UV-curable Resin SANRAD Series, NEOJET Series

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UV-curable resins are resins that are cured by irradiation with ultraviolet (UV) light. They excel in mechanical and electrical properties, chemical resistance, heat resistance, etc., and are used in a wide range of fields and industries, including paints, inks, electronic materials, coating, and semiconductors. In addition, UV-curable resin systems, which do not use organic solvents that are considered VOC components, have come under the spotlight in recent years because of environmental and health benefits. This article introduces 'SANRAD' and 'NEOJET,' series the UV-curable resins from Sanyo Chemical.

What are UV-curable resins?

As shown in **Table 1**, UV-curable resins are superior to conventional thermosetting resins in various aspects[1]. Moreover, the curing system is more energy-efficient because it uses LEDs.
UV-curable resins are broadly classified into radical and cationic polymerization systems. Radical polymerization systems are mainly used because of the high curing rate and large variety of materials. Furthermore, they are composed of monomers or oligomers containing radical polymerizing (meta-) acrylate groups, and additives such as photoradical polymerization initiators and antioxidants. Polymerization starts as radicals are generated from the photoradical polymerization initiator by UV irradiation, and the material cures immediately. Since UV-curable resins are used in various fields and applications, it is necessary to design the composition according to the specific requirements. This includes: adjustment of viscosity and surface tension in accordance with the coating method; selection of the photopolymerization initiator in accordance with the light source; and selection of the agents and optimization of the compounding ratio in accordance with the required mechanical properties, interface characteristics (e.g., adhesion to the base material, release characteristics), optical characteristics (e.g., refractive index, transmittance), and environmental characteristics (e.g., heat resistance, light resistance). Sanyo Chemical has developed UV-curable resins through the design of special monomers and polymers, and provided UV-curable resins that meet the user needs by utilizing the interface control technology that we excel in.

UV-curable resins with good release characteristics from the die

The surface of a material can be fine processed to give it new properties and functions. One such processing method is the "imprint (transcription) method," in which a die with fine roughness on the surface is pressed against the resin, which is then cured to create a pattern **(Fig. 1)**. The imprint method is a simple process that can provide favorable fine pattern over large areas, and as such it attracts attention in various fields including semiconductors, recording media, biotechnology, and optical components. Two types of imprint methods exist: the UV curing method and the heat imprint method. The UV curing method, which does not require high-temperature heating compared to the thermal imprint method, can be used for components that are vulnerable to heat. It also has the advantage of excellent energy saving because it can respond to fine patterns and be manufactured in

Table 1 Characteristics of resin curing methods

	UV curing	Heat curing
Construction cost	Relatively inexpensive	Relatively expensive
Installation space	Compact	Long and large
Curing time	1 second or less	10 seconds or more
Catalyst	Required (photopolymerization initiator)	Required
Ambient temperature	80°C or lower	100°C or higher
Deterioration of base material	No	Yes
Necessity of moisture control	No	Yes

a short period of time. In this method, a UV-curable resin is applied onto the base material film such as PET and the die is pressed against it to be irradiated and cured by the UV light. Once the curing is complete, the die is released and the end product is a film with a fine pattern. In order for the UV-curable resin to be able to form fine patterns, the resin must have the following properties: an ability to penetrate into the die in the liquid state, an ability to separate from the die after molding, an ability to adhere to the base material film, and the dimensional stability. 'SANRAD' series from Sanyo Chemical contains a uniquely designed special release agent that exhibits good release characteristics, which enables highly accurate transcription, even of special shapes and minute patterns. In addition to achieving fine molding, little resin remains inside the die, which helps reduce the die abrasion **(Fig. 2)**.

We have developed a range of products to give the users the ability to choose the resins based on their requirements **(Table 2)**. Furthermore, we offer our customers the option to customize the resins for highly specialized purposes.

UV-curable resins with high adhesion to the base materials

When a UV-curable resin is applied onto the base material such as glass and various films and subjected to UV irradiation to form a cured film, curing shrinkage occurs and stress is generated inside the membrane, which may cause the cured film to peel off from the base material **(Fig. 3)**. Non-polar base materials, especially polyolefin (PP, PE), have low affinity and poor adhesion to UV-curable resins. To address this problem, Sanyo Chemical developed 'NEOJET'

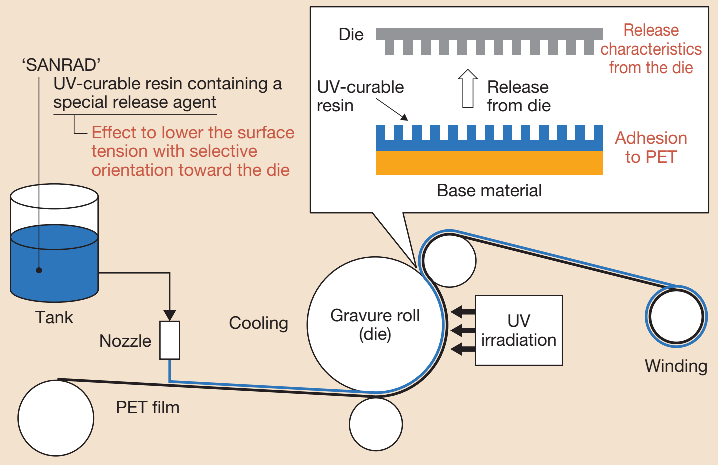

Fig. 1 Example of UV-curable resin molding process using an uneven die (base material: PET film)

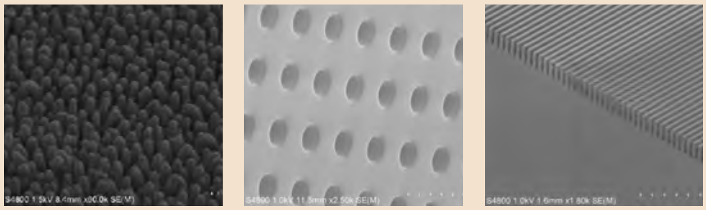

Fig. 2 Example of imprint film molding using 'SANRAD'

Table 2 "SANRAD Series," UV-curable resins with good release characteristics

Name of product		SANRAD RM	SANRAD TF-01	SANRAD FM-01
Characteristics		Standard	High restoration type	Fine molding property type
Properties of product	Solid content (%)	100	100	100
	Viscosity (mPa·s)	4500	500	790
Physical properties after curing	Die release characteristics (mN)	45	45	45
	Refractive index	1.55	1.50	1.51
	Total light transmittance (%)	91	91	92
	Haze (%)	0.3	0.3	0.2
	Tensile elasticity (MPa)	850	80	480
	Elongation (%)	22	2	8
	Tg (°C)	53	40	49
	Adhesion to PET (easy adhesion process)	○	○	○
Regulatory-compliant countries		Japan	Japan, US, Taiwan, China, and Korea	Japan, US, Taiwan, China, and Korea

- Conditions of cured material preparation: Pressing against the die to cure under UV after application on D valve, 1000 mJ (320 mW/cm^2), PET film (A4300 100 μm)
- Die release characteristics: The force to release from the die is measured on an autograph
- Refractive index: Measured with a refractometer at 589 nm
- Total light transmittance, haze: Measured with a hazemeter with film thickness of 100 μm
- Tensile elasticity, elongation: Measured with an autograph with film thickness of 200 μm in accordance with JIS K6251 (Type 3 dumbbell)
- Tg: Measured with RheoGel after preparing strips of width 5 mm and thickness of 1 mm
- Adhesion to PET: Film thickness of 100 μm, grid test

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series; UV-curable resins with high adhesion strength to the base materials. This series combines compounds with high affinity to a base material of our proprietary design, which reduces curing shrinkage and achieves adhesion to non-polar polyolefin base material, glass, and metals **(Fig. 4)**.

Table 3 shows examples of 'NEOJET' series. 'NEOJET PAD', for example, is a grade with high adhesion to non-polar base materials such as polyolefin, and this high adhesion is achieved by bringing its SP value closer to those of polyolefins. It is also compatible with LED light sources for curing, which not only leads to energy savings but also eliminates any heat-induced damage to the PP and PE films, which would occur if the UV sources were high-pressure mercury or metal halide lamps. This product is also suitable for primers and coating materials for various films.

'NEOJET GMAD' is a product of similar design that achieves a high adhesion to glass and metals. This product is also compatible with LED light sources and is suitable for protective and insulating films on metal wiring.

UV-curable resins with high toughness

While needs have recently grown for UV-curable resins that achieve both hardness (hardness, modulus of elasticity) and elongation, which are required for increasing the flexibility of various electronic materials, foldability of smartphones, or decorative films for automotive interior, it has been difficult to satisfy these needs with the conventional UV-curable resins **(Fig. 5)**. For example, while hard coating materials use many multifunctional acrylates, and the hardness and elastic modulus of the cured products

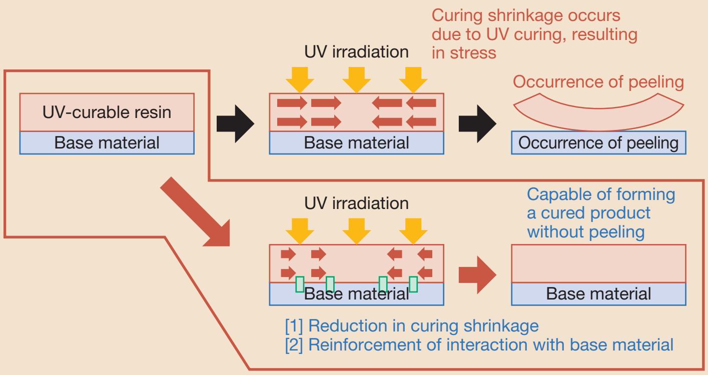
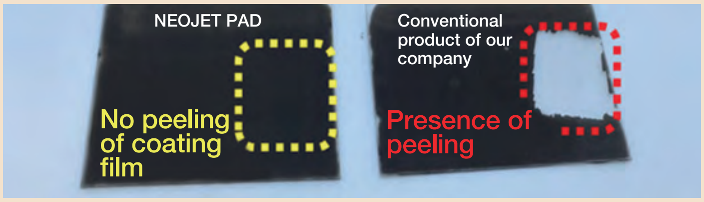


Fig. 3 Adhesion of UV-curable resin



Evaluation method: A cured product was prepared with a black resin on a PP film to conduct a peel test
(Note) Although the UV-curable resin is colored to make the evaluation easy to see, the actual NEOJET PAD is transparent.

Fig. 4 PP adhesion of cured product of NEOJET PAD

Table 3 "NEOJET Series," UV-curable resins with high adhesion to the base material

Name of product			NEOJET PAD	NEOJET GMAD
Characteristics			Plastic adhesion	Adhesion to glass, metal
Properties of product		Concentration of solid content (%)	100	100
		Viscosity (mPa·s)	5	17
Physical properties after curing	Adhesion of base material	Easy adhesion PET	○	○
		PP	○	
		PC	○	○
		TAC	○	○
		Glass		○
		Copper		○
	Total light transmittance (%)		90	90
	Haze (%)		0.5	0.4
	Refractive index		1.53	1.53
	Tensile elasticity (Mpa)		1850	1970
	Elongation (%)		5	9
	Tg (°C)		132	124
Regulatory-compliant countries			Japan, Taiwan, China, and Korea	Japan, Taiwan, China, and Korea

- Conditions for cured product preparation: LED 385 nm, 2000 mJ, 1000 mW/cm^2
- Refractive index: Measured with a refractometer at 589 nm
- Total light transmittance, haze: Measured with a hazemeter with film thickness of 10 μm
- Tensile elasticity, elongation: Measured with an autograph with film thickness of 200 μm in accordance with JIS K6251 (Type 3 dumbbell)
- Tg: Measured with RheoGel after preparing strips of width 5 mm and thickness 1 mm
- Adhesion to PET: Film thickness of 10 μm, grid test

are high, they have little elongation because they form a cross-linking structure derived from the multifunctional acrylates. In addition, UV pressure sensitive adhesives that are used as adhesives, etc. show strong adhesion to the base material if they are designed by lowering the glass transition point of the cured product. However, while they present excellent elongation and flexibility, they exhibit little cross-linking and are low in elastic modulus due to the design with a low glass transition point. 'SANRAD TS' and 'NEOJET FL' series, the UV-curable resins with high toughness from Sanyo Chemical, are grades that achieve a good balance between hardness and elongation, and they are excellent in molding processing properties because the cured resins are hard and resistant to cracking **(Table 4, Fig. 6)**. These are suited to optical films and protection materials for various electronic components.

Conclusion

Performance requirements of UV-curable resins have increased in concurrence with the increases in flexibility, foldability, and performance requirements of displays and electronic devices. In order to satisfy these needs in the future, we will continue to focus on development and create new grades.

References

1) Development of Ultraviolet and Electron Beam Curable Materials (CMC Publishing Co., Ltd.)

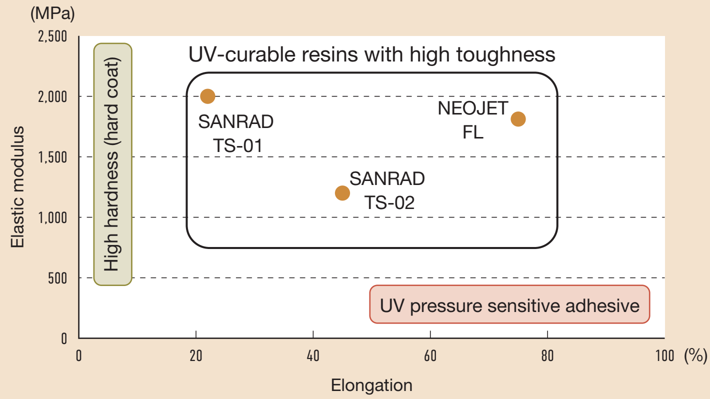


Fig. 5 UV-curable resins with high toughness

Table 4 High toughness UV-curable resins "SANRAD TS" and "NEOJET FL"

Name of product		SANRAD TS-01	SANRAD TS-02	NEOJET FL
Properties of product	Concentration of solid content (%)	100	100	100
	Viscosity (mPa·s)	2200	4200	17
Physical properties after curing	Tensile elasticity (MPa)	2000	1200	1800
	Elongation (%)	22	45	75
	Tg (°C)	57	52	77
	Total light transmittance (%)	91	90	90
	Haze (%)	0.3	0.2	0.6
	Refractive index	1.56	1.57	1.53
Regulatory-compliant countries		Japan	Japan	Japan, Taiwan, China, and Korea

• Conditions for cured product preparation: SANRAD D valve, 1000 mJ (320 mW/cm^2)
NEOJET FL: LED 385 nm, 2000 mJ, 1000 mW/cm^2
• Tensile elasticity, elongation: Measured with an autograph with film thickness of 200 μm in accordance with JIS K6251 (Type 3 Dumb-bell)
• Tg: Measured with RheoGel after preparing strips of width 5 mm and thickness 1 mm
• Refractive index: Measured with a refractometer at 589 nm
• Total light transmittance, haze: Measured with a hazemeter with film thickness of 10 μm

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An origami crane made of a sheet which is a cured product of NEOJET FL
⇒Because of the high toughness of cured product, cracks, etc. do not occur.

Fig. 6 Cured product of NEOJET FL

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