# White Paper

# PolyJet Matrix™ Technology
# A New Direction in 3-D Printing

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## ABSTRACT

The Connex500™ is the first 3-D printing system that jets multiple model materials simultaneously. It offers the completely unique ability to print parts and assemblies made of multiple model materials, with different mechanical or physical properties, all in a single build.

The Connex500™ can also fabricate Digital Materials™ on the fly, enabling users to create composite materials that have preset combinations of mechanical properties.

Based on Objet's PolyJet Matrix™ Technology, the Connex500 simultaneously prints two FullCure model materials and creates 21 types of Digital Materials.

By printing with Digital Materials, the Connex500™ allows printing parts with specific Shore A values to match the values of the intended production materials. This capability opens up new opportunities, bringing much closer to realizing the final product at an early stage, including feasibility testing and over-molding process simulation

## INTRODUCTION

PolyJet Matrix™ Technology is the first technology that enables simultaneous jetting of multiple types of model materials. PolyJet Matrix opens up new opportunities for emulating even the most complex end-products more closely, in less time and at lower cost than ever before.

Furthermore, PolyJet Matrix presents a paradigm shift to the industry as it enables the use of two model materials for the creation of multiple model materials on demand and on the fly.

### How PolyJet Matrix Technology Works

PolyJet Matrix Technology works by jetting two distinct Objet FullCure® model materials (please refer to image 1). The technology can work with any mix of rigid and flexible materials. As an example two rigid materials, two flexible materials, or any combination with transparent material would in turn either creates a mixed part or Digital Materials. For the benefit of the customer it can also use two cartridges of the same material.

PolyJet Matrix technology enables printing parts and assemblies made of multiple model materials, all in a single build. Each material is funneled to a dedicated liquids system connected to the PolyJet Matrix printing block, which contains 8 printing heads. Every head includes 96 50-micron diameter nozzles. Each material has two designated printing heads that are controlled to a perfect synchronization.

The technology controls every nozzle in every print head independently, enabling preset combinations of model materials to be jetted from designated nozzles according to location and model type. The ability to manage the jetting matrix in high precision provides full control of the structure of the material and, hence, of its mechanical properties. This enables the user to choose and fabricate the most suitable materials that most closely emulate the target design.

The created composites are Digital Materials™ which are composed of repeated microscopic building blocks that determine the material's mechanical properties (see Digital Materials below).

In summary, Digital Materials, innovation are composite materials that are fabricated on the fly by the PolyJet Matrix technology process. Based on this method, a wide variety of Digital Materials can be created, each material differing in tensile strength, elongation to break, HDT and/or even in Shore A flexibility.

In addition, the combination of black and white rigid materials (FullCure VeroWhite™ and FullCure VeroBlack™ respectively) generates new materials with a wide range of grayscales

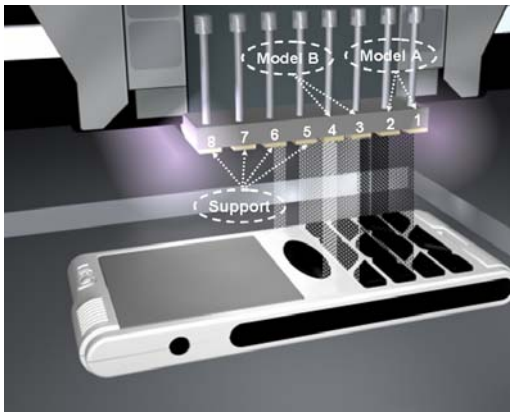


**Image 1**: PolyJet Matrix printing block, built from 8 printing heads.
Heads 1 & 2 jet model material A, while heads 3 & 4 jet model B. Heads 5-8 jet the support material

## FullCure Materials

PolyJet Matrix technology uses Objet's FullCure materials in the printing process, enabling fully cured models that can be handled immediately after print. This is a unique advantage over other RP technologies and materials, which all require lengthy post processing treatments.

Objet's FullCure family of proprietary acrylic-based photopolymer materials enables Objet users to create highly accurate, finely detailed 3-dimensional models and parts for a wide range of applications.

The wide variety of resins within the FullCure family, including those with flexible, rigid transparent, colored and opaque properties, enables models that meet a wide range of fit, form, function and "feel" requirements. FullCure Support material, used in combination with any FullCure Model material, enables models with an unlimited array of complex geometries, including overhangs and undercuts.

All FullCure Model and Support materials are environmentally safe, requiring no skin contact or eye/respiratory exposure to fumes or material. Loading and unloading is similar to the process of installing and removing inkjet cartridges from a paper printer.
The FullCure Tango series of model materials supports new applications by providing different levels of flexibility and elasticity while the FullCure Vero family of model materials makes it possible to produce opaque rigid models. Objet also offers the FullCure720, transparent material.

## Digital Materials

Composite materials have been in use for many years and today are used in many industries, from building construction to sports equipment and aircraft manufacturing.

Objet's Digital Materials are multi-phase composite materials fabricated by PolyJet Matrix technology. Just as composite materials, the main objective of Digital Materials™ is to combine different materials to produce a new material with attributes that are not available in the individual constituents and are unattainable by gradient mix of materials.

Digital Materials are generated on-the-fly based on the two distinct modeling materials that are installed in the system. The selection of the Digital Material is made by the user through dedicated software that determines the appropriate jetting parameters. The materials are created automatically during printing, without any human interference.

Digital Materials have different mechanical and physical properties (as referred in table 1) than the single FullCure modeling materials. This rich set of materials improves upon the mechanical properties of the existing rigid materials - new values of Tensile strength, Flexural strength and Izod Impact. Rubber-like Digital Materials demonstrate new Shore A values that creates new opportunities for many applications.

For example, when the process combines a FullCure rigid material (FullCure720 or Vero family) and a rubber-like material (Tango family), the generated Digital Material will be tougher than the individual materials from which it is comprised.

Other Digital Material™ combinations would yield materials with different Shore A values.

| Materials | Main Characteristic |
|---|---|
| *TangoBlack+VeroWhite* | |
| DM_9110 | Shore 80; Tensile Tear Resistance 7.9 N/mm; Color: Black; **Flexible** |
| DM_9120 | Shore 85; Tensile Tear Resistance 14.6 N/mm; Color: Black; **Flexible** |
| DM_9130 | Shore 95; Tensile Tear Resistance 47.4 N/mm; Color: Gray80; **Flexible** |
| DM_8110 | Izod Impact 26.2 J/m; Color: Gray25; **Rigid** |
| DM_8120 | Izod Impact 25.8 J/m; Color: Gray40; **Rigid** |
| DM_8130 | Izod Impact 34.6 J/m; Color: Gray60; **Rigid** |
| *TangoBlack+VeroBlue* | |
| DM_9210 | Shore 80; Color: Black; **Flexible** |
| DM_9220 | Shore 85; Color: Black; **Flexible** |
| DM_9230 | Shore 95; Color: Black; **Flexible** |
| *TangoBlack+VeroBlack* | |
| DM_9310 | Shore 80; Color: Black; **Flexible** |
| DM_9320 | Shore 85; Color: Black; **Flexible** |
| DM_9330 | Shore 95; Color: Black; **Flexible** |
| *TangoBlack+FC720* | |
| DM_9410 | Shore 80; Color: Black; **Flexible** |
| DM_9420 | Shore 88; Color: Black; **Flexible** |
| DM_9430 | Shore 95; Color: Black; **Flexible** |
| *TangoGray+TangoBlack* | |
| DM_9510 | Shore 65; Color: Gray80; **Flexible** |
| *TangoGray+VeroBlack* | |
| DM_9610 | Shore 80; Color: Gray80; **Flexible** |
| *VeroBlue+VeroBlack* | |
| DM_8210 | Color: Gray65; **Rigid** |
| *VeroWhite+VeroBlack* | |
| DM_8310 | Color: Gray25; **Rigid** |
| DM_8320 | Color: Gray35; **Rigid** |
| DM_8330 | Color: Gray55; **Rigid** |

**Table 1**: 21 types of Digital Materials with different physical and mechanical properties

## First Commercial Implementation: Connex500 3-D Printing System

The Connex500 3-D printing system is the first product that integrates PolyJet Matrix Technology. The Connex500 brings Objet and the 3-D printing industry closer to production and prototyping of the final product, regardless of its material or geometrical complexity.

Connex500 enables parts to be printed simultaneously from multiple materials in a single run (Image 2).

**Image 2:** All the razors in the image were printed simultaneously in a single run, within 12 hours. Every razor is composed of different materials (including Digital Materials) with different mechanical properties (rigid and flexible). These prototypes undergo feasibility tests and assist in defining the end-product's final materials

This capability opens up new opportunities for users, bringing them much closer to realizing their final product at an early stage, including feasibility testing and over-moulding process simulation.

The Connex500 simultaneously prints parts with different mechanical properties. This capability enables the user to test printed prototypes that are very close to the production part in terms of mechanical properties and material combinations, e.g. over-moulding and double injection. Thus it aids in selection of the production materials that will be used in the final product (Image 3). This process saves days of simulating and preparing complex and expensive moulds for double injection. It also eliminates the need for silicon moulds and preparation of different end-product materials for testing by enabling most of the testing to be done on early stage prototypes printed overnight on the Connex500. This capability improves communication between different groups and decision makers in the company, such as R&D, internal/external customers, engineering, marketing, sales and management


**Image 3**: All three razors in the image were printed simultaneously in a single run, within 2 hours. Every razor is composed of different materials including Digital Materials

The Connex500 offers three printing modes:

- Digital Material (DM) printing mode operates at 12 mm per hour in 30 micron-layers, providing the ability to print parts made of multiple model materials including Digital Materials.
- High Quality (HQ) printing mode builds parts at 12 mm per hour in 16-micron (0.0006 inch) layers.
- High Speed (HS) printing mode runs at 20 mm per hour in 30 micron (0.001 inch)-layers.

The Connex500's build volume is 500 x 400 x 200 mm (19.7 x 15.7 x 7.9 inches), eliminating the need to glue together smaller pieces for large models and enabling simultaneous printing of multiple models on a single build tray, cutting production time for models of all sizes.

Printing 600 x 600 dpi in both the X and Y axes, the Connex500 enables thin walls down to 0.6mm, fine details in all dimensions, and a smooth surface finish, assuring high quality for every part. Highly precise printing, with a maximum tolerance of 0.3mm over large models, ensures repeatability and accuracy.

The Connex500 supports four sealed 3.6kg (7.9 lb.) jumbo cartridges of material, allowing unattended operation for extended periods. The system enables the loading of 2 different model material types when using the DM printing mode.

### Mixed parts

The Connex500 is capable of printing a multi-material part in a single build. This capability eliminates the need to design and print separate models using different materials and then put them together in a post process such as gluing. In addition, using multi-material models reduces the time and costs associated with errors in preparing complex moulds for double injection. That can be a significant saving as double injection moulds can be five times more expensive than standard moulds.

### Mixed tray

In order to maximize system yield, the Connex500 has the ability to simultaneously build varied material parts on a single tray and thus meet more

needs faster. Using this feature increases the system's efficiency, as it enables multiple users to build varied models at the same time and then select the most suitable model.

In addition, mixed tray printing increases printing efficiency by enabling jobs of various materials to be printed simultaneously and saves in resin replacement time and material

## Main Applications

### Over molding parts and double injection process simulation

The ability to combine rigid materials and flexible rubber-like materials is a real necessity for applications that have a rigid body with areas of flexible material for grips and protection of the mechanism, and thus require a double injection production process. Examples of this pressing need exist in most of the current products in consumer goods and electronics, automotive, shoes and medical industries. The Connex500 parts are the first tangible tool for simulating double injection moulds (image 4).


**Image 4**: A GPS device printed in a single run emphasizes an over-molded part. In this case, the rubber-like and rigid materials printed on the Connex500 at the same time eliminate the need for providing separate silicon molds of different materials and gluing them together, a process that normally takes several days to perform

### Coating

Printing FullCure Tango over FullCure Vero can create flexible moving parts, such as levers and hinges, for close simulation of the look and feel of rubber-coated products.

The Connex500 user can define, using the Objet Studio, the coating level of a part or its sub-assembly. Use of this feature will bring the appearance of the printed model closer to that of the final product. (Image 5).

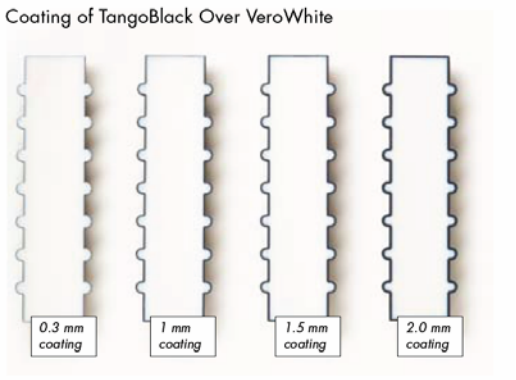


**Image 5**: In this image there are four different prototypes of handles with different thicknesses of flexible material, for testing the most suitable configuration

### Grayscales and tones

Greyscales and Tones – One of the advantages of using more than one model material is the ability to create grayscales and tones. For example, using VeroBlack and VeroWhite as basic materials and combining them in various ratios creates different greyscales. Creating grayscales and tones makes it possible to print marks and signs on a model, mark desired areas of interest and even add captions (Image 6).

**Image 6**: Guitar made from black and white rigid model materials and Digital Materials with different gray scales.

## CONCLUSIONS

Simultaneously prints parts with different mechanical properties, opening the way to savings throughout the design cycle.
It enables close emulation of the look, feel and function of final products, facilitating selection of the end-product materials. In addition, it enables printed prototypes that are very close to the production part in terms of mechanical properties and material combinations, e.g. over-molding and double injection.

Using PolyJet Matrix technology saves days and costs of simulating and preparing complex and expensive molds for double injection.
Finally, using the Connex500 improves communication between different groups and decision makers in the company, such as R&D, internal/external customers, engineering, marketing, sales and management.

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