



PolyJet Materials

A RANGE OF POSSIBILITIES

By Stratasys

Materials are critical to prototyping and production success. At the heart of any great application is the right material: one that performs as needed under the application's conditions. This is just as true for 3D printing as it has always been for molding, machining and casting.

While the 3D printing industry has a wide variety of materials to choose from, ranging from plastic to metal and wax to paper, the selection is often quite limited for a given technology. It is even more restricted for specific 3D printers, with one exception.

PolyJet Materials

A RANGE OF POSSIBILITIES

3D printing using PolyJet™ technology produces highly realistic, functional 3D models in a wide range of materials with properties that span from rigid to rubber and opaque to transparent. In that range, there are materials that perform much like engineering plastics that combine toughness and heat resistance. Using PolyJet photopolymers, designers, engineers and artists can create highly accurate, finely detailed models to answer the prototyping needs of virtually any industry.

For many, PolyJet materials go beyond concept models and prototyping. In dental practices, PolyJet technology makes the tools and appliances used during treatment. In manufacturing, PolyJet photopolymers produce manufacturing aids like jigs and fixtures.

Spanning model-making to manufacturing, companies that use 3D printing need a wide-ranging portfolio of materials so they can match a material with the performance requirements of their intended applications. In a word, they need versatility.

3D PRINTING USING POLYJET TECHNOLOGY

PolyJet technology builds 3D objects by jetting fine droplets of photopolymers, materials that solidify when exposed to UV light. Although photopolymers are a different class of plastics than the thermoplastics and elastomers used in many production environments, they can simulate those materials mechanically, thermally and visually.

Across the PolyJet 3D printer lineup, there are 22 base resins that make the technology versatile. But what makes PolyJet technology truly stand out is its ability to not just combine multiple materials in a single part (multi-material 3D printing), but also to blend select base resins from the original 22 to create hybrid properties and colors. This is what is meant by 3D printing with Digital Materials, and it yields more than 360,000 distinct material options.

Several common traits span all these materials. PolyJet 3D printed parts have precision, high resolution and smooth finishes.

When printing is complete, parts can be used immediately after support material is removed — there is no need for post-curing. PolyJet

PolyJet Materials

A RANGE OF POSSIBILITIES



Figure 1. This full-color multi-material athletic shoe was 3D printed in one piece and represents a range of Shore A values.

photopolymers are also REACH-compliant and environmentally safe.

Material options and proven applications in the PolyJet world have expanded greatly in recent years, so it's reasonable to expect a great deal of experimentation among customers. For optimal success, it is important to understand the mechanics and best practices for PolyJet photopolymers and their corresponding 3D printing platforms.

BASE RESINS

PolyJet technology offers 22 base resins. By “base resins,” we refer to the unblended material, straight from the cartridge. In general, these may be used alone or blended in pairs or trios to create composite Digital Materials.

Considering the high resolution and smooth surface finish of PolyJet technology parts, these base materials are ideal for presentation and display models, form and fit prototypes, and patterns. While testing results will differ from those

PolyJet Materials

A RANGE OF POSSIBILITIES

Material options and proven applications in the PolyJet world have expanded greatly in recent years.

of production plastics, these materials are also used to simulate products in functional testing for early performance evaluations. Pure base resins 3D printed in high-quality mode offer the finest available PolyJet layer thickness: 14-16 microns, or about twice the width of a red blood cell.

Rigid Opaque

The Rigid Opaque collection of materials, a subset of the Vero™ family – is just what it sounds like: rigid and opaque (Figure 1). These seven materials are the most widely used for PolyJet 3D Printers. Rigid Opaque photopolymers are the multi-purpose materials for visual models, engineering prototypes, product assemblies and RTV molding patterns.

| VERO RIGID, OPAQUE MATERIALS | |
|------------------------------------|----------------|
| VeroGray™ | VeroBlackPlus™ |
| VeroWhitePlus™ and Vero PureWhite™ | VeroBlue™ |
| VeroYellow™* | VeroCyan™* |
| VeroMagenta™ | |

Compared with a common engineering plastic like standard ABS thermoplastic, Rigid Opaque photopolymers are stronger and stiffer when compared against industry averages for tensile strength, flex strength and flex modulus¹.

However, Rigid Opaque materials' total profile of characteristics is more similar to an acrylic than to an ABS, PC, polypropylene or polyamide. And this is why Rigid Opaque materials are generally designated for light functional testing, patterns, prototypes and models.

For aesthetics, the Vero family offers seven hues, which include blue, white, black, gray, cyan, magenta and yellow. Regardless of the color, all Rigid Opaque materials share similar mechanical, thermal and electrical properties. The medium shades of VeroBlue and VeroGray provide the best detail visualization, without glare or darkness, and VeroPureWhite, a PolyJet photopolymer that is twice as opaque, 20 percent brighter and more UV resistant than VeroWhite.

PolyJet Materials

A RANGE OF POSSIBILITIES



Figure 2. VeroClear produced these lenses.

TRANSPARENT/TRANSLUCENT

PolyJet technology offers two rigid materials that provide either translucency or transparency, RGD720 and VeroClear™. VeroClear has the same properties as the rest of the Vero family, and RGD720 is also strong and stiff.

RGD720: Rigid translucency

RGD720 is the original, multi-purpose PolyJet material. It is translucent with a slight amber tint. In thin walls, it approaches transparent, but as wall thickness increases, light transmission decreases.

RGD720 is used for form and fit evaluation of assemblies to visualize the placement and interface of internal components and features. It is

RIGID, TRANSLUCENT/TRANSPARENT MATERIALS

RGD720

VeroClear™

also used for visual analysis of fluid flow through a product. Other applications include models for artistic expression and substitutes for cutaway demonstration samples.

VeroClear: Rigid transparency

VeroClear has much in common with RGD720, but with its clarity, it is the first in the lineup of PolyJet materials that has a correlation with commercial thermoplastics. This clear, transparent material simulates PMMA (polymethyl methacrylate), which is commonly known as

PolyJet Materials

A RANGE OF POSSIBILITIES

acrylic or Plexiglas. Strength, stiffness, elongation and impact resistance all fall within the range of average values for PMMA¹. VeroClear's also can be enhanced further through post-processing options.

Like PMMA, VeroClear is used as an alternative to glass for lenses (Figure 2), clear covers, dispensers and light pipes for industries that include automotive, medical, electronics, signs and displays, sanitary ware and lighting fixtures. For the latter, note that VeroClear has a lower heat resistance than PMMA, so temperatures below 70 C (160 F) are recommended.

SIMULATED POLYPROPYLENE

Two PolyJet base resins simulate the characteristics of polypropylene: Durus™ and Rigur™.

Both are semi-rigid, strong and tough. Compared with Vero materials, these have nearly twice the impact resistance, three times the elongation and twice the flexibility. With these properties, both are used for models and prototypes of containers, packaging, toys, battery cases, laboratory equipment, loudspeakers and automotive components. These materials are especially useful

when prototypes have snap-fit components or living hinges — features that need to flex.

Durus and Rigur have similar flex moduli and hardnesses, and they match the average values for polypropylene¹. For all other properties, these materials are quite different, which extends the range of polypropylene characteristics that can be simulated.

SIMULATED POLYPROPYLENE MATERIALS

Durus

Rigur

Durus: Semi-rigid and tough

Durus is the original Stratasys offering for prototyping semi-rigid polypropylene products that can withstand contact forces and give when pulled. Durus is a milky white color.



Figure 3. Rigur material was engineered for prototyping polypropylene products.

PolyJet Materials

A RANGE OF POSSIBILITIES

Rigur: Semi-rigid and strong

This PolyJet material has been formulated for improved dimensional and visual characteristics as well as greater strength. Parts made from Rigur are bright white (Figure 3) and have better surface finishes than Durus. This makes Rigur great for visual applications, and its higher temperature resistance (three times that of Durus) and strength (twice that of Durus) make it a good choice for form, fit and light functional testing of parts that will be produced in polypropylene.

RUBBER-LIKE

The Tango™ family of PolyJet materials simulates thermoplastic elastomers with flexible, rubber-like qualities. Use PolyJet rubber materials for visual, tactile and functional applications such as non-slip surfaces, soft-touch interfaces and sealing faces.

| POLYJET RUBBER-LIKE MATERIALS | |
|-------------------------------|--------------|
| TangoBlackPlus™ | Tango Black™ |
| TangoGray™ | TangoPlus™ |

Applications include rubber surrounds, overmoldings, buttons, knobs, grips, gaskets and boot and hose assemblies. PolyJet rubber material is also used for prototyping outsoles for footwear.



Figure 4. The rubber pads on these headphones have a soft Shore A value of 27. The full model was 3D printed in one piece.

There are four materials in the Tango family, offering hardnesses that range from 27 to 75 on the Shore A scale, which is comparable with rubber bands to tire treads and shoe heels. Rubber-like materials come in black (Figure 4), gray and a semi-translucent off-white.

MEDICAL AND DENTAL

PolyJet photopolymers have expanded beyond their roots as a tool for engineers and designers to become a leading 3D printing technology for medical and dental applications. Recognizing the unique needs of the medical arts, Stratasys has formulated six materials specifically for medical and dental applications.

PolyJet Materials

A RANGE OF POSSIBILITIES



Figure 5. VeroGlaze produces functional dental veneer try-ins.

Property-wise, these materials are nearly identical to Rigid Opaque. The one exception is stiffness, which is nearly 50 percent greater, so these materials are strong and very rigid.

For dental applications, there are four materials.

VeroDent

VeroDent™ has a natural peach tone and is primarily used for dental models generated from patient scans or impressions.

VeroDentPlus

VeroDentPlus™ is also used for dental models, but it comes in dark beige and offers improvements in detail resolution and surface finish.

VeroGlaze

VeroGlaze™ has an opaque, white color that is listed as an A2 in accordance with the Vita shade

guide used in dentistry. The shade and properties make VeroGlaze an ideal material for realistic veneer samples (Figure 5) that allow the patient and doctor to visualize the results of a prosthetic prior to performing the treatment.

Bio-compatible

Bio-compatible material is used by both medical and dental professionals when the 3D printed part will have bodily contact. It has five approvals: cytotoxicity, genotoxicity, delayed type hypersensitivity, irritation and USP plastic class VI. With these approvals, Bio-compatible material can be used for direct skin (up to 30 days) and short-term mucosal-membrane contact.

MEDICAL AND DENTAL MATERIALS

| | |
|------------------------------|----------------|
| VeroDent | VeroDentPlus |
| VeroGlaze | Bio-compatible |
| Hearing Aid (rose and clear) | |

This clear, colorless material is suitable for orthodontic appliances, delivery and positioning trays, dental try-ins and surgical guides.

Hearing Aid materials are used to rapidly manufacture accurate hearing aid molds with smooth, comfortable surfaces. The hearing aid

PolyJet Materials

A RANGE OF POSSIBILITIES

materials are available in two colors, clear and rose clear, and they have received medical certification.

ENGINEERING PLASTIC SIMULATION

Five PolyJet materials simulate engineering plastics, which expands the application base further into functional testing and manufacturing tools.

| ENGINEERING PLASTIC SIMULATION MATERIALS | |
|--|------------------------------|
| High Temperature | Digital ABS (green or ivory) |
| Digital ABS2 (green or ivory) | |

Four of the five are Digital ABS™, and these are discussed in the Digital Materials section. The fifth is a material that can take the heat.

High Temperature: Stiff and strong

As its name indicates, this material is for applications that have elevated temperatures. Straight from the 3D printer, High Temperature material has up to a 55°F higher heat deflection temperature (HDT) than any other PolyJet base resin. With an optional thermal post cure, HDT climbs to 80°C (176°F), which is close to that of an average ABS¹.



Figure 6. High Temperature material can withstand hot fluids.

But thermal resistance isn't its only advantage. High Temperature also has 150 to 200 percent of the strength and rigidity of the average ABS values. Even its impact strength reaches the low end of all ABS materials¹.

High Temperature is a wise choice for functional testing with hot air or water, such as evaluations of plumbing fixtures and household appliances (Figure 6). Temperature resistance may also be a consideration for show pieces that will endure intense, hot lights. If temperature isn't a consideration, High Temperature may be a good choice for prototypes that need very high stiffness and strength.

PolyJet Materials

A RANGE OF POSSIBILITIES

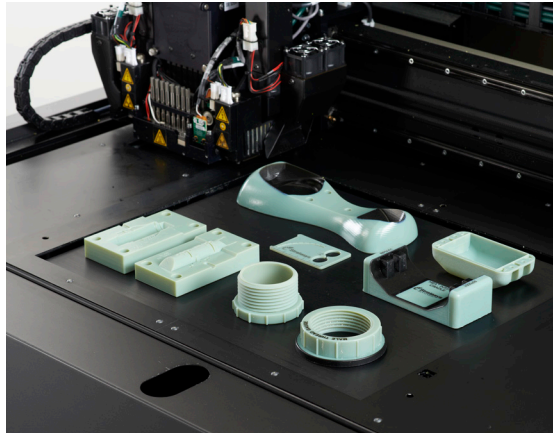


Figure 7. Digital ABS in green produced all these functional items (clockwise from left): low-volume custom injection mold; pocket tool; assembly fixture based on product geometry; housing prototype and mating cradle fixture; and two precise threaded check gauges, each complementing a production part to test accuracy. Rubberized surfaces and text were 3D printed directly onto the parts using TangoBlackPlus.

DIGITAL MATERIALS

PolyJet Digital Materials are composites created by simultaneous jetting of up to six materials from the material portfolio of 22 base resins. By blending materials in specific concentrations and matrices, PolyJet technology offers a wide palette of properties and visual characteristics.

Digital Materials are exclusive to a subset of PolyJet-driven 3D printers. See details in “3D Printers,” page 11.

Digital ABS: Rigid, tough and opaque

Digital ABS extends the simulation of engineering thermoplastics beyond the thermal resistance,

toughness and transparency of High Temperature, Rigur and VeroClear. As its name indicates, this material closely approximates ABS. Compared with the averages for ABS¹, Digital ABS has the same or higher values for strength, flexibility, durability and heat resistance. Its impact resistance is below average for ABS¹ but still within the range of all ABS offerings, and three times that of Vero.

Four Digital Materials simulate ABS. They are Digital ABS and Digital ABS2, both in green and ivory. The primary difference between them is that Digital ABS2 retains its rigidity and toughness in thin-walled parts (< 1.2 mm/0.04 in.). This makes Digital ABS2 ideal for consumer electronics and other consumer goods, including small appliances and cell phones, which require high stability with thin-walled geometries.

All of the Digital ABS materials can be used for functional prototypes — even those with snap fits — patterns, prototype tooling for injection molding and manufacturing aids such as jigs, fixtures and gauges (Figure 7).

Rubber: Varying flexibility

By blending rubber materials with Digital ABS or Rigid Opaque, the range of properties expands

PolyJet Materials

A RANGE OF POSSIBILITIES



Figure 8. Various colors and Shore A values are displayed on this palette.

dramatically, from soft-touch with subtle color to decidedly un-rubber-like materials that offer 10 Shore A hardness values ranging from 35 to 100. Counting the options for color, there are hundreds of digital material options for rubber.

This range of rubber-like properties is unrivaled in the 3D printing industry. With it, designers and engineers can match the flexibility of production elastomers or test a number of slightly different options to find just the right feel (Figure 8).

Colors and Tints: Product realism

Digital Materials extend more than the range of material properties. They offer a large palette of opaque colors and translucent tints. For rigid plastics, there are thousands of unique color options, some of which can be created using

either a rigid or rubber base resin, which increases the possible combinations of total properties in a single part.

3D PRINTERS

PolyJet-driven 3D printers offer a range of capabilities, all using the same jetting technology. While all offer high-resolution, smooth-finish parts that require no post-printing curing and little effort for support removal, the family of printers differs in the type and number of materials available and the number of materials that can be simultaneously jetted.

Objet® and Objet Eden: One material at a time

These systems print with one base resin at a time. The number of supported materials ranges from one to 15. Systems include the Objet24, Objet30, Objet30 Pro, Objet30 Prime, Objet Eden260VS.

OBJET AND OBJET EDEN MATERIALS

| | |
|--|-----------------------|
| Rigid Opaque | RGD720 |
| Durus | Rigur |
| Rubber-like | High Temperature* |
| Bio-compatible | VeroDent/VeroDentPlus |
| VeroGlaze | Hearing Aid |
| *Excludes VeroCyan, VeroMagenta and VeroYellow | |

PolyJet Materials

A RANGE OF POSSIBILITIES

Connex3: Setting the standard for prototyping

Objet500 Connex3, Objet350 Connex3 and Objet260 Connex3 add three-component blends to the portfolio of materials possible. The result: more than 1,000 material options in a spectacular range of colors and mechanical properties. To create the broad color options, Connex3 uses VeroCyan, VeroMagenta and VeroYellow. Connex3 can build as many as 82 materials into one part or mixed tray. The optional Stratasys Creative Colors software, powered by Adobe, brings the number of color options per part up to 1,000 and enables gradients and color textures, as well as a streamlined workflow ideal for parts with complex color features.

Material options

- 17 base materials
- All Rigid Opaque colors
- 127 Digital Materials including a range of durabilities, translucencies and shades; dozens of Simulated Polypropylene and High Temperature materials in rigid and flexible composites
- 1,000 rigid color materials that result from pairs or trios of Vero, and, with optional Stratasys Creative Colors software, many more subtle options that fall between these designated Digital Materials
- 237 flexible colors, each unique in its combination of color and Shore A value
- 12 strong and durable blends of Digital ABS with rubber for Shore A values of 35 to 100 in a variety of shades.

Stratasys J750: The Breakthrough Solution in Realism, Versatility and Efficiency

The Stratasys J750 is the only true full-color 3D printer that delivers the best aesthetics and material properties. This 3D printer features new PolyJet print heads and runs six base resins simultaneously. Full-color parts can incorporate a range of flexible Shore A values or translucencies along with the ability to print more than 360,000 colors. The Stratasys J750 offers finer layers compared with previous PolyJet capabilities with 14-micron layer lines in high-quality mode. It is the fastest multi-material 3D printer, printing two- and three-component Digital Materials in high speed, giving it high efficiency and a lower cost per part with virtually no need for material changeover. It also features a new intuitive interface, PolyJet Studio, where texture mapping and gradients can be used for photorealistic detail that transfers directly from designer's native software.

Material options

- 14 base material options (including Vero PureWhite)
- 127 Digital Material options (See Connex3)
- More than 360,000 color options when cyan, magenta, yellow, black and white are loaded
- 237 flexible colors, each unique in its combination of color and Shore A value
- 12 strong and durable blends of Digital ABS with rubber for Shore A values of 35 to 100 in a variety of colors
- Thousands of transparent and translucent colors

CONCLUSION

PolyJet technology delivers a large portfolio of material possibilities to meet the 3D printing needs of a wide range of industries and a diverse set of requirements in design, engineering, manufacturing and artistic applications.

Through color and properties, product realism is possible well before a product launch. With more than 360,000 options, PolyJet materials offer the versatile 3D printing solution that lets you see, touch, feel, test, analyze and use new products that have thermoplastic or elastomer characteristics.

1. Source: MatWeb.com



info@stratasys.com

STRATASYS.COM

HEADQUARTERS

7665 Commerce Way, Eden Prairie, MN 55344

+1 800 801 6491 (US Toll Free)

+1 952 937 3000 (Intl)

+1 952 937 0070 (Fax)

2 Holtzman St., Science Park, PO Box 2496

Rehovot 76124, Israel

+972 74 745 4000

+972 74 745 5000 (Fax)

stratasys[®]

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