ADVANCEMENT IN RP RESINS AND THEIR NOVEL APPLICATIONS

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Abstract

TSR-821 is a photo curable resin based on epoxy materials, developed for a functional testing model. It shows flexibility of polypropylene (PP) with high flexural modulus of ABS, 2.2 GPa, and is useful not only for verification model but also for snap-fit parts. TSR-2090X is a very unique photo resin based on imide compounds, newly designed for engineering prototypes. TSR-2090X shows particular stability for water, and is useful for mass production part. TSR-2081 is an inorganic filled photo curable resin based on epoxy materials, designed for injection molding die, and gives more than 200 mold products of ABS or PP.

1. Introduction

The stereolithography has become very powerful tool for manufacturing industries, such as automotive, home-electronics industries and etc. in order to save time and cost. The fundamental technology of the stereolithography consists of four elements; hardware, software, photo-curable resin and know-how to use, whereas they are based on the key technologies for the fabricating model, all of which are required to be proven a good result. Among them, photo-curable resin is the most important element for the stereolithography, because the customer uses a shaped plastic model for his purpose. We have been making a lot of efforts on developing a high performance resin with high functionality in order to expand new markets, such as rapid production by stereolithography.

2. Application of the stereolithography

The products made by the stereolithography are useful for (a) verification model for a engineering design, working model for design based engineering, master model for wooden pattern, plastic die, master model for founding or master model for lost-wax, master model for vacuum casting, parts for small-quantity production and vacuum casting die, injection molding die for pre-production, and (b) a three dimensional copy for human body, shoe model, stereo map, a medical simulation model for surgery, support equipment and training model. The usage will be expanded owing to the successful development of new valuable resins. In the near future, mass production parts (which can be made only by the method of stereolithography) produced by the stereolithography will become popular.

3. RP Resins

In order to get three-dimensional object by stereolithography, more than hundreds or thousands layers are needed to laminate by each 0.1mm or 0.15 mm thick cured layer. Thus, curing speed of the resin is quite important to complete the model within a limited time. An exposing time at one point by a UV laser beam is the range from the order of microsecond to millisecond, which is almost corresponding to a lifetime of exited state of a photo initiator used in the resin. This is the reason why poly-functional oligomers and/or monomers are used to get a suitable reaction speed. This causes poor properties for the cured model. Table -1 summarizes the short history of the stereolithography resins mainly used for a verification model. At starting generation, the customer satisfied with the complete model whether it was accurate or not. At 1st generation the customer discussed about accuracy of the model. The researchers focused into the accuracy of their resins. CIBA, Asahi-Denka and we made good result in each resin. At next generation, stability for humidity was a serious matter to get better model. A lot of works and efforts were done for removing humidity affect. At 2nd generation the customer can deal with the model without special care for atmosphere. Current period is considered to be the 3rd generation to get durable resins in the market. The customers always expect technology advancement. All of resin manufacturers are developing more advanced, high performance resins in order to satisfy the customer needs.

Table-1. Short history of the stereolithography resins

Year	-1993	1994	1998	2001-	2002-
Generation	Starting Generation	1st Generation	2nd Generation	3rd Generation	4th Generation
Base Resin	UA / EP	EP	EP	EP	EP
Item	Model	Accuracy	Humidity	Durability	ABS
CIBA vantico	XB-5081-1	SL-5180	SL-5510	SL-7540	SL-7560
DSM-SOMOS	SOMOS-3100		SOMOS-7100	SOMOS-9100	
3DS (RPC)				AccuDur	
JSR	SCR-310		SCR-701	SCR-710 SCR-735	
Asahi-Denka	HS-661 (EP)	HS-673S	HS-680	HS-681	HS-690X
Teijin Seiki CMET		TSR-800	TSR-820	TSR-1938N TSR-821	

We have already developed some new functional resins with high performance and functionality, such as heat-stability, large impact strength, tensile strength, elongation at break and etc. in order to satisfy the customer needs.

3.1 New Durable Resin for Snap-Fit Model (TSR-821)

For a long time stereolithography model had been considered to be brittle and easy to break because of its poor mechanical properties. So, the usage of model is limited. The model is required to be tough and flexible. A vantico SL-7540 was well accepted by its flexibility and durability. However the resin has a modulus of 1.1-1.4 GPa corresponding to that of polypropylene (PP), the thin plain is very week and vend by its weight. We decided to develop a new resin having ABS level modulus of 2.2 GPa. And very tough and flexible resin named TSR-821 based on epoxy materials is obtained for the functional testing model. TSR-821 shows flexibility of polypropylene (PP) with high flexural modulus of ABS, 2.2 GPa. This is very useful not only for verification model needed high accuracy but also for snap-fit parts. The mechanical properties are listed in Table-2. Figure-1 shows a typical example of the model made by TSR-821 resin. Figure-2 shows the bending test result of 1mm thick test piece with width of 20mm by self-weight under ambient atmosphere (25-27°C with humidity 60-75%) comparing with vantico SL-7540. We can easily understand that TSR-821 shows smaller self-bending and stable than SL-7540.

Figure-1. Typical examples of TSR-821.

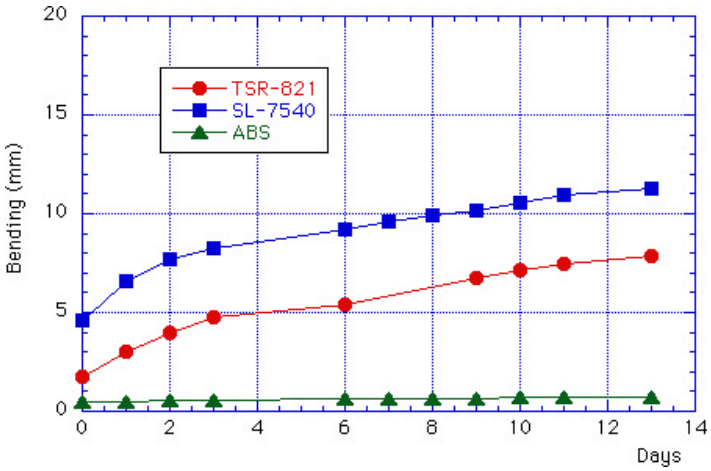

Figure-2. Bending by self-weight under the ambient atmosphere.

Self-tapping test was done as following conditions;

1. Tapping screw: Nominal diameter size is JIS M4 (depth = 20 mm, pitch = 1.5)
2. Boss shape: Height = 25 mm, external diameter = 8 mm
3. Testing trial: 5 times

Table-2 Self-tapping test result for TSR-821 and HS-680.

Resin	Prepared hole diameter (ratio to tapping screw)		
	3.4 mm (85%)	3.6 mm (90%)	3.8 mm (95%)
TSR-821	5/5	5/5	5/5
HS-680	0/5	0/5	4/5

TSR-821 shows a perfect result for self-tapping test. It is enough durability for assembling equipments or sets. TSR-821 has a mechanical performance very close to ABS properties except heat distortion temperature. This resin is highly expected for general use of rapid prototypes.

3.3 Imide Based Water Resist Resin (TSR-2090X)

We have been made lots of efforts on developing a high performance photo curable resin applicable for rapid manufacturing in order to expand the stereolithography market. We have developed a very unique resin based on imide acrylate materials. The new resin is useful for mass production part by laser stereolithography. Figure-3a and 3b show change in properties of cured TSR-2090X resin under each water solution (water, HCl, NaClO). The cured resin showed particular stability under their water solution condition. Recently Dr. Miyake of HITACHI Ltd., reported a very smart equipment for water analyzer made of this imide based part in the equipment (see Figure-4). By using this technology, the equipment size is reduced to 1/120 and the price is also reduced to 1/4. The new equipment was put into the market at the end of 1999. This is the first example used for a commercial based mass product by stereolithography technology. The product of new material brings an innovative technology that we have never imaged.

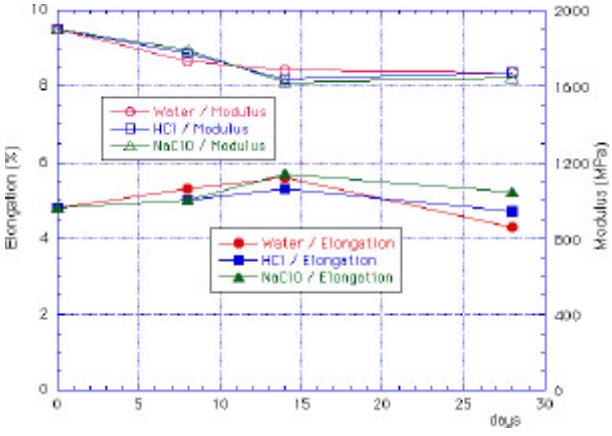

Figure-3a

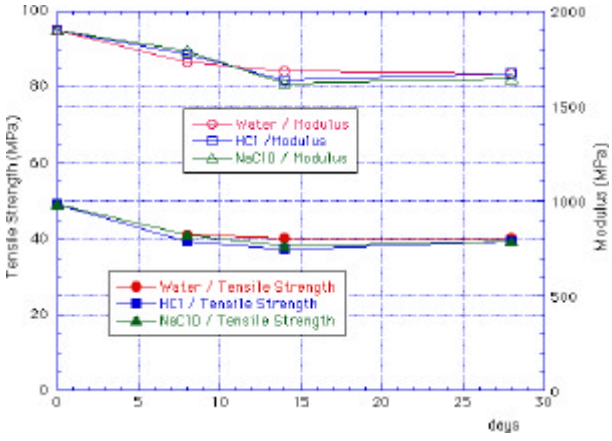

Figure-3b

Figure-3a Change in elongation and tensile modulus under each water solution.
Figure-3b Change in tensile strength and modulus under each water solution.

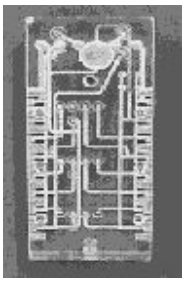

Figure-4.

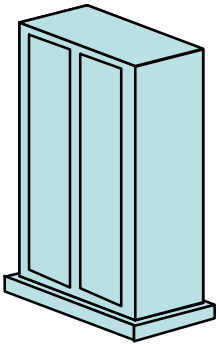

Figure-5

Figure-4 Manifold by stereolithography for commercial part using TSR-2090X.
Figure-5 Comparison of new type with current model

3.4 Injection Molding Die by Stereolithography (TSR-2081)

We have already succeeded in developing a series of resins called TSR-750's based on urethane acrylates (UA) useful for injection molding die in 1994. Photo-radical reaction of UA is affected by air oxygen to give rough top surface, on the other hand, epoxy based resin shows very smooth surface because epoxy reaction is not interfered by air oxygen. TSR-2081 is an inorganic filled photo curable resin based on epoxy materials, designed for injection molding die by laser stereolithography. Cured TSR-2081 die has very smooth edge and surface, suitable for trial injection molding die. The die gives more than 200 moldings of ABS or PP (see Figure-6). The mechanical properties are also summarized in Table-3.

Figure-6. Injection molding die of TSR-2081 and its injected ABS product.

Table-3. Characteristics of TSR-821, 2081 and 2090X

Items	TSR-821	TSR-2081	TSR-2090X
Base resin	Epoxy	Epoxy	Imide
Viscosity (mPa.s)	380	4000-7000	300
Specific gravity	1.12	1.55	1.14
Tensile strength (MPa)	49	88	61
Elongation (%)	13-15	2	4.4
Tensile modulus (GPa)	1.8	7.8	2.4
Flexural strength (MPa)	70	153	81
Flexural modulus (GPa)	2.2	10.4	2.6
Impact strength (kJ/m^2)	4.8	1.5	-
HDT (°C)/1.82MPa	52	120	80 (Tg)

4. Summary

New liquid photo resins, TSR-821, 2081, and 2090X, for rapid prototyping by UV Laser are developed. Hardened TSR-821 shows high impact strength with high flexural modulus with ABS properties. This is very useful not only for verification model but also for snap-fit testing model. TSR-2090X shows a particular stability for water, and useful for mass production part. This is the first example that the fabricated model by the stereolithography is used for the commercial based instrument. Cured TSR-2081 is very tough having milky white color, useful for injection molding die giving more than 200 ABS molds. The developing of a new resin will enable rapid prototyping to evolve into rapid production system in the near future.

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Key Words
photo-resin, stereolithography, snap-fit, molding die, production part, imide, rapid prototyping, rapid manufacturing