Applications Guide

Updated Q1-07

Objet Geometries

Applications Guide

OBJET

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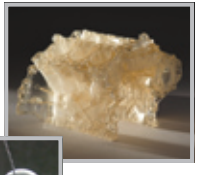
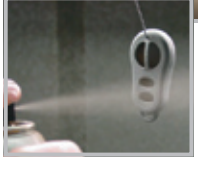
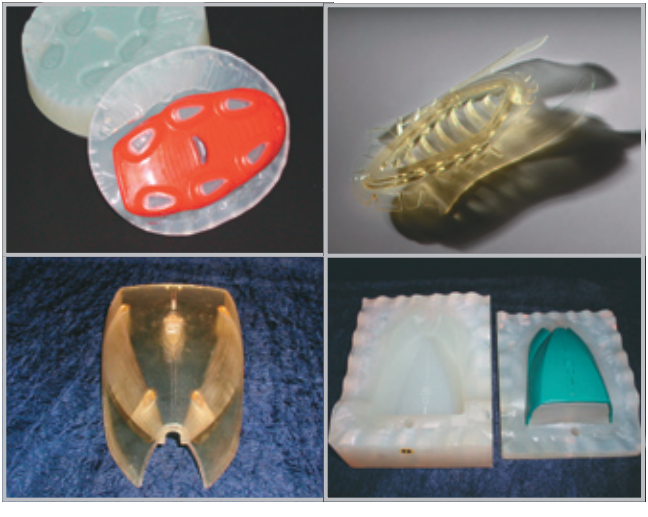




1. Silicon Molding for Vacuum Casting

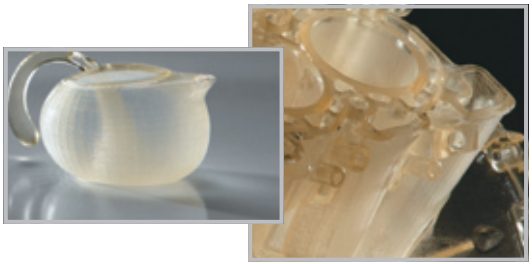


Silicon Molding with Objet

- Why PolyJet is best
- Customer references
- Advantages of Silicon Molding
- Recommended silicons
- Process tips

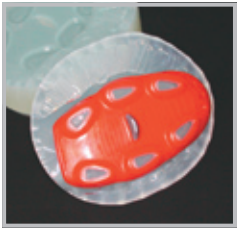
Why PolyJet for Silicon Molding

- Crisp details
- Excellent accuracy of 100-200µm
- Thin walls of 600µm
- Smooth surfaces
- Fast overall build to get master



Why Silicon Molding

- Fast inexpensive molds
- Excellent detail reproduction
- Option of using multiple materials
- Good material properties, close to that of thermoplastics
- Undercuts
- Good for up to about 50 parts
- Bridges the gap between rapid prototyping and hard tooling



Suggested Silicons to use

- VTX 950 from MCP
- Shinetsu Addition Cure KE1310ST
- Wacker 4644 silicon
- RTV630 from MG Chemicals
- Axson 291

Addition vs. Condensation Cure

- Two types of silicon

Addition:

- A+B to harden
- Can accelerate with heat
- No outgassing
- No shrinkage, best for high precision parts

Condensation:

- Hardens with condensation or a catalyst (also A+B)
- No heat acceleration
- Outgassing can occur
- Shrinkage can occur

- Most of our customers use Addition-type for precise parts and in order to accelerate curing time

Process Suggestion to Avoid Inhibition

Inhibition issues solved with the following procedure:

- Clean part with WaterJet
- Put into sodium hydroxide (caustic soda) for one hour
- Clean once again with WaterJet (use only fresh water source; not a recycled water)
- Blow water off with air and let the parts dry (do not dry in ovens which has greasy or oily enviroment)
- Sand blast the part, if possiblle
- Ensure UV light intensity is suffient
- Recommended printing mode is Matte (not glossy)
- Avoid touching the cleaned part by bare hands

User Tips: Avoid Inhibition

- Issues that affect inhibition
  - some paints and lacquers
  - super glue
  - fingerprints on the model
  - mixing the silicone in PVC containers
  - mixing silicone at the wrong temperature.
- Extra time should be spent preparing the model
  - Extra water jetting at a higher pressure and then a fine sand blast.
  - Also cure the silicone in an oven at 35˚C (or higher) rather than at 23˚C that the manufacturers recommend
- Inhibition is worse in glossy mode, better in matte

2. Investment Casting

Investment Casting with Objet

- Why PolyJet for investment casting
- Recommended procedures
- Customer Reference

Why PolyJet for Investment Casting

- Crisp details
- Undercuts
- No warpage or shrinkage
  - Excellent accuracy of 100-200µm
- Thin walls of 600µm
- Smooth surfaces
- Burns out

Investment Casting Definition

1. Create a wax or RP pattern in the image of the intended part
2. Surround the pattern with solid investment or a ceramic slurry shell
3. Melt or burn out the pattern leaving behind a hollow ceramic shell
4. Pour molten metal into the ceramic shell
5. The ceramic shell is removed
6. Resulting metal parts are finished according to customer requirements.

How to Investment Cast

- Start with raw CAD file
- Add gating for entry of metal and exit of support and burnt out Objet part
  - 2 gates at opposite ends of the part ensures complete removal of residual ash and ceramic dust
- Hollow out all bulky areas with wall thickness of 1–3mm

How to Investment Cast

- Best results at 1.2–1.3mm thickness taking into account
  - part strength
  - ash content
  - no defects
- Build Objet part

How to Investment Cast

- Remove support material, including most of resin inside
  - Leaving support inside results in cracked molds due to higher thermal expansion of support
  - In complicated geometries, one suggestion to remove support, without damage to model, is Tetra Methyl Ammonium Hydroxide (25%) for a few hours – but very toxic
  - No swelling or damage to the model material
  - Parts with thicknesses between 3–5mm leave little room to remove support material.

Two Burnout Methods

1. Flash fire burnout at 800˚C – hollowed out 1.2–1.3 mm walls

2. Slow ramp up is best for most parts, where
   - Some support is left inside
   - Part with complicated geometry
   - 2–3 mm wall thickness

- In both case, investment shell washing is mandatory with strong stream of tap water and vigorous shaking and draining.
- If parts were painted double check for pigment material that did not decompose completely, use a clear lacquer or enamel where possible.
- Burn out shell at 800˚C for a minimum of 4 hours, cool and wash with water, dry and preheat to pouring temperature as normal
- Recessed lettering has much better finish if built with the letters in a vertical plane. Letter depth should be 1 mm maximum.

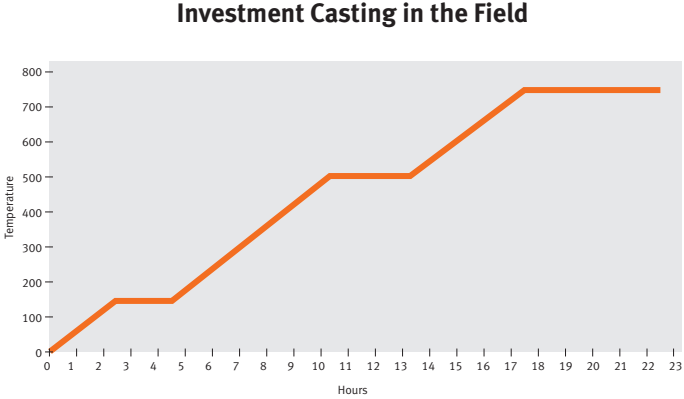
Optimum Burnout Cycles

1. Flash fire burnout
   - Alternate burnout method, flash fire at 800˚C or ramp up cold oven to 800˚C, 4 hours minimum at 800˚C

1. Slow ramp up
   - 90˚C 2 hours
   - 120 ˚C 2 hours
   - 150 ˚C 2 hours
   - 170 ˚C 2 hours
   - 210 ˚C 4 hours
   - 250 ˚C 4 hours
   - 800 ˚C 4 hours+

- This burnout cycle is not compatible with investment casting wax

Alternative Slower Burn Out Process



Investment Casting in the Field

Two New Services from *Precision Metalsmiths, Inc.*

FAST Metal Prototypes

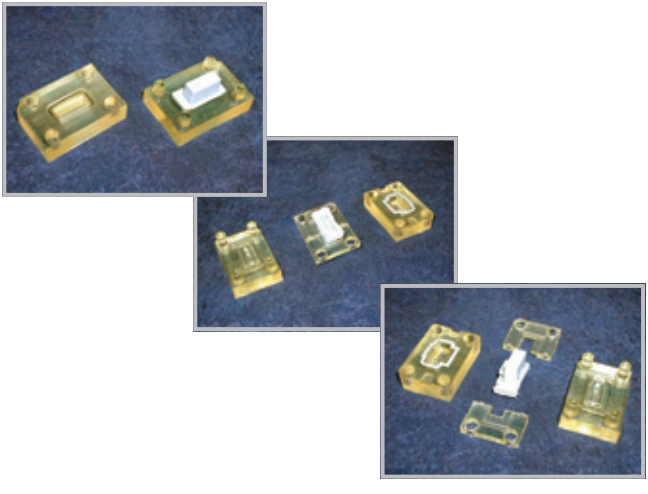
PolyJet part

COMPUTER MODEL
Your print or computer CAD file generated into 3D geometry. Our techniicians add appropriate gating for investment casting

PLASTIC PROTOTYPE
3D solid model is directly printed out in a UV curable resin in layers .0006 of an inch thick. High resolution part arrives a few hours later

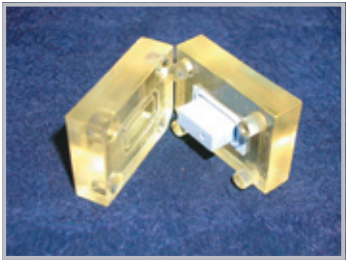
METAL PROTOTYPE
PMI proprietary processes use the model to directly investment cast your prototype in any stainless steel, aluminum or copper-based alloy

3. Rapid Tooling of Silicon Parts In Consumer Electronics



Rapid Tooling with PolyJet

Models produced with PolyJet technology on the Eden RP system produce durable models with outstanding feature detail and excellent surface characteristics.

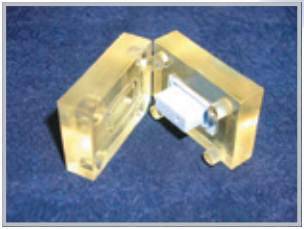


Direct Tooling: How does it works

Convert model drawing into Mold using a tooling function, a standard feature in solid modeling software. 4 alignment pins and holes are then added, to ensure that the two halves of the mold line up perfectly.

Some CAD Modeling software program give automatic parting lines while in others, these parting lines must be chosen. In this particular application, no other special features needed to be added such as draft angles.

Direct Tooling: How does it works

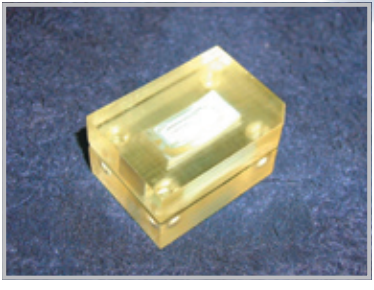


Suggested Silicon is RTV630 from MG Chemicals, two part with hardener with Silicone primer SS4155 and pours it into both halves of the mold.

See website for more details about this silicon:
www.mgchemicals.com/products/630.html

The two parts are then manually fit one onto the other (no vacuum chamber, due to the press fit, no air bubbles are created):

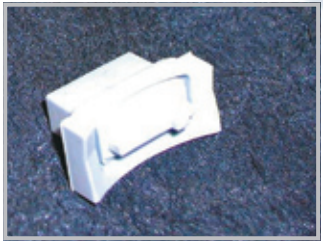
Direct Tooling: How does it works



The full mold is then placed into an oven for either:

- 1 hour at 80°C, which did not result in any warping for these parts or
- 3 hours at 50°C, which may be required for certain geometries

Direct Tooling: How does it works



Part is then ready for functional use, with rubber-like properties such as 250% elongation at break.

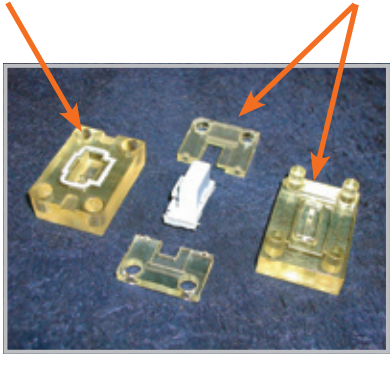
This mold can be reused for about 50–100 sample parts.

The entire process can be completed in 3–4 hours.

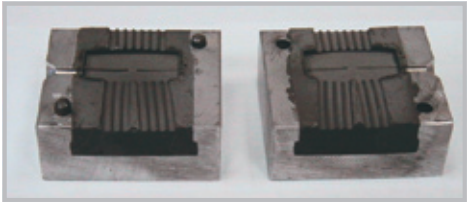
Geometries with undercuts

This technique can also be used for more sophisticated parts with undercuts by adding space for

overflow resins and additional inserts

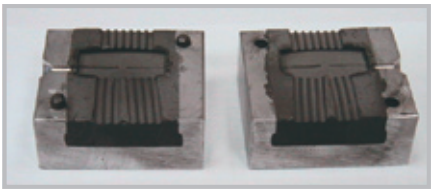


4. Aluminum Epoxy molding



Aluminum Epoxy Molds Highlights

- Use Objet part as master
- Inexpensive and relatively fast way to produce up to a few hundred copies.
- Can produce copies with thermoplastic, engineering materials
- Ideal for low to medium complexity models
- High complexity models requires many metal inserts



Two halves of Aluminum epoxy mold as an insert into an Aluminum mold

How to make Alu Epoxy Molds 1

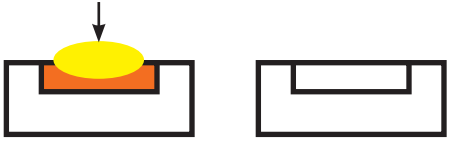
- Prepare 2 Aluminum molds with place for insert

- Build Objet master

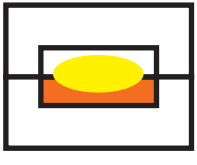
- Place Putty or Plasticene in one side of mold (alternatively, wood and wax can be used)

How to make Alu Epoxy Molds 2

- Press model (Objet master) in gently in mold-side with putty

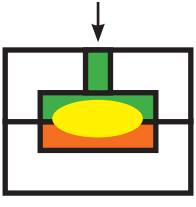


- Close second half of mold

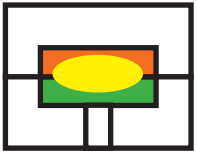


How to make Alu Epoxy Molds 3

- Put in Aluminum epoxy and hardener



- Turn mold around



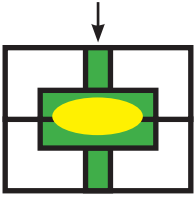
How to make Alu Epoxy Molds 4

- Open up mold

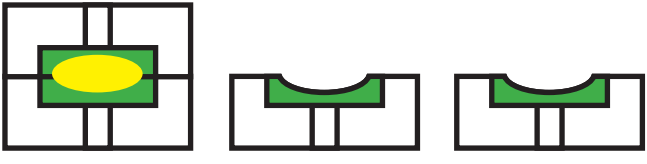
- Remove putty

How to make Alu Epoxy Molds 5

- Close and put in Aluminum epoxy and hardener



- Seal holes and mold is ready



Additional information

- Time
  - 24 hours at 110˚C for each side of mold to harden
  - Total 48 hours
- Tolerance:
  - +0.1mm for small parts
  - up to +0.3mm for large parts
- Materials required for tooling
  - Aluminum epoxy A+B, Material and hardener required
  - Available “off the shelf” (eg. Zinca from Ciba)
- Placement
  - The Aluminum mold should be placed inside an Aluminum box
- See page 56–57 of Wohlers Report 2003 for more details

5. Rubber Molding in Jewelry

Objet Ring as Master in Rubber Mold

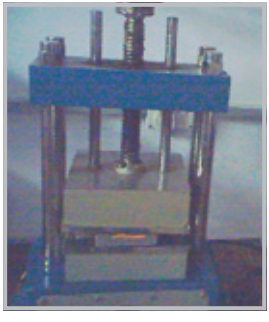
- Rubber mold for injection of wax parts
- The rubber is heated to 200˚C and built using pressure.
- The following describes the the rubber mold process:

Objet Ring as Master in Rubber Mold

Step 1:

Place the Objet part in rubber slices

Objet Ring as Master in Rubber Mold



Step 2:

Press and heat to create rubber mold

Objet Ring as Master in Rubber Mold

Step 3:
Inject Wax

Objet Ring as Master in Rubber Mold

Step 4:

Open the mold

Objet Ring as Master in Rubber Mold

Step 5:

Pull out ‘undercuts’ release

Objet Ring as Master in Rubber Mold

Step 6:

Pull out ring

Objet Ring as Master in Rubber Mold

Step 7:

Final Wax Model

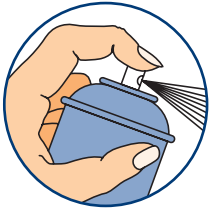
6. VLT Molding

VLT as Alternative Rubber Mold

- CASTALDO® VLT™ Silicone Molding Rubber can be vulcanized at any of a wide range of time and temperature combinations depending on the characteristics and requirements of your model material. Below are some suggested combinations for a typical mold ¾" / 19 mm thick
  - 88˚C / 190˚F for 30 minutes
  - 82˚C / 180˚F for 45 minutes
  - 76˚C / 170˚F for 60 minutes
  - 71˚C / 160˚F for 90 minutes

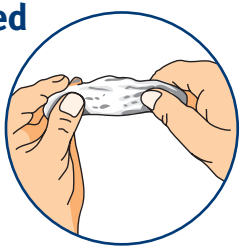
VLT: How does it work?

The only change from established mold making techniques required by CASTALDO® VLT™ Silicone Molding Rubber may be the need to coat the wax or plastic model with a Release Spray before vulcanizing to ensure easy release of the model after vulcanization. Teflon® (PTFE) sprays work very well.



The advantages of VLT Molding Rubber

- **Tools and Technology:** The VLT™ Molding Rubber utilizes the simple tools and easy technologies.
- **Easy to work with:** VLT™ Molding Rubber has the consistency of modeling clay or putty
- **Easy to cut**
- **Shrinkage:** Rubber shrinkage is only 1.4%
- **No release spray needed**
- **High shine finish**
- **High tear**



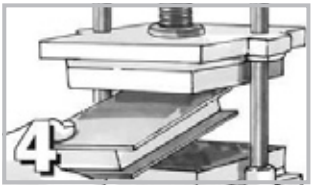
VLT Molding Rubber: The Process

Silicone Molding Rubber is soft and pliable, with a consistency like putty or molding clay

Place the Objet model inside the Silicone Mold

Placing and embedding the rubber onto model

VLT Molding Rubber: The Process



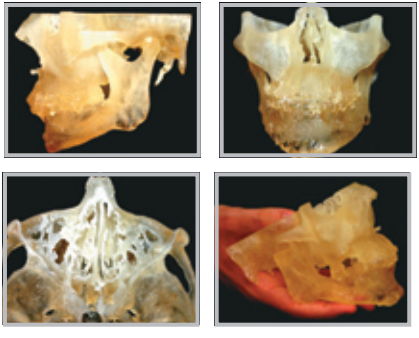
Curing Silicone Jewelry Molding Rubber Molds involves no mixing, and at low temperature.

The Silicone Jewelry Molding Rubber Molds are then to be cut and open by hand.

Parting lines are easily controlled and corrected by hand when used with the powder separation.

Finished molds can be complex with cores, straight plugs or even spiral plugs.

7. Medical Applications



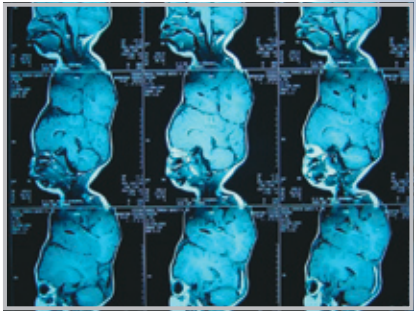
Why PolyJet for Medical applications

- Outstanding detail and fine features that will withstand support removal
- Clear amber color in order to view parts such as facial sinuses
- Durable resin which preserves delicate structures such as the floor of the orbit and the nasal concha
- Fast overall build time to final model enables use for trauma or tumors
- Ability to cut and fix plates and screws on to model

RP Advantages in Medical Applications

- Surgery simulation
- Production of surgical guides over bones
- Reduction of surgical risks
- Reduction of time and hospital costs
- Production of personal prostheses
- Communication to patient
- Planning without patient presence

From MRI to Biomodel



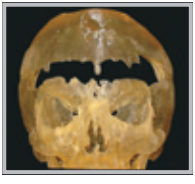
MRIs of the scanned heads of the conjoined twins

- 3 MRI scans at different angles
- Combined into a single, 3-D model
- Merge the scans with Materialise's MIMICs software
- Included the maze of blood vessels
- Ready to produce 3-D Biomodel with Objet

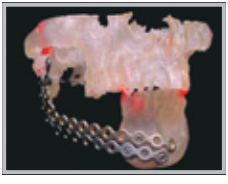
Successful Testing

- USP Class VI
- Cytotoxicity
- ISO10993 Sensitization
- ISO10993 Irritation
- Above testing led to successful penetration to implant market and helped with oral testing models

Other Medical & Dental applications



Temporomandibular ankylosis



Bone loss – carcinoma

Hemimandibular Hyperplasia and Implant planning

Transpalatal distraction

Appendix: RP Medical Software

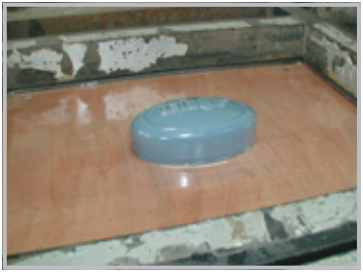
- 3D Doctors – USA
- Analyze – USA
- Anatomics – Australia
- Julius – Germany
- Mimics (Materialise) – Belgium
- Simpleware – UK
- Tomovision – Canada
- Velocity Pro – USA
- Vworks – South Korea

8. Vacuum Forming

Vacuum Forming

- Benefits
  - Easy
  - Inexpensive
  - Quick to perform
- Applications
  - Packing

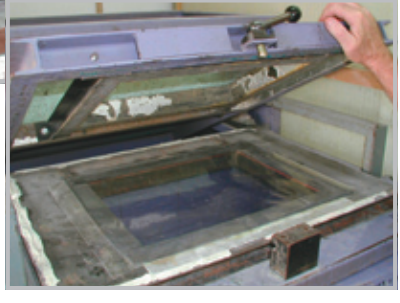
Vacuum Forming



- Cutting the PVC sheet

- Placing the Objet model on plate

Vacuum Forming

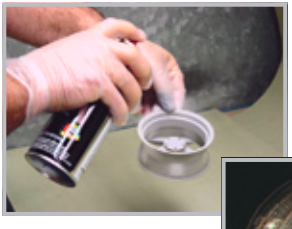


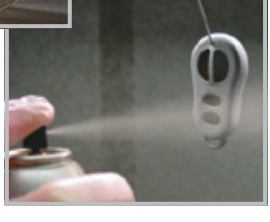
- Heating the PVC sheet

Vacuum Forming

- Vacuum to be applied – Shape deformed

9. Cleaning Gluing Painting



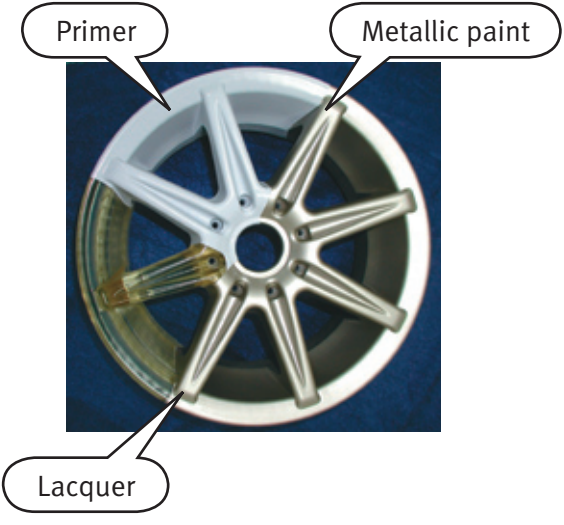


Cleaning, Gluing & Painting

Please find here enclosed simple instructions to clean, glue together and paint two parts built on the Eden RP system, after support removal on the WaterJet.

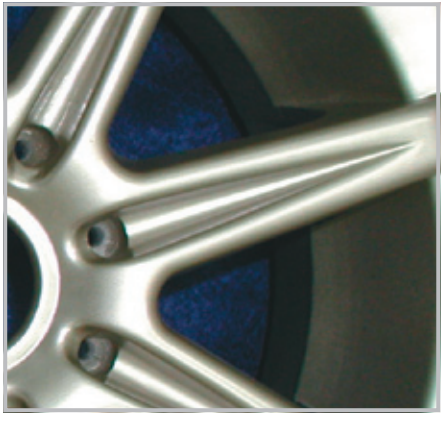
These techniques were used to create the following wheel hub from 4 separate parts built on 4 different Eden systems.

Cleaning, Gluing & Painting



4 invisible seams

Close up, no sign of seam



Gluing and Painting Instructions

The following document explains how this was done, using two simple rectangular models built on the Eden to facilitate viewing of the finishing technique.

Prepare the following materials (from left to right):

a) Sandpaper
b) Masking tape
c) “Exacto” knife utility blade
d) Crazy glue
e) Sodium bicarbonate
f) Small utensil to transfer sodium bicarbonate to seam
g) Propanol
h) Spray Paint or lacquer

Gluing and Painting Tools Required

Cleaning (after WaterJet)

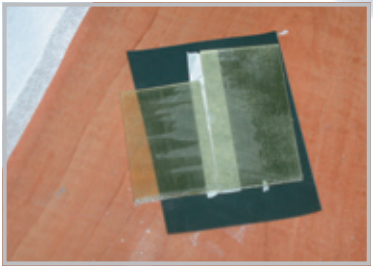
a) Use propanol to remove any residues of oil on the surface

a) Sodium Hydroxide (caustic soda) is also an optional cleaning procedure. However propanol is best for preparation for painting.
b) Acetone is not recommended.

Gluing 1

a) First clean with Propanol as mentioned above in Cleaning section 2.
b) You can use two different types of “Crazy Glue” (e.g. Loctite or other brands)
   1. Use liquid, instant glue, for an instant fit
   2. Use a gel for the ability to slightly move around the two pieces being fit together, to optimize the fit between the two parts
a) Use an “Exacto” knife to scrape both surfaces, to straighten surface and give a rough/granular surface to improve adhesion

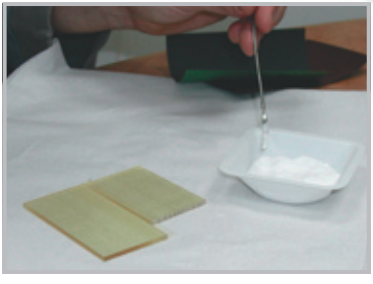
Gluing 2



d) Use masking tape to fix the two surfaces together from underneath

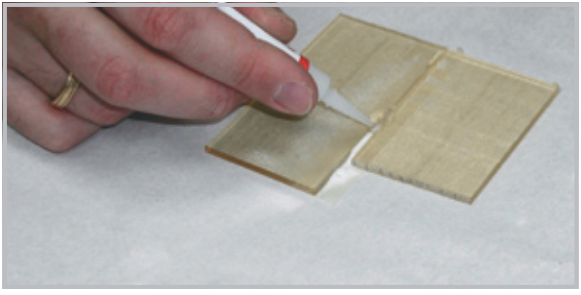
Note the two surfaces are laid down unevenly *intentionally* to simulate a case of uneven geometries or where the seam needs to be filled. With build accuracy of well below 200 microns in most cases, you will achieve in practice a much better fit than that shown

Gluing 3



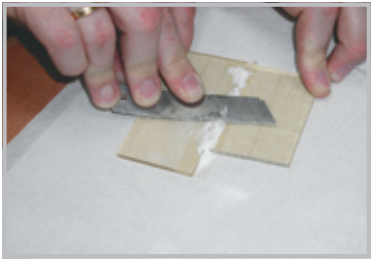
e) Fill the gap with powder sodium bicarbonate; there is no need to press or compress the powder, the small particles fill the gap.

Gluing 4



f) Pass instant gel glue over the whole gap and sprinkle a bit of sodium bicarbonate to completely fill the top surface of the seam.

Gluing 5



g) After a few minutes, scrape the surface of the seam in both directions (left to right, and up and down) again with the “Exacto” knife to remove any leftover material for the final finish.

Preparation for Painting or Lacquer

a) Use 400–600 grit sandpaper (with liquid soap and water to avoid sticking) to smooth surface

Preparation for Painting or Lacquer 2

b) Rinse with water
c) Clean surface with propanol (as mentioned at the start of the document)
d) For lacquer: paint on a layer of lacquer

Preparation for Painting or Lacquer 3

e) For paint: paint on a layer of primer
f) After surface is completely dry, paint with a quick drying paint (for example Krylon)

* It is not recommended to use epoxy-based paint which dries more slowly

Painting or Lacquer

Final painted parts

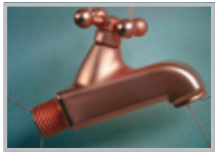
g) After surface is dry, protect paint with lacquer

For complicated geometries, use sandblasting (pellets) instead of sanding and then clean surface with propanol (#4) and continue with #5–8 above.

Due to super fine build layers and smooth surfaces, you get outstanding detail and excellent depth perception due to opaque surface. There is no sign of the seam.

10. Metal Coating






Metal Coating

Advantages of Room Temperature Electroless Nickel

- High Hardness
- Excellent Corrosion Resistance
- Vary coating thickness
- Good Wear Resistance
- Low Friction
- Applicable For Non-Metal Models
- Uniform Coating Thickness
- “Cold” Process

Typical Applications for Electroless Nickel?

- Mechanical Components
- Plastic Moulds, Dies, Screws And Fittings
- Household Equipment
- Automotive Components
- Medical Components
- Aerospace Components

Metal Coating

- Model prior to plating

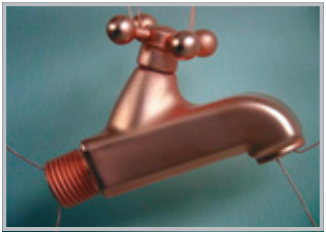
- Metallizing the Model

Metal Coating

- Sanded part after coating with 100 microns of copper

- Non-Conductive Spots

Metal Coating



- Nickel Coated Model

- Cooper Plated Model

Metal Coating

- About The Process: Recommended Polishing technique
- Most polishing processes starts with manual polishing by sandpaper, by the following order:
  - Polish using sandpaper grit #400.
  - Polish using sandpaper grit #600.
  - Polish using sandpaper grit #800.
  - Copper coating.
  - Polish using sandpaper grit #1000.
  - Buffing.
  - Nickel Coating.

Important Note: Surface smoothness is the key for glossy finish.

Metal Coating

- Examples of Plated Models

11. Dying Models

Dying

Benefits

- Quick
- Inexpensive
- Unlimited colors
- Retains translucency

Applications

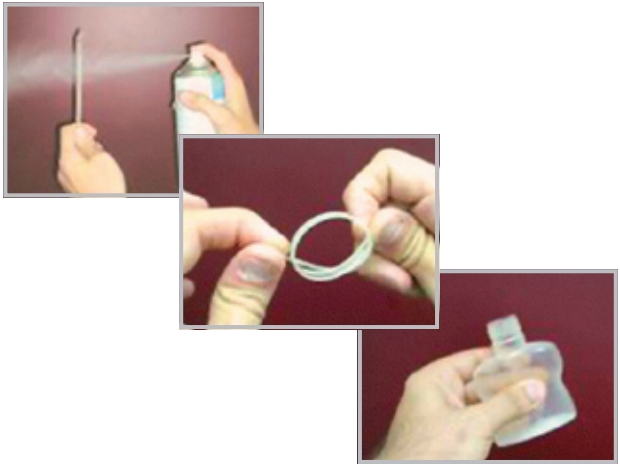
- Lenses
- Quick concept models

Dying

Dying Materials

- Use Leather Dye available in large color selection
- Clear Lacquer Recommended
- As alternative, add color pigments to clear lacquer spray.

12. RP Tempering



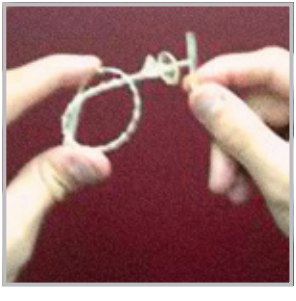
RP Tempering

RP Tempering Highlights

- Increasing parts' flexibility
- Heat resistance of 300° F (148° C)
- Avoid screw boss or snap features to break
- Avoid time-effect with RP
- Tempering coating

RP Tempering

Improved flexural modulus

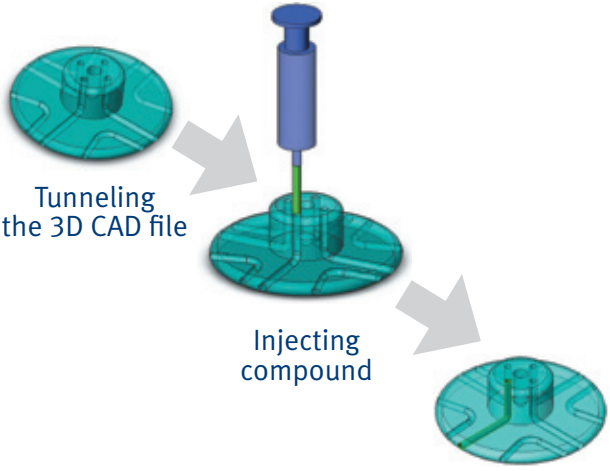


Improvement in Impact

Enhance stresses Improvement in Impact within RP part

RP Tempering – Tunneling

Tunneling: Increasing part flex, torsion while maintaining tensile or flexural modulus



Objet Geometries

Applications Guide

Third Edition

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