	●●	●	●●●●	●●●●
EBECRYL 1606	●●	●	●●●	●	●●●●●
EBECRYL 1608	●●	●	●●●	●	●●●●●
EBECRYL 3420	●●	●●	●●●	●●	●●●●
EBECRYL 3608	●●	●●	●●	●●	●●●
EBECRYL 3700 / 25OT	●●	●	●●●	●	●●●●●
EBECRYL 3701	●●●	●	●●●	●●●	●●●
EBECRYL 3702	●●●	●●	●●	●●●	●●●
EBECRYL 6040	●●	●	●●●	●	●●●●●

Additives

EBECRYL® 373	●	●●●●	●●●●●	●	●●●
EBECRYL 350					●●
EBECRYL 1360					●●●●

(*) : EBECRYL UV curable resin

Adhesion	*Rubber compatiblity*	*Viscosity - 25°C mPas*	*Viscosity - 60°C mPas*	*Dilution monomer %*	
●●	●●●●●	16000			
●●	●●●	90			
●●●	●●	115			
●●●	●●●●	160			
●●	●●●	1000			
●	●●●●	1400			
●●	●●●	80			
●●●	●●●●●	28500			
●●●●	●●●	90000	1500	TMPTA	40
●●●●	●●●●	90000	1500	OTA 480	40
●●●●	●●●●	100000	1800	TMPTA	32
●●●	●●	8600			
●●●●●	●	40000		TPGDA	40
●●	●●●	47500		OTA 480	25
●	●●●●●	125000	3500		
●●●	●●●	75000	1850		
●	●●●●●	20000		OTA 480	20
●●	●●●	45000			
●	●●●	25000			
●●	●●●●	42500			
●●	●●	30000		TMPTA	20
●	●●●		1000	OTA 480	15
●●	●●●	22000			
●	●●●		1000	OTA 480	15
●	●●●	35000		OTA 480	25
●●●	●●●●		7000		
●	●●●●		3600		
●	●●●	25000			

●	●●		
●●●●●			
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Key

	●	→	●●●●●
Adhesion	Poor		Very good
Ink water balance	Poor		Very good
Misting	High		Low
Pigment wetting	Poor		Very good
Reactivity	Low		High
Rubber compatibility	Affects ink rollers		No effect on ink rollers
Tack	High		Low

Standard ink formulations for evaluation of binders for UV Offset inks:

The formulations indicated below have only been designed to provide us with a test method to evaluate our new development products. They are representative enough to give an indication of the way our products perform in UV Offset inks. However, they can not be considered as recommended formulations and are not meant to deliver optimal performance in all applications.

For paper and board:

Type	*Name*	*%*	*Property*
Polyester acrylate	EBECRYL® 657, EBECRYL 870, IRR 559	24 - 28	Pigment wetting, ink water balance.
Epoxy acrylate	EBECRYL 3700/25OT EBECRYL 3420	37 - 44	Reactivity, hardness, Solvent resistance.
Stabilizer	ADDITOL® S 120	1	
Pigment		14 - 21	
Filler	Talc	3 - 6	Reducing misting (and tack).
Photoinitiator	PI blend(1)	8 - 10	
Monomer	OTA 480 (GPTA)	2 - 6	Viscosity adjustment.
Wax	Rad-Wax 62EB(2)	1	Scratch resistance.

(1) PI Blend :
14 % ADDITOL® BP,
34 % ADDITOL BDK,
7 % IRGACURE 369 (*),
13 % ADDITOL ITX,
32 % ADDITOL EPD
(*) Supplied by Ciba Specialty Chemicals.
(2) Supplied by Kromachem.

For plastics (and metals):

Type	*Name*	*%*	*Property*
Diluted polyester	EBECRYL® 436 EBECRYL 446	30 - 40	Adhesion.
Urethane acrylate	EBECRYL 220	20	Scratch resistance, hardness.
Stabilizer	ADDITOL S 120	1	
Pigment		14 - 21	
Filler	Talc	3 - 6	Reducing misting (and tack).
Photoinitiator	PI blend(1)	8 - 10	
Monomer	TMPTA	7 - 11	Viscosity adjustment, adhesion.
Wax	Rad-Wax 62EB(2)	2	Scratch resistance.
Silicone acrylate	EBECRYL 350	0.5	Slip.

(1) PI Blend :
14 % ADDITOL® BP,
34 % ADDITOL BDK,
7 % IRGACURE 369 (*),
13 % ADDITOL ITX,
32 % ADDITOL EPD
(*) Supplied by Ciba Specialty Chemicals.
(2) Supplied by Kromachem.

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