Multi-material 3D printing creates parts that simulate finished products, which improves functional evaluations and overall appearance. Using PolyJet™ multi-material technology, a single part can have a variety of mechanical properties, opacities and colors (Figure 1).

The Connex family of 3D printers uses several base resins that are simultaneously blended to create digital materials. These materials are capable of making parts with a broad range of characteristics, including more than 1000 color options (Figure 2). This gives designers and engineers a single-operation prototyping choice for parts that would otherwise require multiple fabrication steps.

Multi-material 3D printing reduces the time and expense for design evaluation of prototypes that combine multiple properties such as rigid, rubber-like, overmolded, clear, or colored features. It also increases the utilization and cost-effectiveness of the 3D printer by reducing downtime for material changeovers and increases the variety of material characteristics produced in a single build.

Ultimately, the multi-material capability of the Connex™ 3D Printing System offers users the ability to make parts with final-production features and characteristics, simply and quickly, without the need for additional processing or assembly steps.

![Figure 1: Multi-material, multi-color bicycle helmet made with Connex3 3D Printing System.](image1.png)

![Figure 2: Example of color and transparency options available with rubber-like materials.](image2.png)
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1. Process Overview

Creating parts with multiple material properties in a single operation is unique to 3D printing. The only requirement for PolyJet multi-material printing is that a digital model must be separated into discrete shells with materials assigned to them.

2. Connex Technology

Multi-material printing requires a PolyJet Connex platform that can simultaneously jet two or three model materials during the 3D printing operation (Figure 3). This allows parts to have material properties ranging from rigid to flexible and clear to opaque in a wide range of colors and hues.

The Connex multi-material capability facilitates better realism of prototype parts, especially in the following areas:

- **Functionality**
  With many different digital material options available, prototypes can simulate final-production parts with combinations of rigid and rubber-like properties along with strong and durable materials (Figure 4). Creating prototypes with these characteristics in a one-step process is not possible in any other way.

- **Appearance**
  With over 1,000 colors, hues and tints available*, prototypes have the appearance of production parts. Prototypes may also incorporate 3D printed text, logos and graphics (Figure 5).

* The number of materials and colors is dependent on the Connex platform used.
2.1. Printing options

Connex multi-material technology offers three options:

- **Mixed tray**
  With this option, parts within a single build will be made with different materials (Figure 6). This eliminates the need for material replacement between builds and allows simultaneous printing of parts with different properties. Mixed tray operations can dramatically reduce operating costs, improve capacity and enhance responsiveness to part requests.

- **Mixed part**
  This option prints a part or assembly that has varying material properties in user-specified regions. The printed model offers product realism, such as rigid parts with overmolded, soft-touch grips (Figure 7). Mixed parts eliminate the need for printing individual pieces and gluing them together. This approach also offers dramatic savings in printing and post-production processing.

- **Digital Materials**
  Digital materials are composites that are created by blending two or three model materials (Figure 8). They can be used in both mixed-tray and mixed-part modes. There is a wide selection of digital materials that produce parts with a range of physical, mechanical and visual properties. See Section 3 for more details.

3. Digital Materials

PolyJet Digital Materials are multi-phase composites created by the simultaneous jetting of multiple model materials. The main objective of digital materials is to combine different PolyJet resins to produce a new material with attributes that are not available in the individual constituents. The result is a range of materials with improved mechanical and visual characteristics not available in single-material formulations.

For example, digital materials produce parts that can be transparent to opaque, with any degree of translucency in between. They can also be a single color or a combination of hues, with textural and structural qualities that range from soft and flexible to hard and rigid (Figure 9).

The selection of digital materials is made through dedicated software that determines the appropriate jetting parameters. The materials are created automatically during printing.

4. Multi-Material Applications

4.1. Rubber simulation

Digital materials are available with flexible, rubber-like properties in a wide range of Shore A hardness values (Figure 10). This allows for the simulation of many types of rubbery parts. Also, a part can have regions with different hardness values, which range from Shore A 27 to Shore A 95.

Example applications include seals, gaskets, tires and footwear soles.
4.2. Translucence

Using combinations of transparent and opaque materials, parts are produced in a range of translucent colors (Figure 11). Translucence is available with both rigid and rubber-like materials.

Uses include medical devices, human organ models, display panels and sunglass lenses.

- **Note**
  
  For the best results, translucent models should be polished after printing and support removal.

4.3. Overmolding

Overmolding is growing in popularity because of the benefits of incorporating multiple textures on parts to enhance feel, appearance and durability.

Connex technology revolutionizes this process by jetting multiple materials to create both rigid and flexible surfaces in a single build process (Figure 12). A model can be constructed quickly and affordably, which is ideal when the design is still in flux. This solution is much less costly and time consuming than the alternatives, so it is rapidly replacing injection and RTV molding for overmolded prototypes.

Several applications include power tools, medical devices, consumer electronics, and jigs and fixtures.

4.4. Living hinges

A living hinge is a thin, flexible connection made from the same material as the parts that it joins together.

Products with living hinges are typically injection molded plastic and are commonplace in disposable packaging. However, multi-material 3D printing provides a faster and less expensive prototyping option to injection molding. Simply select a low durometer material for the hinge and print it with the two rigid pieces it connects.

Typical uses include caps, closures, clips and clamps.

4.5. Labeling and texturing

Texturing and labeling are used to enhance appearance and for identification purposes (Figure 14). By utilizing Connex multi-material capability, prototypes exhibit true-to-life, end use product characteristics.

The unique combination of color scaling and excellent printing accuracy of the Connex multi-material system allow for precise labeling and marking.

This application is used with product identifiers, branding and instructions for use.
5. Design (CAD)
Multi-material printing begins with the creation of a CAD model that provides the digital definition for the 3D printing process.

If the entire part will have a uniform coating using a second PolyJet material, skip to Section 6.3.

5.1. Create a multi-bodied assembly (CAD).
To assign materials to regions of a part, the Objet Studio™ software needs each region represented as a separate shell. This is achieved by segmenting the CAD model into discrete solid bodies. In effect, a single part becomes an assembly with one “component” for each material.

Model each region of the part so that they are flush with no gaps and no overlaps between adjacent regions. Do not union adjacent regions with different material properties in a Boolean operation. Instead, allow them to be separate CAD entities.

When modeling is complete, export the CAD model using the option that saves each component of an assembly as a separate STL file (Figure 15).

Alternative file format - VRML
Prior to exporting the CAD model, assign color values to each part in the assembly. This is often completed using an appearance-editing function. The colors assigned in the CAD model should match the specific color combinations provided in the PolyJet color pallets (ie., CMY, CMK, MYT etc.).

After assigning all colors to the assembly, save the file in VRML (virtual reality modeling language) format. From the export options, select the VRML 97 format and check the option to save the assembly in a single file.

5.2. Create text (optional).
The multi-material function may be used to print text and artwork in a material with a contrasting color or different material properties.

- Improve legibility.
  Create text no smaller than 0.8 mm (0.03 in). PolyJet can produce smaller text, but it will have a translucent quality that diminishes legibility.

  Also embed text and similar graphical features in the main body of the part to maintain opaqueness (Figure 16). When modeling is complete, export the CAD model as multiple STL files, then proceed to Step 6.

5.3. Create a multi-bodied assembly (STL software).
If a CAD model is created as a single body, STL manipulation software, like Materialise® Magics, may be used to create the shells that Object Studio requires for material assignment.

Begin by importing the STL file. Then select each material region and split it from the body of the STL. Note that this action will yield an open shell
that must be closed using the software’s repair functions. The following instructions are specific to the Materialise Magics software application.

- Import the STL file.
- Create the shell for region 1.
  - Select Marking > Surface and select the surface for the region (Figure 17).
  - Select Separate Marked from the options in the window (Figure 18).
- Repeat the prior step for all regions.
- Repair each region to make them watertight STLs.
- Save each region as a separate STL file (Figure 19).

6. File Processing


6.1.1. Import files.

Import the STL files into Objet Studio to prepare them for 3D printing. If STL manipulation software was used to create the solid bodies, import all of the STL files using the Import as an assembly command.

6.1.2. Create separate shells.

Select the part, and then separate the files into shells (Model > Separate to Shells icon) (Figure 20). Skip this step if STLs for each region have been created in a CAD or STL manipulation software program.

6.1.3. Assign materials.

Select a shell from the Model Tree, or select it by clicking on the STL file, and assign the desired material using the material dropdown menu.

Repeat the selection and material assignment for all shells.


6.2.1. In Objet Studio, make sure the specific materials that were chosen in the CAD process are loaded in the printer.

6.2.2. Import files

Import the VRML assembly file into Objet Studio to prepare them for 3D printing. When colors have been assigned to the bodies in the VRML, Objet Studio will automatically assign a best-match color to each shell.

6.2.3. Reassign colors (optional).

After reviewing the colors automatically assigned to each body, manually reassign colors to each shell as needed. To do this, select the shell from the Model Tree, or select it by clicking on the STL file. Then select the desired color from the color palette.
6.3. Apply coating (optional).

The coating function in the Objet Studio software applies a thin layer of material over the entire part. For example, this may be used to add a rubbery coating or a tinted, translucent layer.

Select the STL file and then select **Coat With** from the toolbar (Figure 21). A dialog box opens for the selection of the material and specification of the coating thickness, which may be between 0.3 mm and 3.0 mm (0.012 in and 0.118 in).

Note that the coating function does not increase the size of the part. The combination of the base and coating material will match the dimension in the STL file.

6.4. Set surface finish.

For vibrancy, high contrast and good visibility of text, labels and graphics, orient the part such that these features are facing upward and select the **Glossy** finish (**Left click > Glossy**).

For most other applications, and especially when working with color, select **Matte finish** for uniform surface appearance (**Left click > Matte**).

7. Key Process Considerations

### Table 1: Common obstacles and resolutions.

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<th>Resolution</th>
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<td><strong>Uneven appearance</strong></td>
<td>Variation in color or appearance between matte and glossy surfaces.</td>
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<tr>
<td><strong>Color bleeding</strong></td>
<td>Dark colors bleed through lighter colors.</td>
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<tr>
<td><strong>Variable properties</strong></td>
<td>Where shells overlap, unintended color, transparency and mechanical properties result.</td>
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7.1. Resolution details:

- **Tray parameters:**
  - Orient parts such that visual surfaces do not have support material contact.
  - Set printing mode to **Matte**.

- **Part Design:**
  - Split the file into one or more STLs to allow each piece to have all visible surfaces in an upward-facing direction when using **Glossy** finish.
  - Adjust the thickness of exterior bodies/shells to prevent bleedthrough, using a minimum thickness of 2 mm (0.8 in) when colors have a high contrast.
  - Perform Boolean operations so that adjacent bodies do not overlap.
8. Tools And Supplies

8.1. Required items:
- 3D CAD software
- Objet Studio

8.2. Optional items:
- STL editing software such as Materialise Magics, netfabb Professional or equivalent

9. Recap – Critical Success Factors

9.1. Actions:
- Separate CAD model into shells/bodies.
- Eliminate gaps and overlaps between shells/bodies.

9.2. Eliminate obstacles:
- Avoid support material on visual surfaces.
- Split the STL file and bond parts in post-processing.

Figure 22: Bicycle seat with printed pressure color map.
POLYJET MULTI-MATERIAL 3D PRINTING

CONTACT
For questions about the information contained in this document, contact Stratasys at www.stratasys.com/contact-us/contact-stratasys.