

# RECENT PROGRESS OF RP RESINS AND SYSTEMS BY CMET INC.

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**ABSTRACT:** New liquid photo-resins, epoxy based TSR-821 and 2081, and imide based 2090X, for stereolithography by UV Laser are developed. TSR-821 shows flexibility of polypropylene (PP) with high flexural modulus of ABS, 2.2 GPa useful for a snap-fit model. Injection molding die by TSR-2081 gives more than 200 moldings of ABS or PP. TSR-2090X indicates a particular stability for water, and useful for mass production part. Multi-laser, multi scanner system called SOLIFORM Multi is developed shows high speed and high accuracy. New He-Cd laser system named Rapid Meister 2500F shows high resolution of 0.1mm slit and wall.

**KEYWORDS:** photo-resin, stereolithography, snap-fit, molding die, production part, multi-laser, high resolution

## 1. INTRODUCTION

The stereolithography has become very popular in the field of manufacturing, such as automotive and home-electronics industries to cut time and cost. Among the technology of stereolithography, photo-curable resin is the most important element, 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 cultivate a new market, such as rapid production by rapid prototyping with stereolithography. The customer also requests a high speed and high accuracy system.

## 2. 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 order of microsecond to millisecond, which is almost corresponding to a lifetime of excited state of a photo initiator. 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 resin. 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.

### 2.1 SNAP-FIT MODEL RESIN (TSR-821)

Stereolithography model is believed to be brittle and easy to break because of its poor mechanical properties. So, the engineer has to handle the models very carefully. The model is required to be tough and flexible. Very tough and flexible resin named TSR-821 based on epoxy materials is developed for the functional testing model. TSR-821 shows flexibility of polypropylene (PP) with high flexural modulus of ABS, 2.2GPa

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This is very useful not only for verification model but also for snap-fit parts. The mechanical properties are listed in Table-1. Figure-1 shows a typical example of the model by TSR-821 resin. Figure-2 shows the bending 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 showed smaller self-bending than SL-7540.

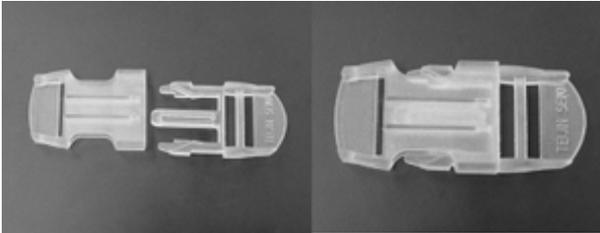


Figure-1. Typical example of snap-fit resin TSR-821.

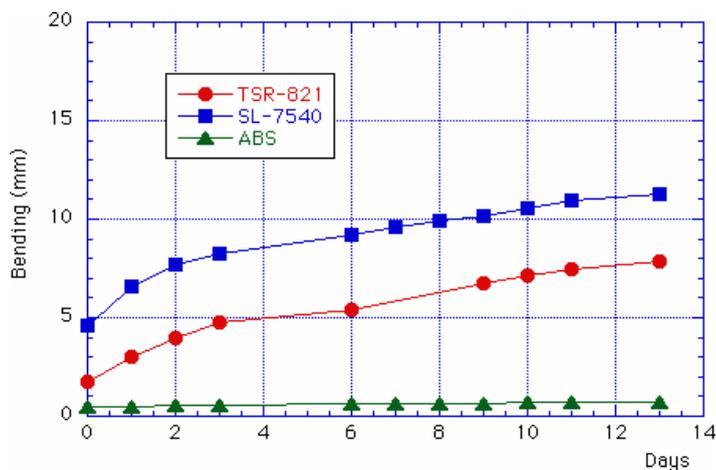


Figure-2. Bending by self weight under the ambient atmosphere.

## 2.2 INJECTION MOLDING DIE BY STEREO LITHOGRAPHY (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-3). The mechanical properties are also summarized in Table-1.



Figure-3. Injection molding die of TSR-2081 and its injected ABS product.

### 2.3 WATER RESIST RESIN (TSR-2090X)

We have been made lots of efforts on developing a high performance photo curable resin based on imide material in order to expand the stereolithography market from rapid prototyping to rapid production. 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-5a and 5b 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 mass product by stereolithography technology. The product of new material brings innovative technology that we have never imaged.

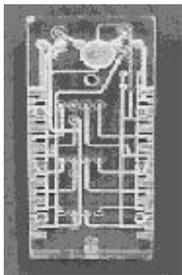


Figure-4. Manifold by stereolithography for commercial part using TSR-2090X.

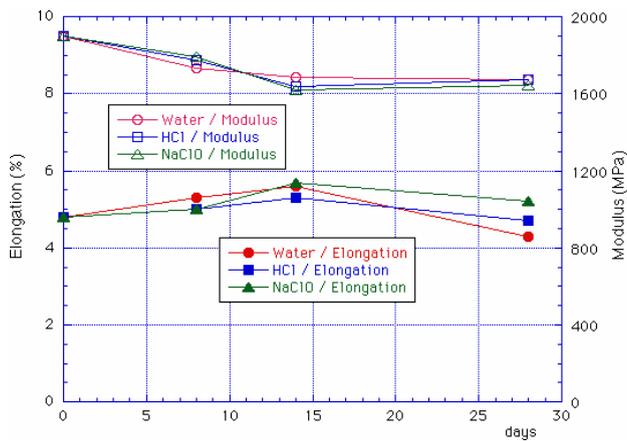


Figure-5a Change in elongation and tensile modulus under each water solution.

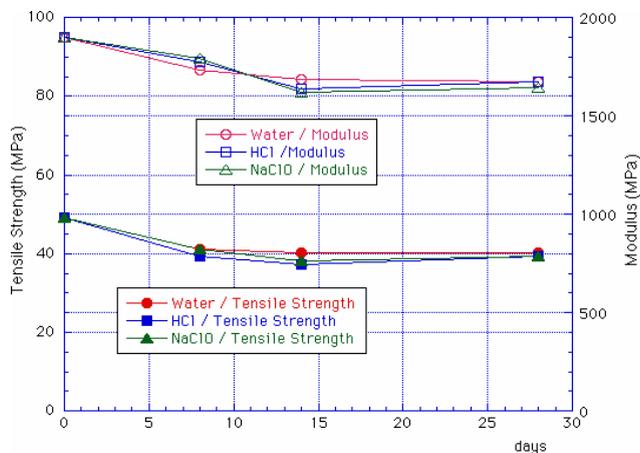


Figure-5b Change in tensile strength and modulus under each water solution.

Table-1. Characteristics of TSR-821, 2081 and 2090X

Items	TSR-821	TSR-2081	TSR-2090X
Base resin	Epoxy	Epoxy	Imide
Viscosity (mPa)	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 <sup>2</sup> )	4.8	1.5	-
HDT (°C)/1.82MPa	52	120	80 (Tg)

### 3. CMET NEW RP SYSTEMS

#### 3.1 CMET SOUP-II System

10 years ago when the stereolithography was put into the market, the three dimensional model was accepted with amazing. In those days people did not expect for the accuracy in the model. Today, the stereolithography has become very popular systems in manufacturing industries and is used as a common tools. The stereolithography of the first generation is attached with He-Cd laser as a UV light source. The system of the last second generation is dominated by Ar ion laser. And current third generation, solid state laser used third harmonic generation technology becomes very popular. The accuracy has changed from 200-300 $\mu$ m to 50-100 $\mu$ m for 200mm size model accompany with stability and economically. Fabrication speed has very much enhanced by laser power and writing manner achieving 4-5 times faster than the last systems.

A SOUP-II600GS system having solid state high power laser appeared in the Asian market in 1998 by CMET Inc. This system pursues both high accuracy and high fabrication speed attached with normal and fine mode. The fine mode is accomplished by reducing the writing area from 600mm size to 300mm size. Using the fine mode, we can get a very fine and cool model with 0.3mm gap slit, as shown in Figure -6.

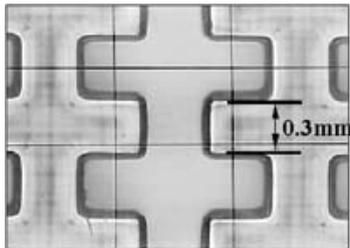


Figure-6 Realization of 0.3 mm slit by SOUPII-600GS

#### 3.2 SOLIFORM Multi series

In order to expand the stereolithography system, we believe that the system should be placed to a manufacturing tool. This means that the usage of the system should be changed from rapid prototyping machine (RP) to rapid manufacturing (RM) one. Among the complicated product, such as a three dimensional manifold (see Figure-5), which is too difficult to make by using conventional manner, is suitable for the technology of stereolithography. For the rapid production by stereolithography, it is necessary to make the product with stable condition and short time. In order to accomplish this object, the multi-laser, multi scanner system has been developed and put into the market by CMET Inc. This system is expected for following performance.

- i) Accelerated writing speed
- ii) Reducing curing curl.
- iii) Multi mode curing system.

iv) Keeping accuracy

A 4 lasers/ 4 scanner system showed remarkably reduced for writing time, it becomes about 5 to 6 times faster than a 1 laser/ 1 scanner system, keeping its accuracy. From 2000 the systems are running in a specified customer. Figure-7 shows a comparison of fabrication time with each laser-system. This figure showed remarkable reducing of fabrication time. Figure-7 shows an example of 4-laser. 4 scanner type system, called SOLIFORM Multi 600-Q. By pursuing speed and accuracy. this is one answer that CMET gives for our customers. And this system has a potential for expansion to 1m size, we are very much expected by the customer who needs extra large model such as 1m or 1.5 m in the industry of automotive, heavy electrics and so on.



Figure-7 SOLIFORM Multi 600-Q having 4 lasers. 4 scanners

### 3.3 Rapid Meister 2500F

We just put into the RP market a ultra resolution RP system called Rapid Meister 2500F with He-Cd UV laser, the technology was derived from SOUP-II 600GS fine mode. This system is developed for the customers of precision part industries who mainly make prototypes of connector or precision mechanical part. Figure-8 shows Rapid Meister 2500F. Figure-9 shows realization of 100mm slit by Rapid Meister 2500F.

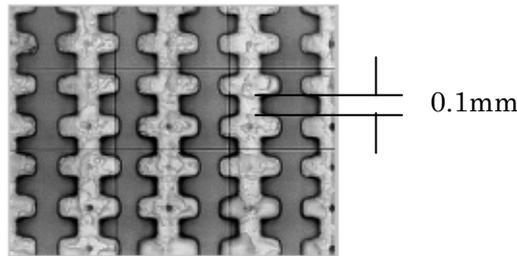


Figure-8 Rapid Meister 2500F      Figure-9 High resolution of 0.1mm

This system has a following advantages;

- 1) Very stable 40 mW He-Cd laser,
- 2) Realizing 100 $\mu$ m slit model
- 3) A new re-courting system with a new level sensor
- 4) Minimum slice pitch 20 $\mu$ m is available
- 5) 30% faster than a current SOUP 250GH
- 6) Easy removal plate by magnetic releasing mechanism.
- 7) Leg-less fabrication by flexible plate, to give smooth base face and easy removal of support

## 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 PP properties and color. This is very useful not only for verification model but also for snap-fit testing model. Cured TSR-2081 is very tough having milky white color, useful for injection molding die giving more than 200 ABS molds. 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 instrument. The developing of a new resin will enable rapid prototyping to rapid production system in near future. Multi-laser, multi scanner SLA type system called SOLIFORM Multi are developed. Newly developed He-Cd laser system named Rapid Meister 2500F shows high resolution of 0.1mm slit and wall.

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