FAKULTA STROJNÍ TUL

3D digitalizace a Rapid Prototyping

Jiří Šafka, Jakub Macháček

jiri.safka@tul.cz, jakub.machacek@tul.cz

Technologie PolyJet, PolyJetMatrix

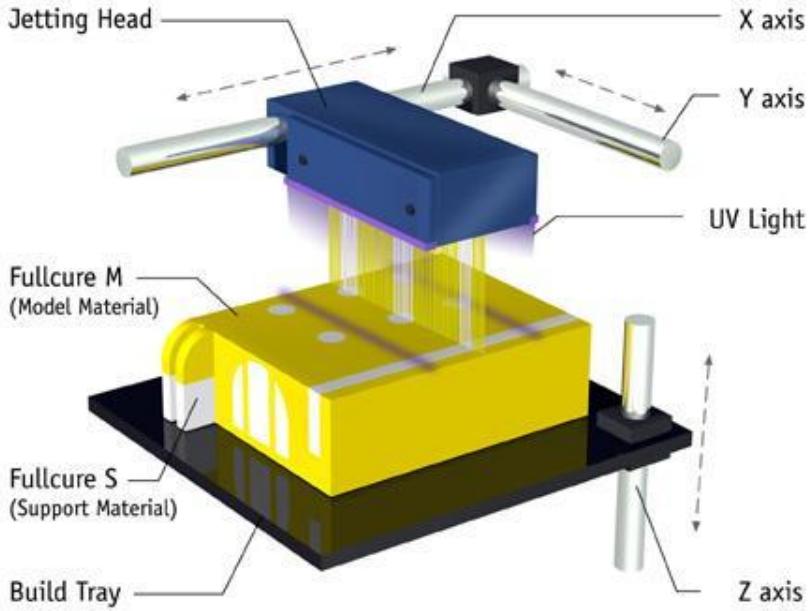
Obsah

- **Princip technologie PolyJet, PolyJet Matrix**
- **Objet Connex 500**
- **Objet J750**
- **Ukázka přípravy dat pro 3D tisk**
- **Ukázky praktických příkladů využití zařízení**
- **Praktické testy v laboratoři 3D tisku**

3D tisk obecně

Technologie PolyJet

Technologie PolyJet



The Objet PolyJet Process

Technologie PolyJet

Technologie PolyJet

Jednokomponentní 3D tisk
Nastavitelná výška vrstvy od 28 mikrometrů

Objet 24

234 x 192 x 148,6 mm

Technologie PolyJet

Dvoukomponentní 3D tisk
Nastavitelná výška vrstvy od 16 µm
Objet 1000 plus

1000 x 800 x 500 mm

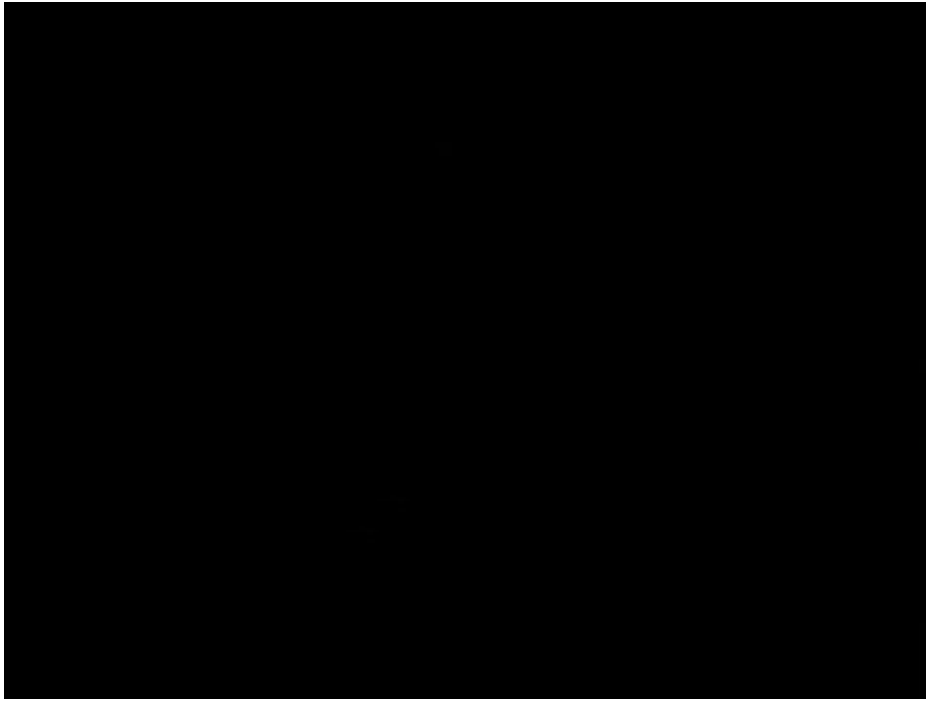
Technologie PolyJet

Dvoukomponentní 3D tisk
Nastavitelná výška vrstvy od 16 µm
J4100

1000 x 800 x 500 mm

Technologie PolyJetMatrix

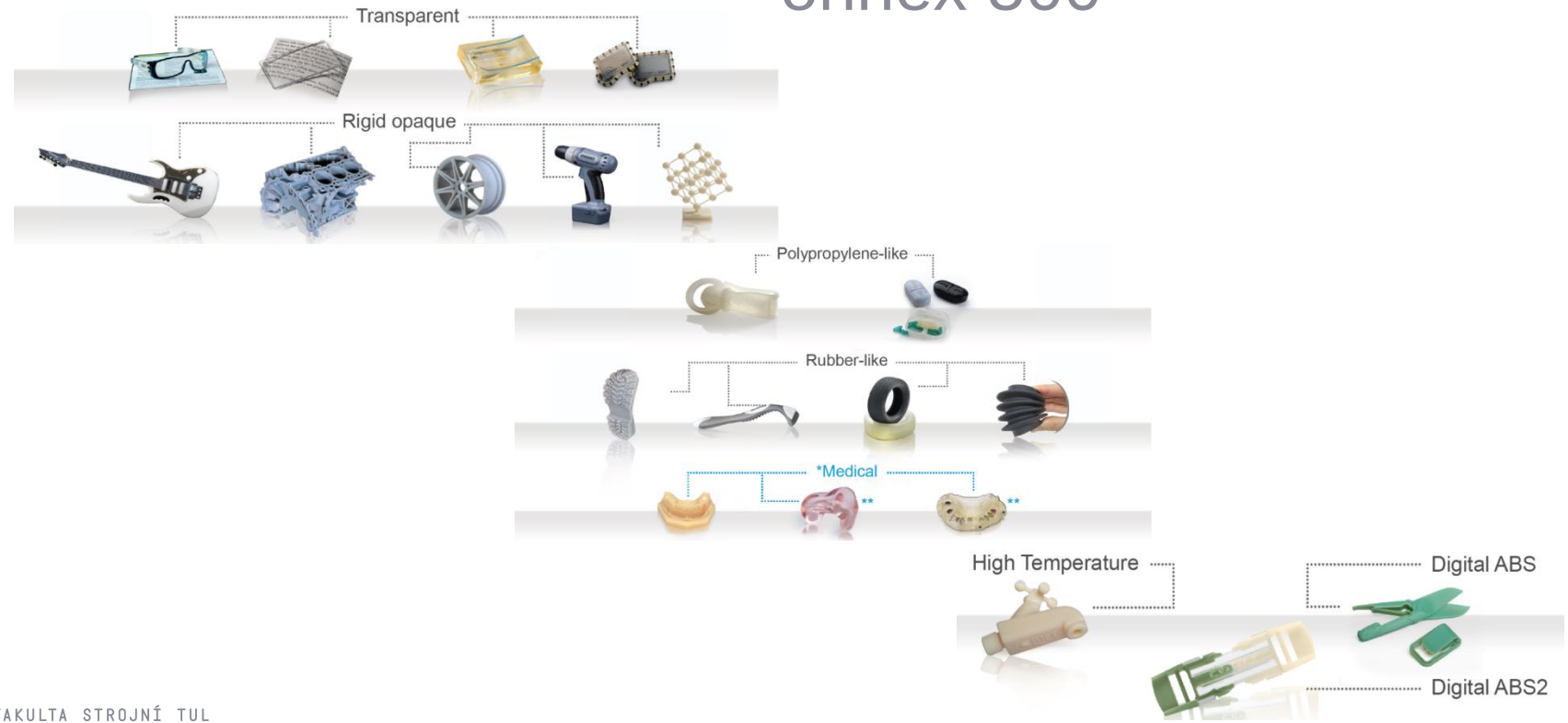
Technologie PolyJetMartix



Objet Connex 500

- **První 3D tiskárna s možností dvoukomponentního tisku**
- **Možnost stavby dvou materiálů zároveň (PolyJet Matrix)**
- **Tisk z 14 různých materiálů**
- **Využití až 104 kombinací digitálních materiálů**
- **Tloušťka vrstvy 16 nebo 30 µm**
- **Pracovní prostor 500 × 400 × 200 mm**

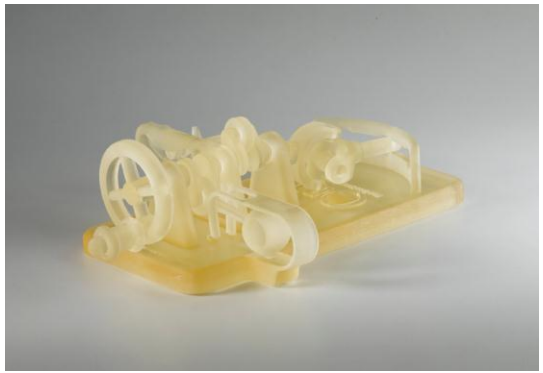
Objet Connex 500

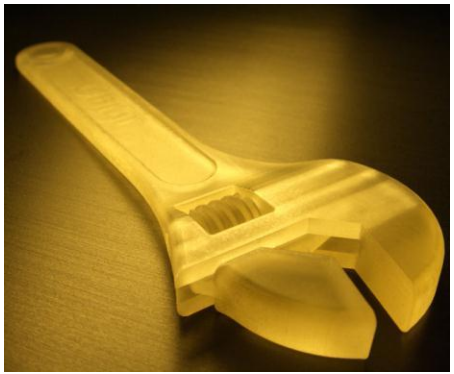


Materiály

- **Fullcure®705B, 706B – podpůrný**
- **Fullcure®720 – základní materiál**
- **VeroClear – pevný, průhledný**
- **VeroBlue – pevný, modrý**
- **VeroWhite – pevný, bílý**
- **VeroBlack – pevný, černý**
- **VeroGrey - pevný, šedý**
- **TangoBlack – flexibilní, černý**
- **TangoGrey – flexibilní, šedý**
- **TangoPlus – flexibilní, průhledný**
- **TangoBlackPlus – flexibilní, černý**
- **Durux White – pružný, bílý**
- **MED 610 – bio-kompatibilní**
- **RGD materiály**

FullCure®720





- **Základní materiál**

	ASTM	Units	Metric	Units	Imperial
Tensile strength	D-638-03	MPa	50-65	psi	7250-9450
Elongation at break	D-638-05	%	15-25	%	15-25
Modulus of elasticity	D-638-04	MPa	2000-3000	psi	290,000-435,000
Flexural Strength	D-790-03	MPa	80-110	psi	12000-16000
Flexural Modulus	D-790-04	MPa	2700-3300	psi	390,000-480,000
HDT, °C @ 0.45MPa	D-648-06	°C	45-50	°F	113-122
HDT, °C @ 1.82MPa	D-648-07	°C	45-50	°F	113-122
Izod Notched Impact	D-256-06	J/m	20-30	ft lb/inch	0.375-0.562
Water Absorption	D-570-98 24hr	%	1.5-2.2	%	1.5-2.2
Tg	DMA, E»	°C	48-50	°F	118-122
Shore Hardness (D)	Scale D	Scale D	83-86	Scale D	83-86
Rockwell Hardness	Scale M	Scale M	73-76	Scale M	73-76
Polymerized density	ASTM D792	g/cm3	1.18-1.19		
Ash content	USP281	%	0.01-0.02	%	0.01-0.02

VeroClear

- **Transparentní materiál**

	ASTM	Units	Metric	Units	Imperial
Tensile strength	D-638-03	MPa	50-65	psi	7250-9450
Elongation at break	D-638-05	%	15-25	%	15-25
Modulus of elasticity	D-638-04	MPa	2000-3000	psi	290,000-435,000
Flexural Strength	D-790-03	MPa	80-110	psi	12000-16000
Flexural Modulus	D-790-04	MPa	2700-3300	psi	390,000-480,000
HDT, °C @ 0.45MPa	D-648-06	°C	45-50	°F	113-122
HDT, °C @ 1.82MPa	D-648-07	°C	45-50	°F	113-122
Izod Notched Impact	D-256-06	J/m	20-30	ft lb/inch	0.375-0.562
Water Absorption	D-570-98 24hr	%	1.5-2.2	%	1.5-2.2
Tg	DMA, E»	°C	48-50	°F	118-122
Shore Hardness (D)	Scale D	Scale D	83-86	Scale D	83-86
Rockwell Hardness	Scale M	Scale M	73-76	Scale M	73-76
Polymerized density	ASTM D792	g/cm3	1.18-1.19		
Ash content	USP281	%	0.01-0.02	%	0.01-0.02

Skupina Vero

VeroWhite

VeroBlue

VeroGray

VeroBlack

- **Velmi pevný materiál**
- **Možnost barevných kombinací**

	ASTM	Units	Metric	Units	Imperial
Tensile strength	D-638-03	MPa	50-65	psi	7250-9450
Elongation at break	D-638-05	%	10-25	%	10-25
Modulus of elasticity	D-638-04	MPa	2000-3000	psi	290,000-435,000
Flexural Strength	D-790-03	MPa	75-110	psi	11000-16000
Flexural Modulus	D-790-04	MPa	2200-3200	psi	320,000-465,000
HDT, °C @ 0.45MPa	D-648-06	°C	45-50	°F	113-122
HDT, °C @ 1.82MPa	D-648-07	°C	45-50	°F	113-122
Izod Notched Impact	D-256-06	J/m	20-30	ft lb/inch	0.375-0.562
Water Absorption	D-570-98 24hr	%	1.1-1.5	%	1.1-1.5
Tg	DMA, E»	°C	52-54	°F	126-129
Shore Hardness (D)	Scale D	Scale D	83-86	Scale D	83-86
Rockwell Hardness	Scale M	Scale M	73-76	Scale M	73-76
Polymerized density	ASTM D792	g/cm3	1.17-1.18		
Ash content VeroGray, VeroWhitePlus	USP281	%	0.23-0.26	%	0.23-0.26
Ash content VeriBlack	USP281	%	0.01-0.02	%	0.01-0.02

Skupina Tango

TangoBlack

TangoGray

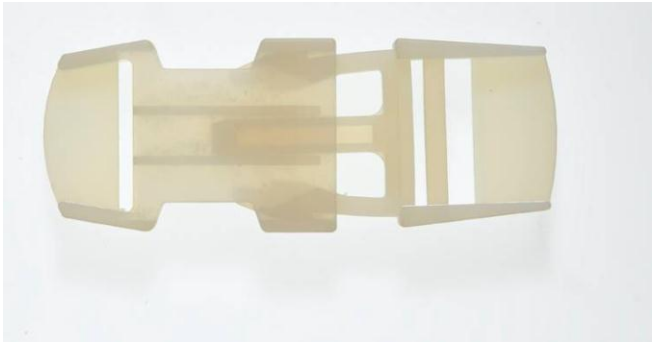
TangoPlus

TangoPlusBlack

- **Velmi pružný materiál**
- **Možnost barevných kombinací**

	ASTM	Units	Metric	Units	Imperial
Tensile strength	D-412	MPa	0.8-1.5	psi	115-220
Elongation at break	D-412	%	170-220	%	170-220
Compressive set	D-395	%	4-5	%	4-5
Shore Hardness (A)	D-2240	Scale A	26-28	Scale A	26-28
Tensile Tear resistance	D-624	Kg/cm	2-4.	Lb/in	18-22
Polymerized density	ASTM D792	g/cm3	1.12-1.13		

Durus White (Endur)

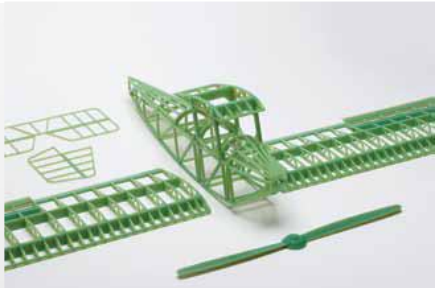


pevný, bílý materiál

	ASTM	Units	Metric	Units	Imperial
Tensile strength	D-638-03	MPa	20-30	psi	2900-4350
Elongation at break	D-638-05	%	40-50	%	40-50
Modulus of elasticity	D-638-04	MPa	1000-1200	psi	145,000-175,000
Flexural Strength	D-790-03	MPa	30-40	psi	4350-5800
Flexural Modulus	D-790-04	MPa	1200-1600	psi	175,000-230,000
HDT, °C @ 0.45MPa	D-648-06	°C	37-42	°F	99-108
HDT, °C @ 1.82MPa	D-648-07	°C	32-34	°F	90-93
Izod Notched Impact	D-256-06	J/m	40-50	ft lb/inch	0.749-0.937
Water Absorption	D-570-98 24hr	%	1.5-1.9	%	1.5-1.9
Tg	DMA, E»	°C	35-37	°F	95-99
Shore Hardness (D)	Scale D	Scale D	74-78	Scale D	74-78
Rockwell Hardness	Scale M	Scale M	no data	Scale M	no data
Polymerized density	ASTM D792	g/cm3	1.15-1.17		
Ash content	USP281	%	0.10-0.12	%	0.1-0.12

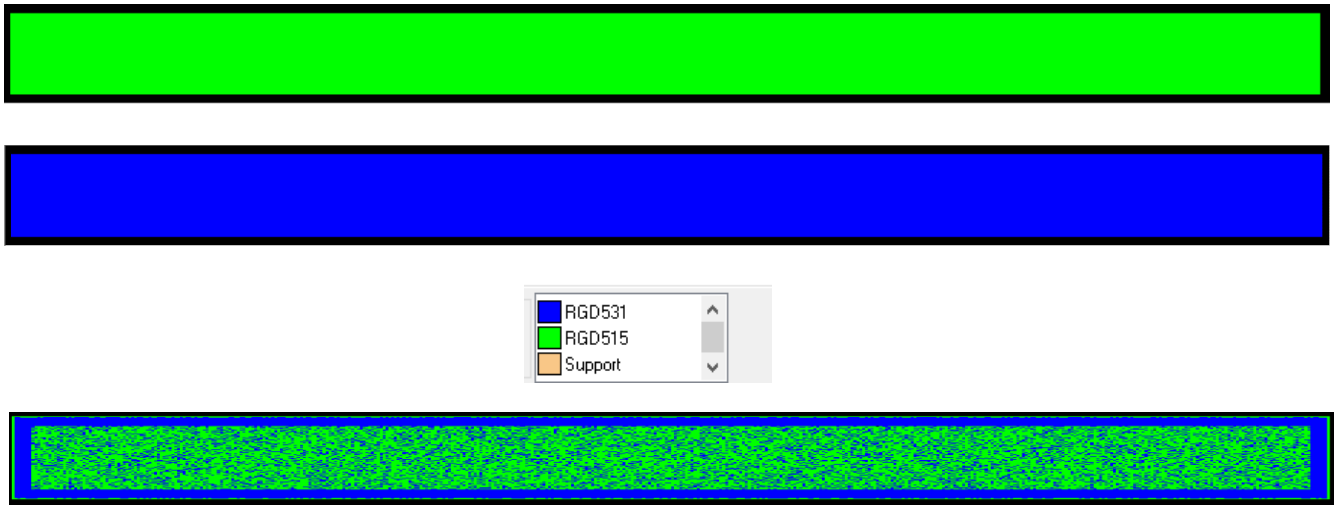
dABS like material (RGD515,535)

vhodný pro funkční prototypy



	ASTM	Units	Metric	Units	Imperial
Tensile strength	D-638-03	MPa	55-60	psi	8000-8700
Elongation at break	D-638-05	MPa	25-40	psi	25-40
Modulus of elasticity	D-638-04	MPa	2600-3000	psi	375,000-435,000
Flexural Strength	D-790-03	MPa	65-75	psi	9,500-11,000
Flexural Modulus	D-790-04	MPa	1700-2200	psi	245,000-320,000
HDT, °C @ 0.45MPa	D-648-06	°C	58-68	°F	136-154
HDT, °C @ 0.45MPa after thermal post treatment procedure A	D-648-06	°C	82-90	°F	180-194
HDT, °C @ 0.45MPa after thermal post treatment procedure B	D-648-06	°C	92-95	°F	198-203
HDT, °C @ 1.82MPa	D-648-07	°C	51-55	°F	124-131
Izod Notched Impact	D-256-06	J/m	65-80	ft lb/inch	1.22-1.50
Tg	DMA, E»	°C	47-53	°F	117-127
Shore Hardness (D)	Scale D	Scale D	85-87	Scale D	85-87
Rockwell Hardness	Scale M	Scale M	67-69	Scale M	67-69

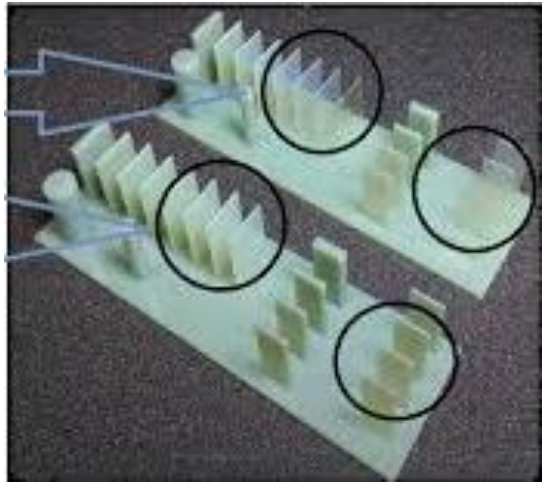
dABS like material (RGD515,535)



dABS like material (RGD515, 535, 531)

dABS – 1. generace

dABS2 – 2. generace



High Temperature material (RGD525)

vhodný pro tepelně namáhané prototypy

	ASTM	Units	Metric	Units	Imperial
Tensile strength	D-638-03	MPa	70-80	psi	10,000-11,500
Elongation at break	D-638-05	%	10-15	%	10-15.
Modulus of elasticity	D-638-04	MPa	3200-3500	psi	465,000-510,000
Flexural Strength	D-790-03	MPa	110-130	psi	16,000-19,000
Flexural Modulus	D-790-04	MPa	3100-3500	psi	450,000-510,000
HDT, °C @ 0.45MPa	D-648-06	°C	63-67	°F	145-163
HDT, °C @ 0.45MPa after thermal post treatment procedure A	D-648-06	°C	75-80	°F	167-176
HDT, °C @ 1.82MPa	D-648-07	°C	55-57	°F	131-135
Izod Notched Impact	D-256-06	J/m	14-16	ft lb/inch	0.262-0.300
Water Absorption, %	D-570-98 24hr	%	1.2-1.4	%	1.2-1.4
Tg	DMA, E»	°C	62-65	°F	144-149
Shore D	Scale D	Scale D	87-88	Scale D	87-88
Rockwell Hardness	Scale M	Scale M	78-83	Scale M	78-83
Polymerized density	ASTM D792	g/cm3	0.97-0.98		
Ash content	USP281	%	0.38-0.42	%	0.38-0.42

Bio – kompatibilní materiál – (MED610)

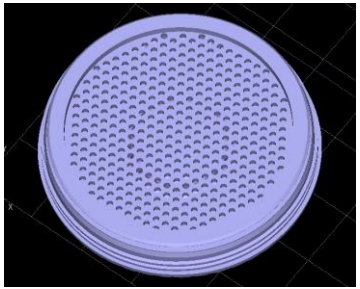
vhodný pro otestování zdravotně nezávadných pomůcek

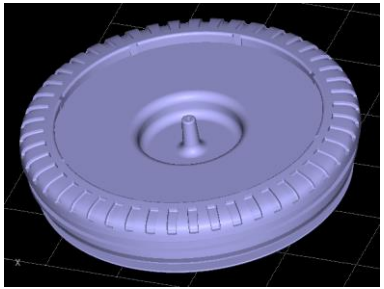
Property	ASTM	Metric		Imperial	
Tensile Strength	D-638-03	MPa	50-65	psi	7,250-9,450
Modulus of Elasticity	D-638-04	MPa	2,000-3,000	psi	290,000-435,000
Elongation at Break	D-638-05	%	10-25	%	10-25
Flexural Strength	D-790-03	MPa	75-110	psi	11,000-16,000
Flexural Modulus	D-790-04	MPa	2,200-3,200	psi	320,000-465,000
Izod Notched Impact	D-256-06	J/m	20-30	ft lb/in	0.375-0.562
HDT at 0.45 MPa	D-648-06	°C	45-50	°F	113-122
Water Absorption	D570-98 24 Hr	%	1.1-1.5	%	1.1-1.5

Porovnání rychlosti 3D tisku technologií FDM a PolyJet

Technologie vytlačování plastu (FDM) - stroj Stratasys Dimension, tloušťka vrstvy 0,25 mm, materiál ABS

Velikost modelu	Průměr [mm]	Výška [mm]
	114	24,7

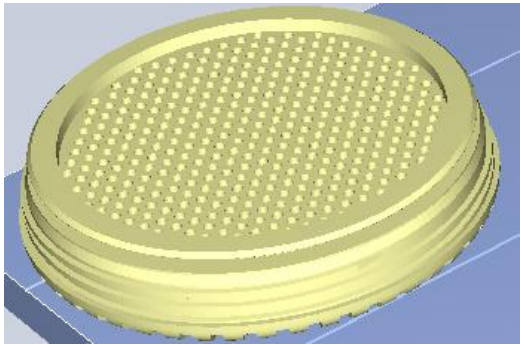




Stavební materiál [g]	Podpůrný materiál [g]	Doba stavby [hod.]
66,87	**41,71**	**10:53**

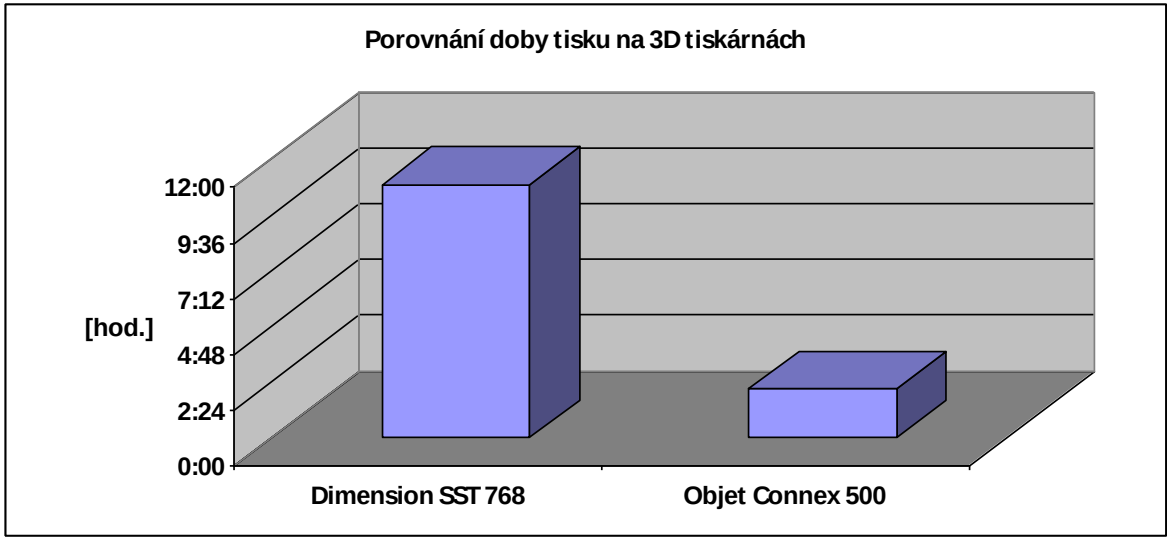
Porovnání rychlosti 3D tisku technologií FDM a PolyJet

Technologie PolyJetMatrix, tloušťka vrstvy 0,03 mm, materiál Fullcure®720



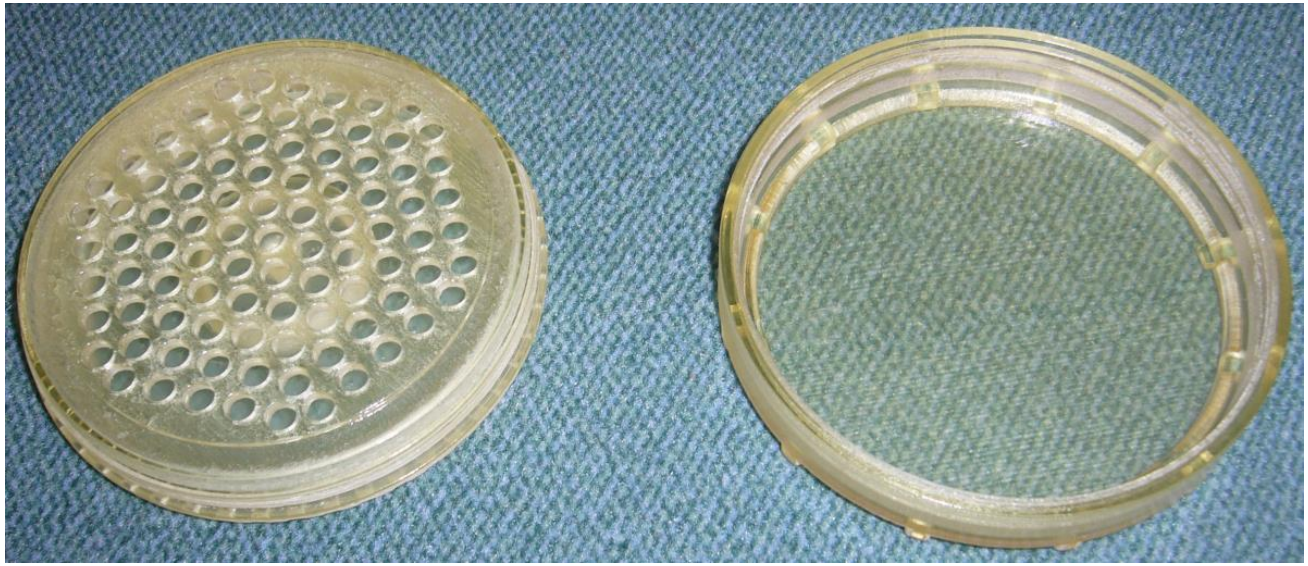
Stavební materiál [g]	Podpůrný materiál [g]	Doba stavby [hod.]
157	**181**	**2:06**

Porovnání rychlosti 3D tisku technologií FDM a PolyJet



Rozdíl v časové náročnosti je již skoro 9 hod.

Porovnání rychlosti 3D tisku technologií FDM a PolyJet



Tvrdý čirý & Podobný pryži (DM)

TangoBlackPlus + VeroClear

TangoPlus + VeroClear

20 Digitálních kombinací

Tvrdé materiály
Různé odstíny šedi

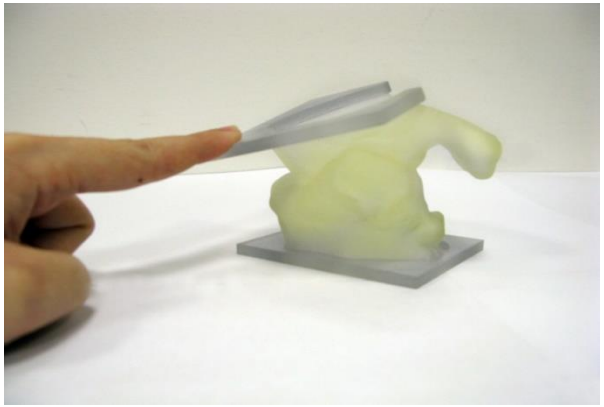
Tvrdé materiály
PP like DM

Pryžové materiály
Shore 27, 40, 50, 60, 70, 85 a 95
(bez výměny materiálu)

Tvrdý čirý & Podobný pryži (DM)

TangoPlus + VeroClear

Heart Valve made of TangoPlus & VeroClear



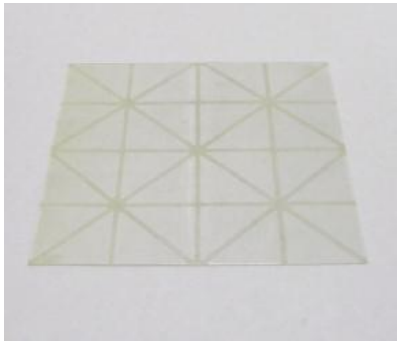
Functional testing of a heart valve

Rigid Transparent with Shore 60 DM

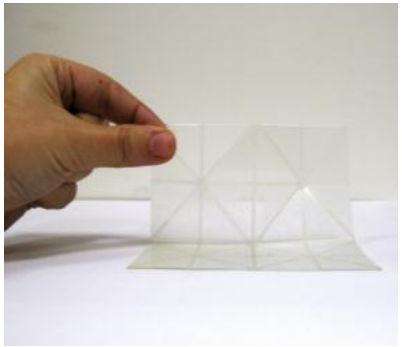
Tvrdý čirý & Podobný pryži (DM)

TangoPlus + VeroClear

Origami



VeroClear triangles connected with TangoPlus DM Shore 40



Wall Thickness of 0.6mm

Exceptional demonstration of living hinges

Origami – 4D printing

Tvrdý čirý & Podobný pryži (DM)

Rigid Gray Transparent with Shore 60 DM

Rigid Transparent with Shore 50 DM

TangoBlackPlus + VeroClear

Rigid Transparent with Shore 40 DM

Rigid Transparent with Shore 95 DM

Tvrdý čirý & Podobný pryži (DM)

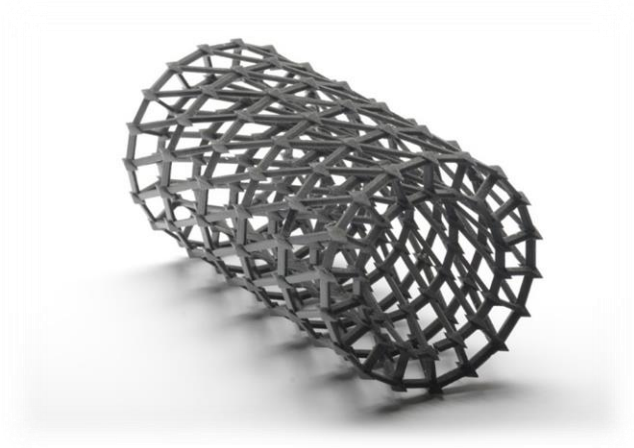
TangoBlackPlus + VeroClear

Ideal Standard – CG, Germany
Pipe made of VeroClear and inside Tango BlackPlus Rubber-like DM Shore 40

- Nozzles made of rubber-like DM Shore 85
- Internal disk made of PP-like DM,
- External disk made of transparent light gray rigid DM

VeroBlackPlus

- VeroBlackPlus nový materiál s vysokou rozměrovou stabilitou
- Základ je z materiálu VeroGray – stejné mechanické vlastnosti



Tvrdý černý & Podobný pryži (DM)

TangoPlus + VeroBlackPlus

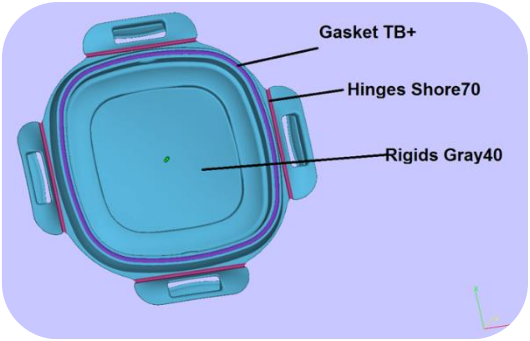
VeroBlackPlus + TangoBlackPlus

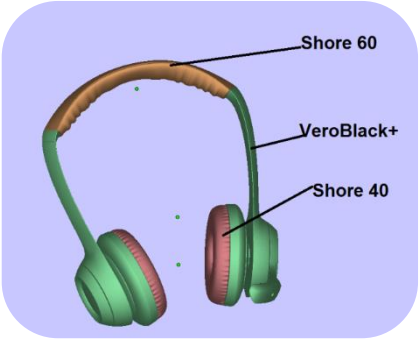
16 Digitálních kombinací

Tvrdé materiály
Od tvrdých po PP like

Pryžové materiály
Shore 27, 40, 50, 60, 70, 85 a 95A

Tvrdý černý & Podobný pryži (DM)





Tvrdý s teplotní odolností & Podobný pryži

TangoPlus + High Temp

TangoBlackPlus + High Temp

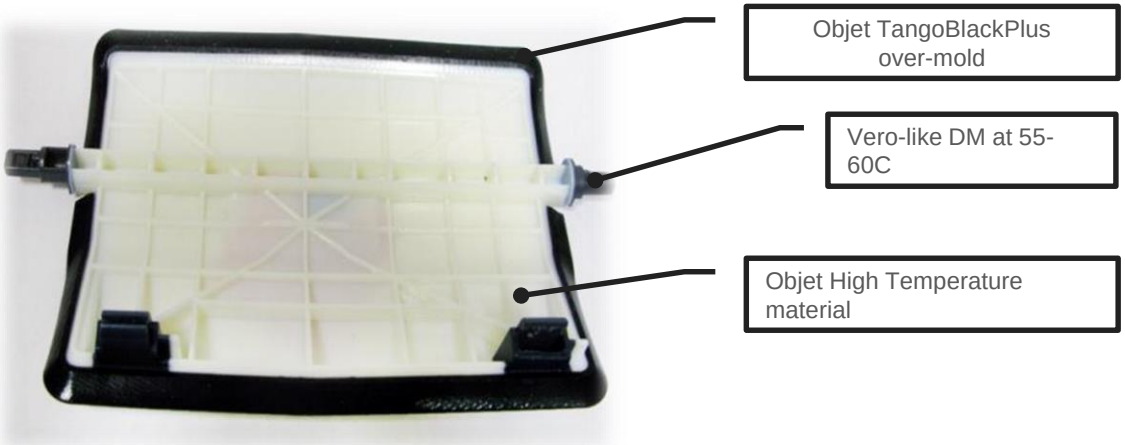
19 digitálních kombinací

Tvrdé teplotně odolné materiály
Různé stupně šedi

Houževnatý DM
teplotní odolnost až 56C

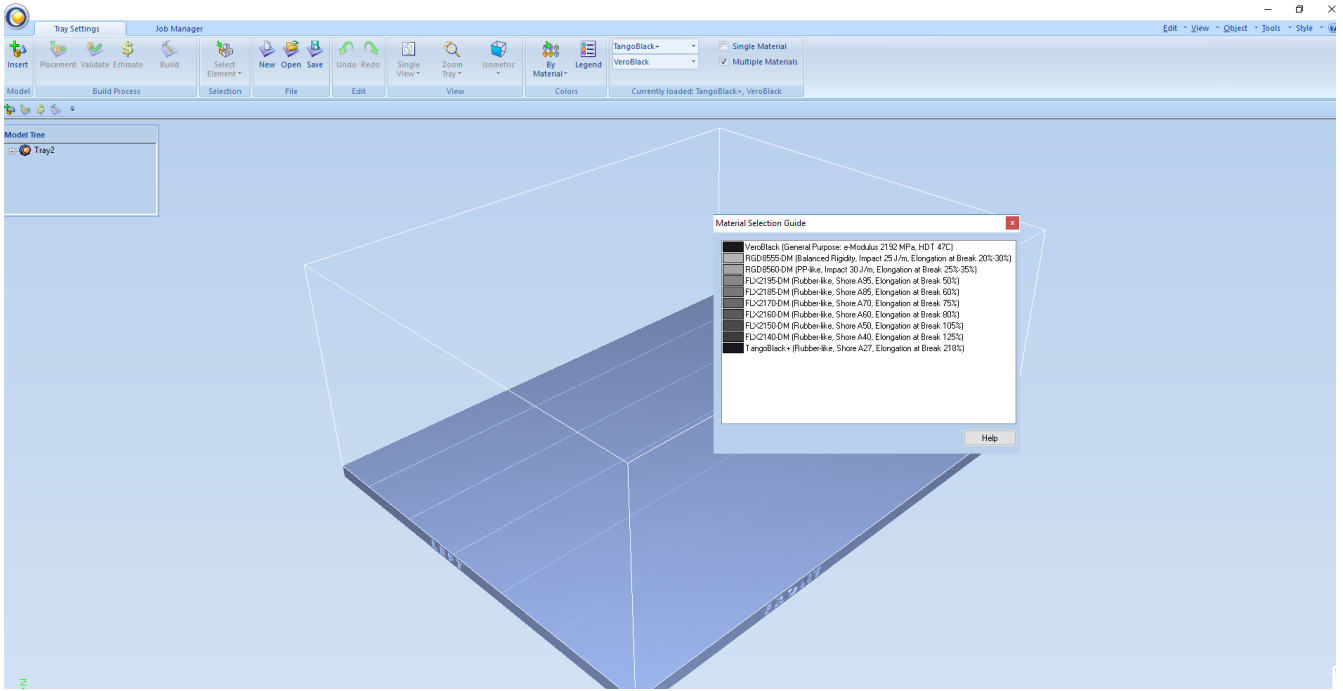
Pryžové materiály
Shore 27, 40, 50, 60, 70, 85 a 95A

Tvrdý s teplotní odolností & Podobný pryži

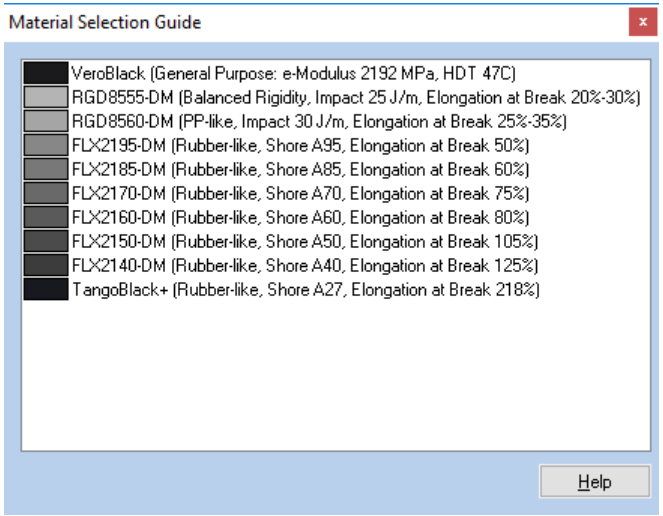


- Car air inflow where air comes directly from the motor
- Part was assembled – no breakage
- Part was tested for 15 days at 60°C
- Full functionality, no deformation

Software Objet Studio

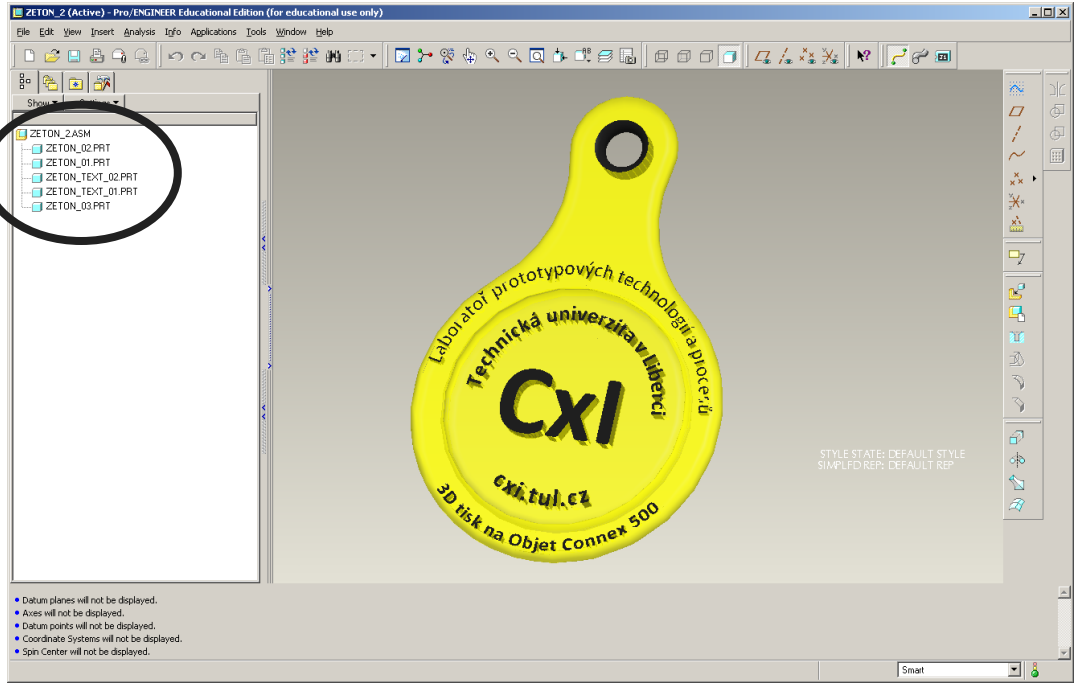


Software Objet Studio

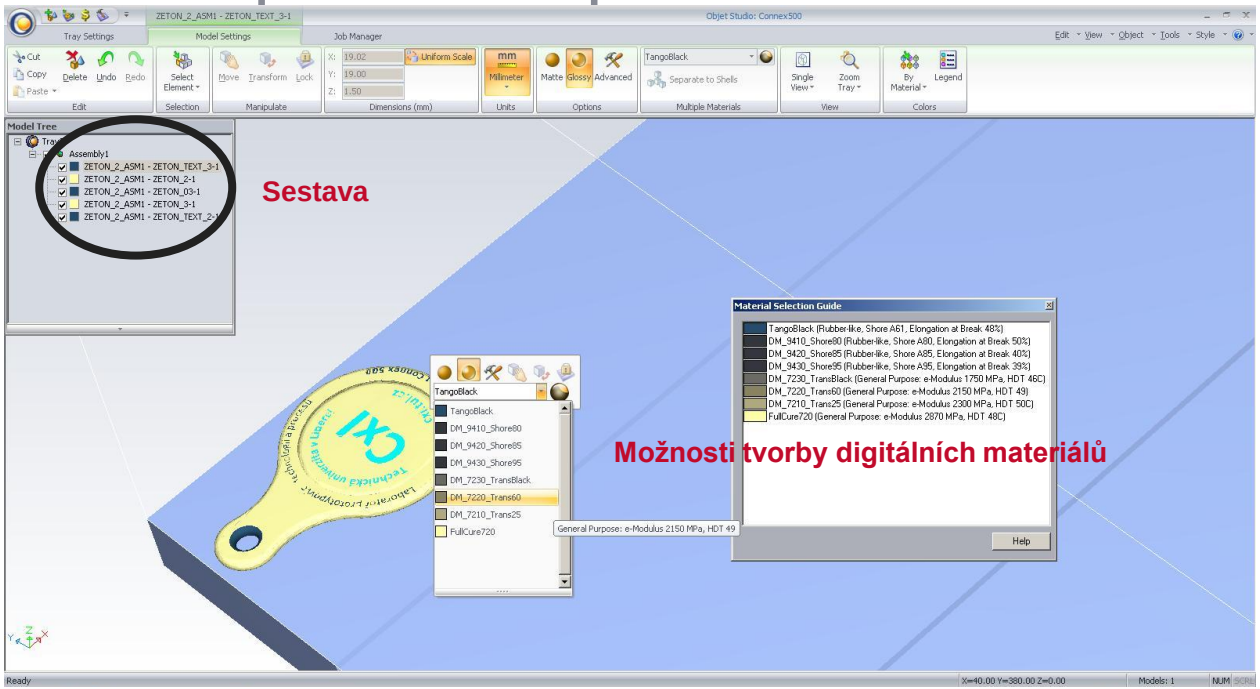


Příprava dat pro vlastní 3D tisk

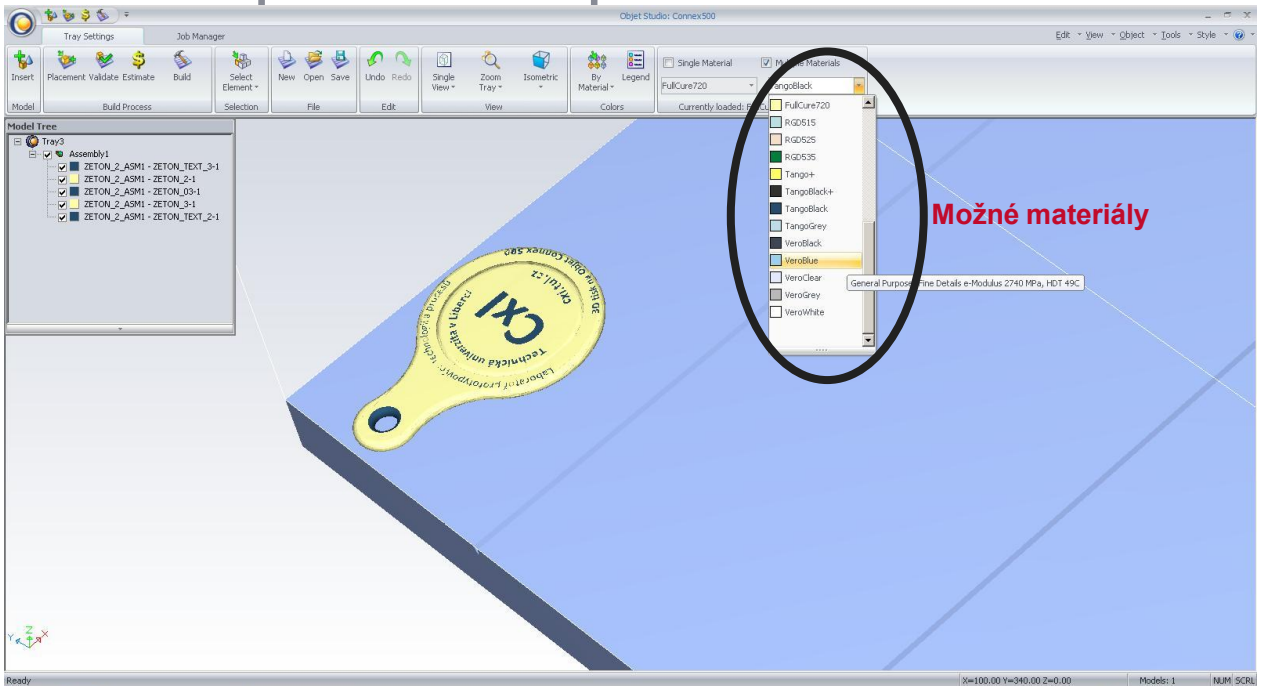
Sestava



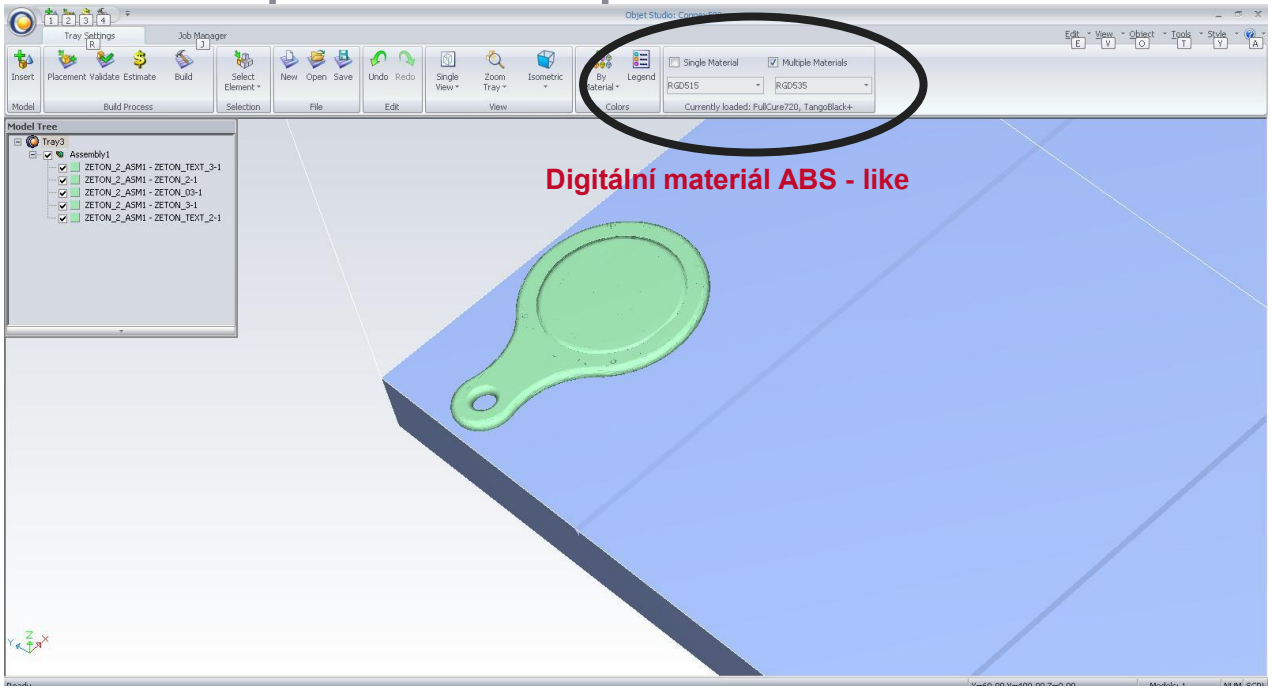
Příprava dat pro vlastní 3D tisk



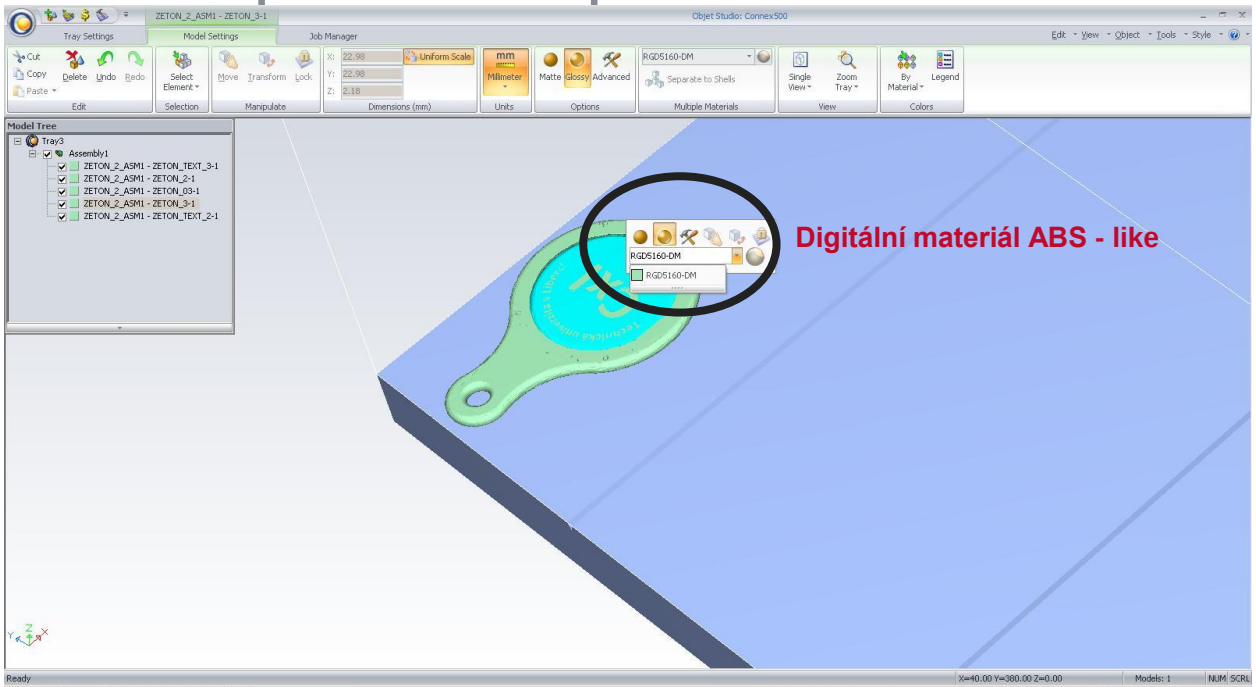
Příprava dat pro vlastní 3D tisk



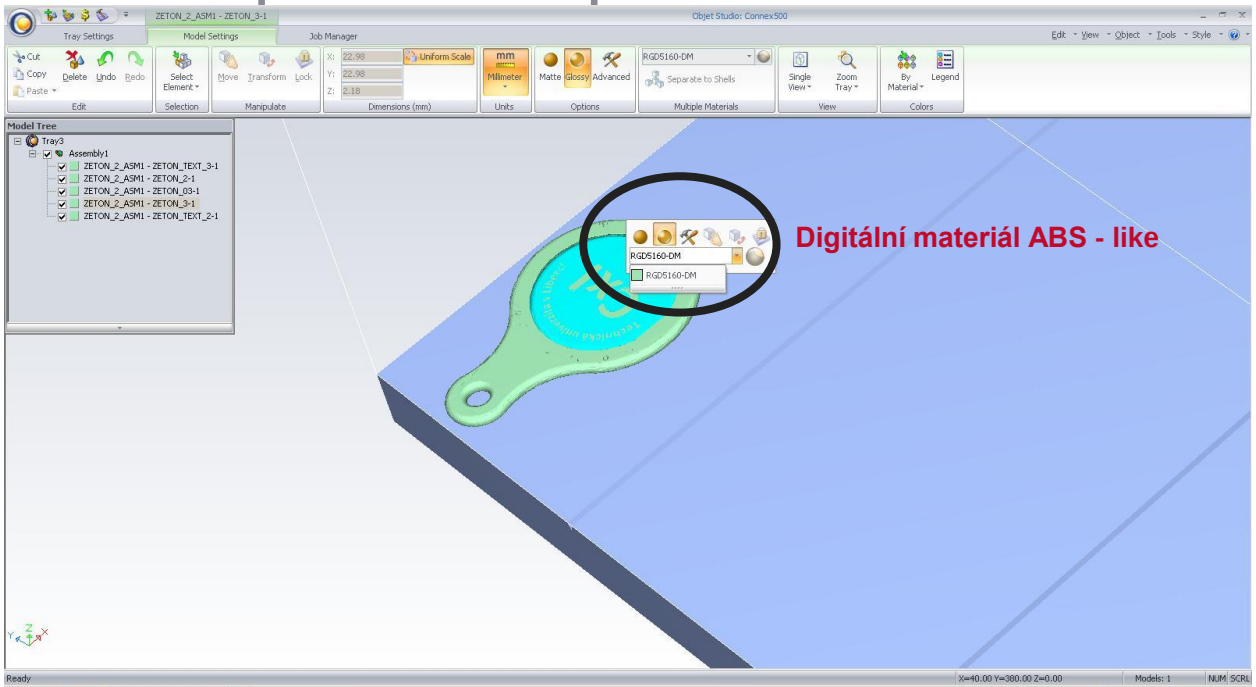
Příprava dat pro vlastní 3D tisk



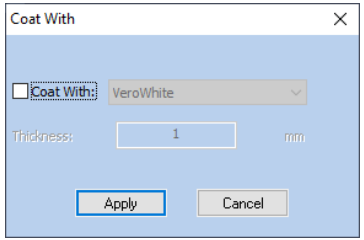
Příprava dat pro vlastní 3D tisk



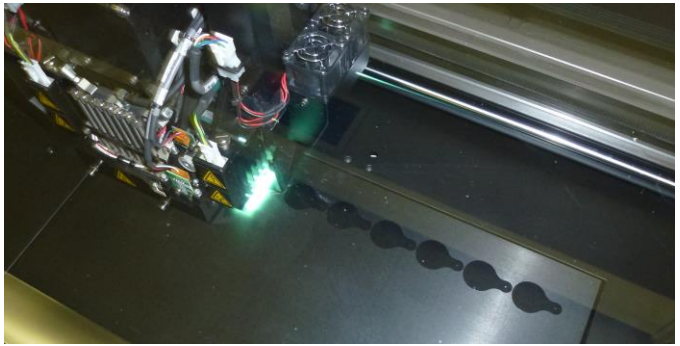
Příprava dat pro vlastní 3D tisk



VeroClear + UltraClear na Connex 500



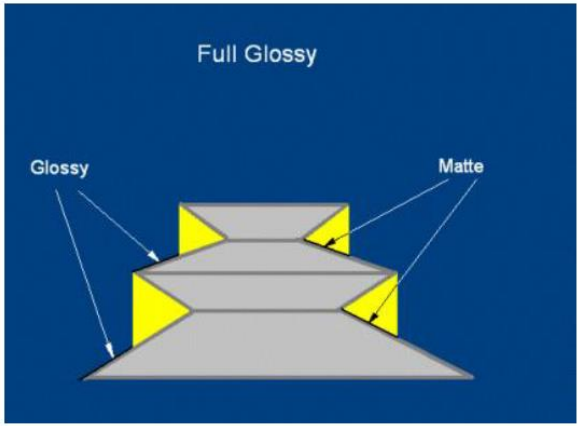
Technologie PolyJet - výrobky



Glossy - Matte

Glossy

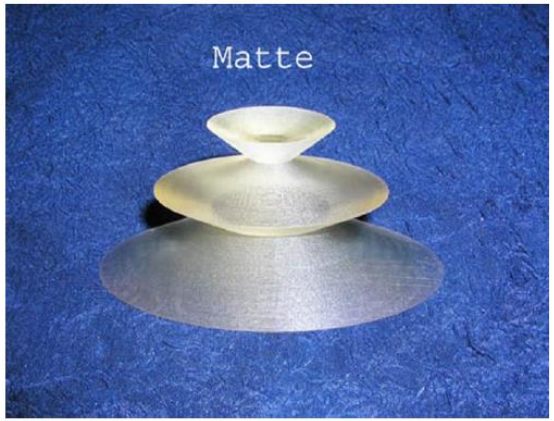
- Support only where necessary
- Matte bottom, glossy top surface(s)

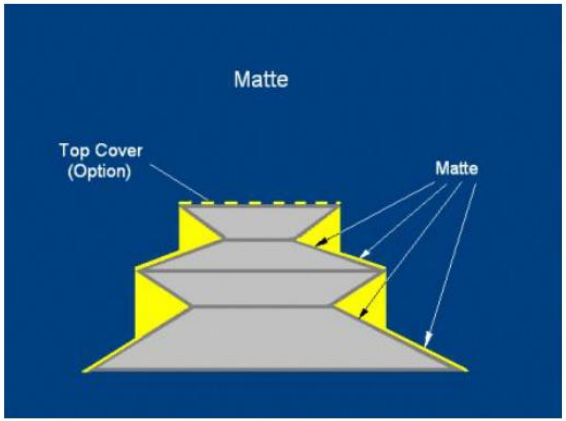


Glossy - Matte

Matte

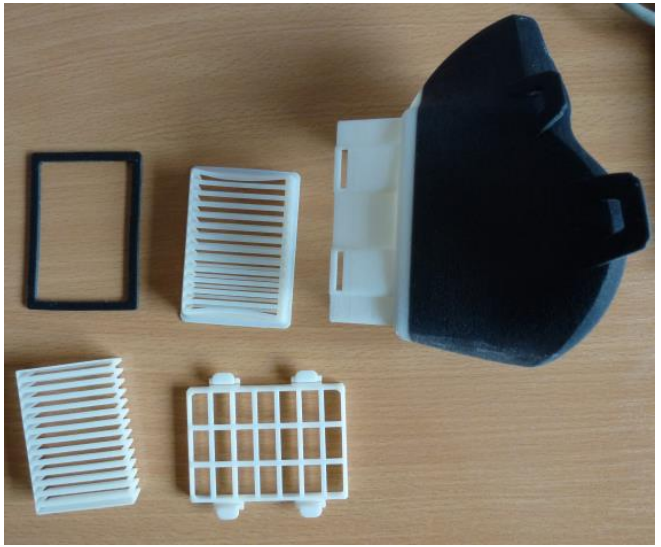
- All surfaces interface support
- Uniform finish





Technologie PolyJet- výrobky

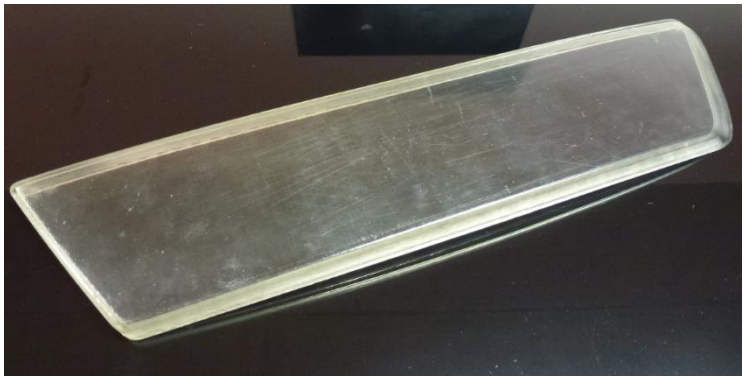
Technologie PolyJet - výrobky



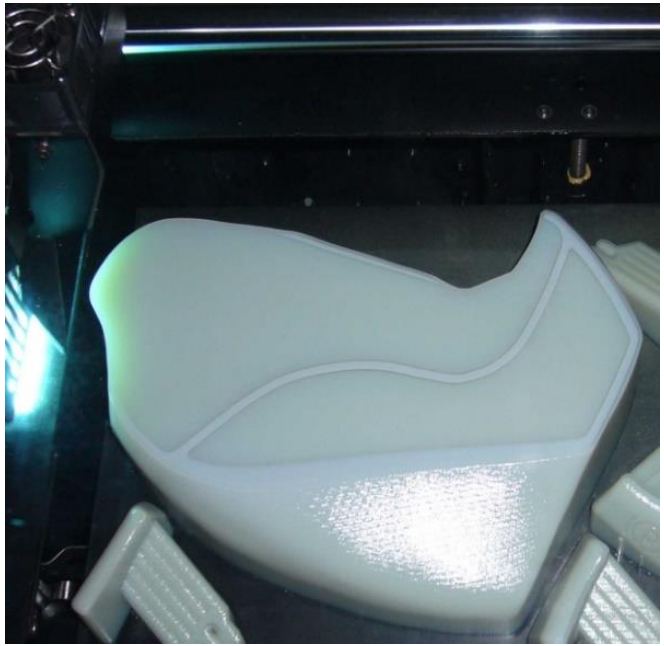
Technologie PolyJet - výrobky

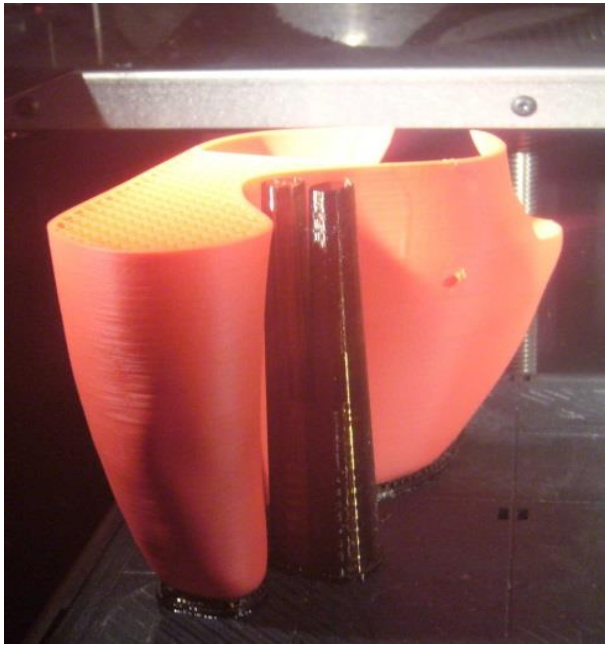
- Doba tisku 4hodiny
- Možnost probarvení

- Doba obrábění cca 16hod.
- Pouze jeden materiál



Technologie PolyJet - výrobky





Technologie PolyJet - výrobky

Technologie PolyJet - výrobky

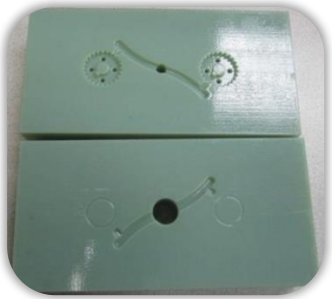
Technologie PolyJet – formy pro vstřikování

Injection molding is the most commonly used manufacturing process for producing high precision, complex plastic parts.

Traditionally… tooling for injection molding is a slow and expensive process

Printing the mold with Inkjet technology using ABS-like material allows:

- Short series production
- Prototyping from the real plastic material
- Drastically reduced time and costs



Material injected-
Acetal (POM) - 30 parts were injected

Technologie PolyJet – formy pro vstřikování

Case Study 1

Industry: Automotive

Material injected: PE (Polyethylene)

at 190°C

Number of parts*: 10

* Mold is available for additional use

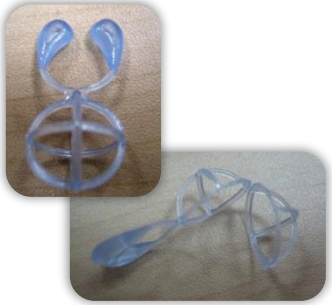
Case Study 2

Industry: Toys

Material injected: PP (Polypropylene)

at 220°C

Number of parts: 80



Technologie PolyJet – formy pro vstřikování

Case Study 3

Industry: General

Material injected: PP (Polypropylene) &ABS

at 220-230°C

Number of parts: 20 PP, 16 ABS

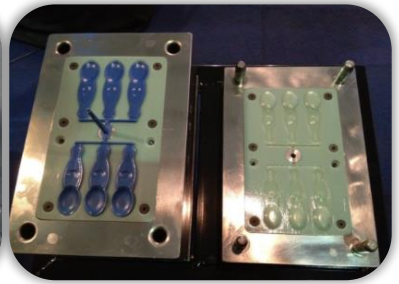
Technologie PolyJet – formy pro vstřikování

Case Study 4

Industry: General

Material injected: PP (Polypropylene)

at 220-230°C



600 parts (100 injection cycles) were successfully injected

No degradation to the mold, still totally functional

Technologie PolyJet – formy pro vstřikování

Technologie PolyJet - vyfukování

What is Blow Molding?

- Blow molding is a process that produces hollow plastic parts, mainly bottles and containers.
- It is based on inflating preheated plastic against a mold in the desired shape.
- Many of the products that we use in our day-to-day life are blow molded, such as drink bottles, containers, toys, even the fuel tanks in our cars.

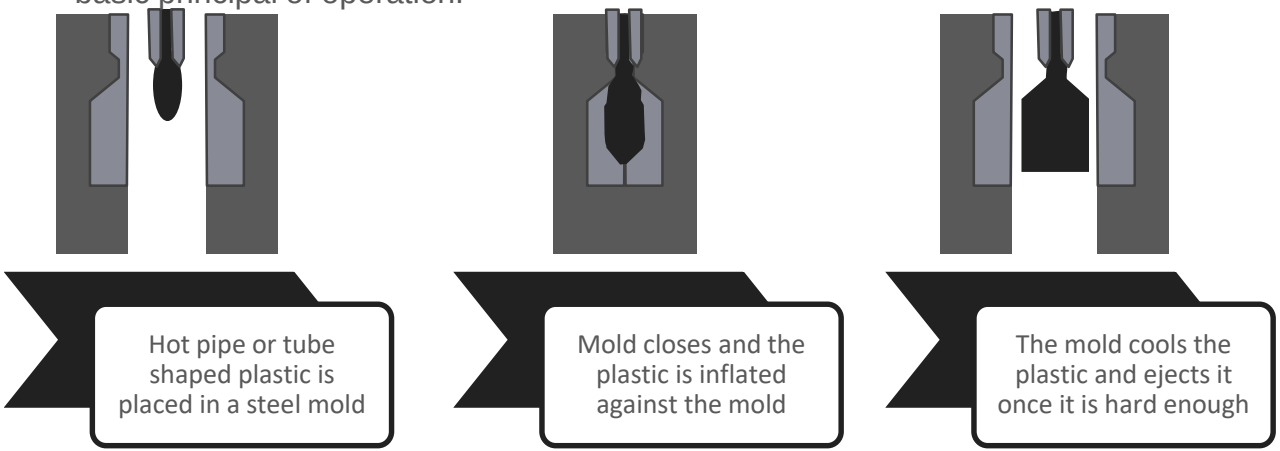
Technologie PolyJet - vyfukování

The Blow Molding Process

- There are three main types of blow molding:

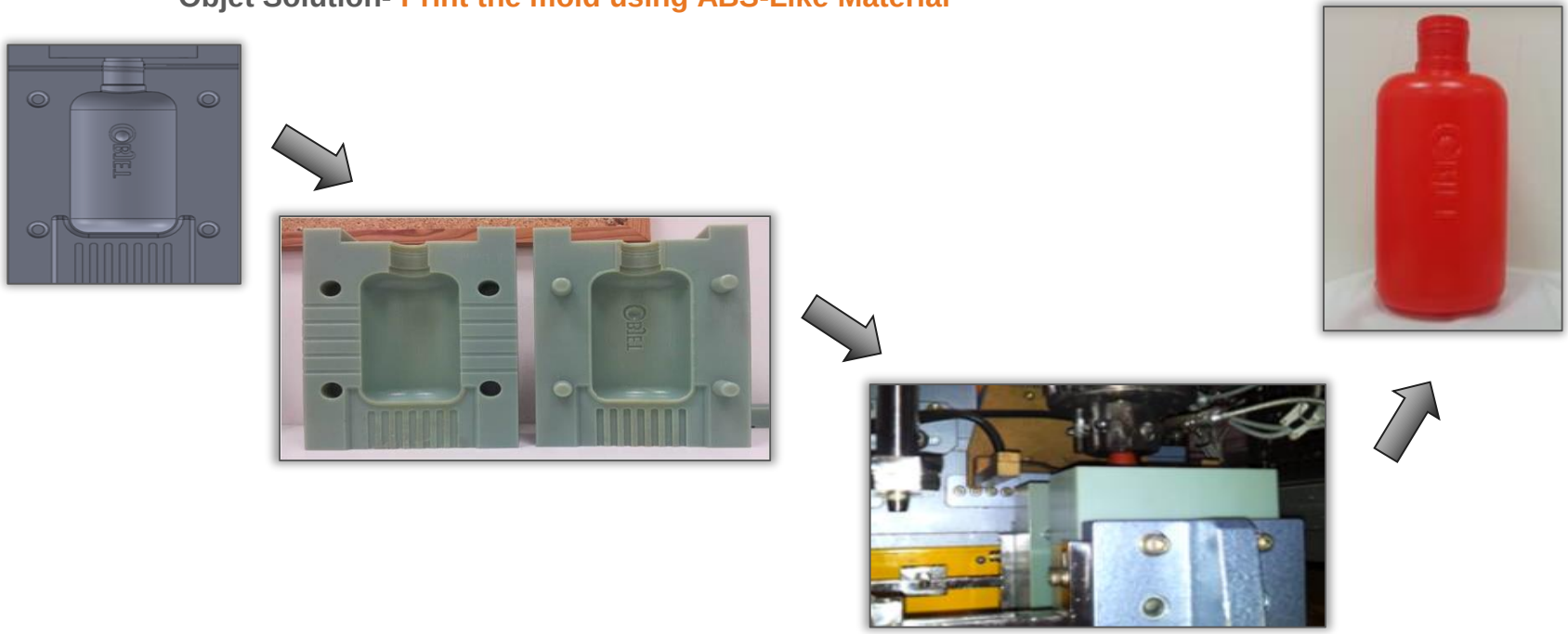
  Extrusion blow molding, Injection blow molding and stretch blow molding
- Each type has a slightly different process but they all have a common,

  basic principal of operation:



Technologie PolyJet - vyfukování

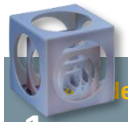
Objet Solution- Print the mold using ABS-Like Material



Technologie PolyJet - vyfukování

Technologie PolyJet

3rd Generation Multi-Material Technology



1 Material

Highly accurate, finely detailed models with ultra-thin walls.

2 materials

The world's first multi-material 3D printer.

Connex 1/2/3

Materials

Stratasys introduces the first-ever color and multi-material 3D printer.

2016. J750

6

Materials

The world’s only full color, multi-material, high resolution

Stratasys J750

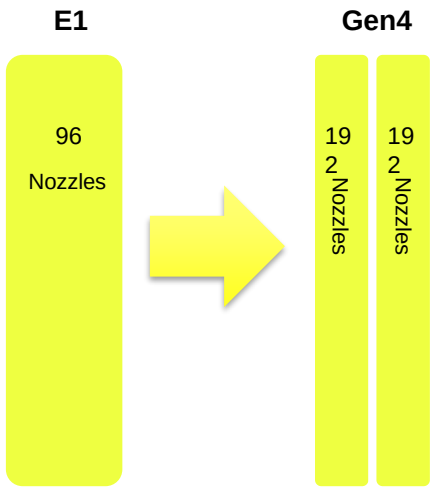
Stratasys J850

Technologie PolyJet

Stavební prostor:	490 x 390 x 200 mm
Tloušťky vrstev:	14 nebo 28 µm
Skupiny materiálů:	Kompletní plně barevný 3D tisk
	Kombinace ABSlike + Pryž (Tango nebo Agilus)
	Transparent
	Rigid materials
	Rubber-like
	Bio-Compatible
	Dental

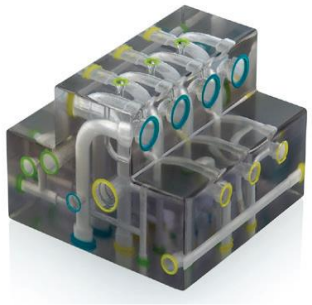
J750/J850

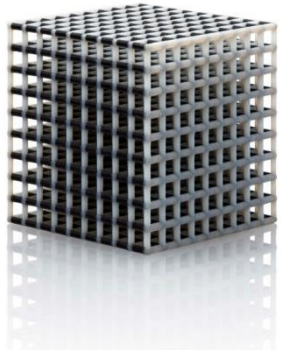
- New, improved print heads bring you greater speed, accuracy, and versatility:
- 2 material channels in 1 print head
- 4 times the number of nozzles.



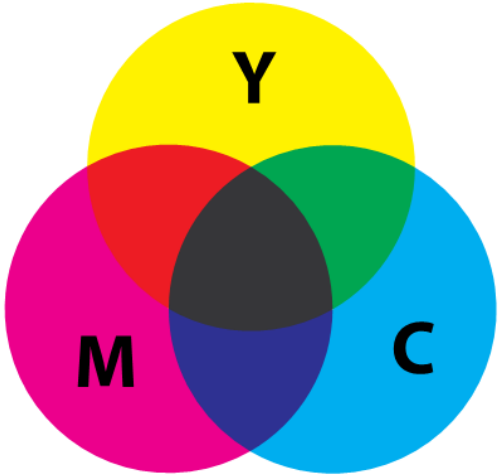
SUP706 Soluble Support

- Allows cleaning of **fine details**
- Allows cleaning of **complex interior cavities**
- **Hands-free support removal**
- **Quicker** support removal (with WaterJet and semi-manual)
- **Reduces time and labor** in the post-process of support removal

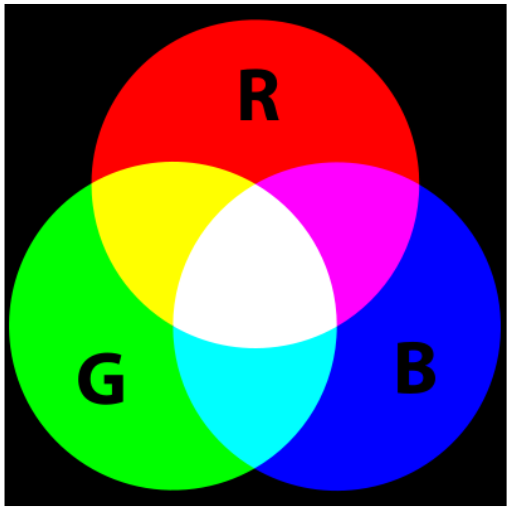




J750 - Color Print

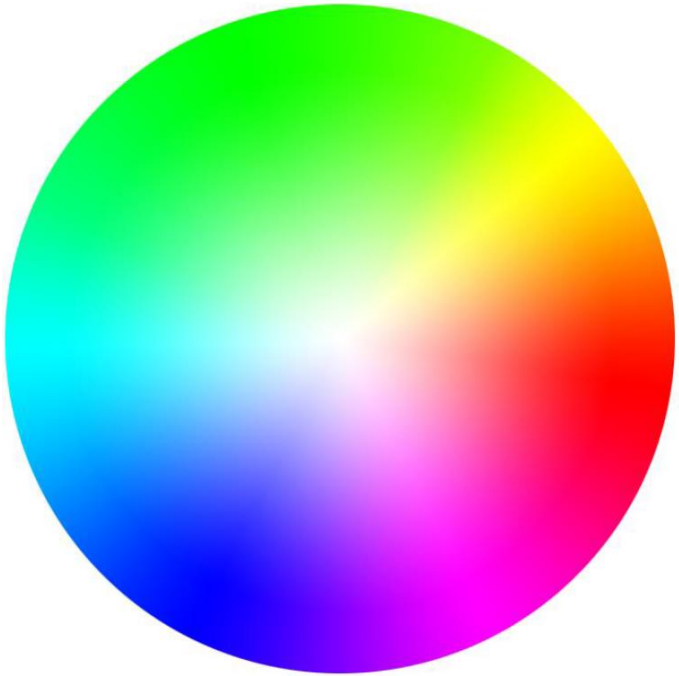


CMYK-CYAN, MAGENTA, YELLOW, BLACK



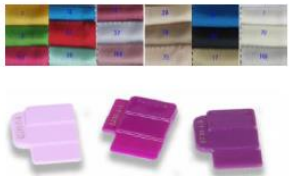
sRGB-RED, GREEN, BLUE

J750 - Color Print



J750 - Color Print

J750 - Color Print



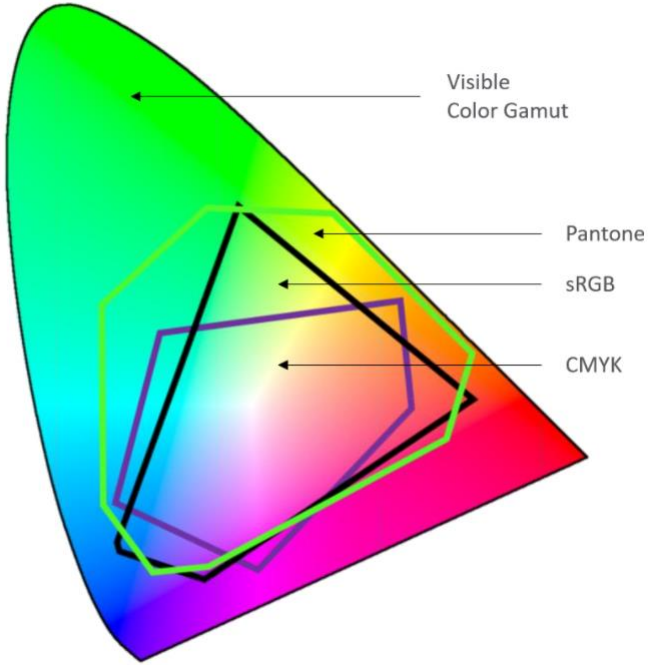
Pantone barvy

J750 - Color Print

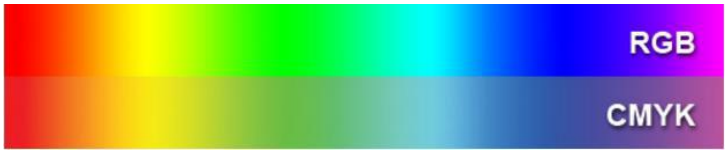
J750 - Color Print

J750 CMYK

J750 - Color Print



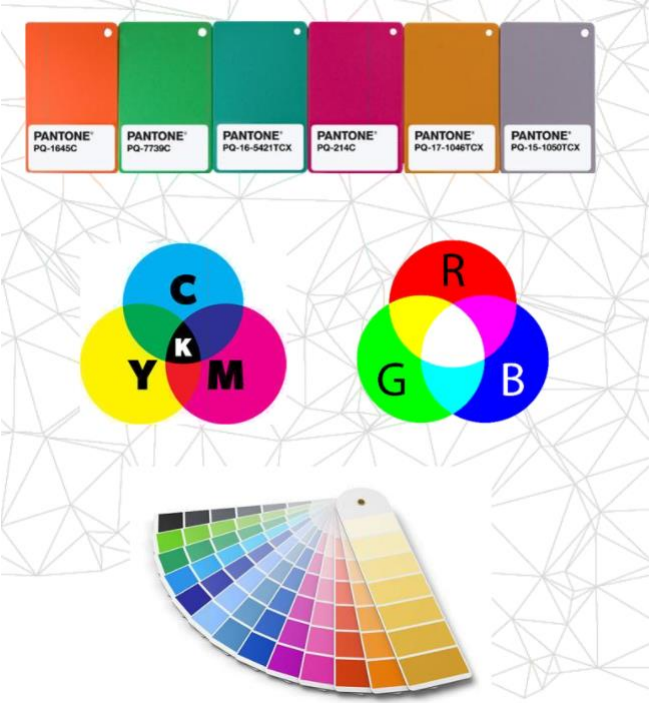
J750 - Color Print

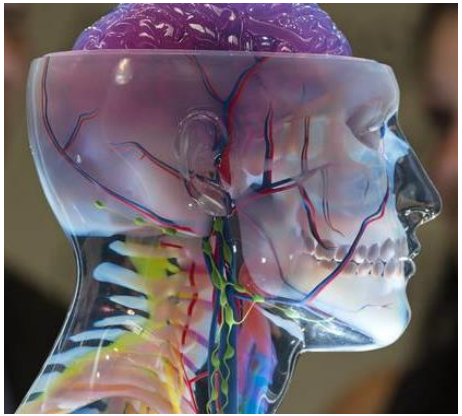


J750 - Color Print

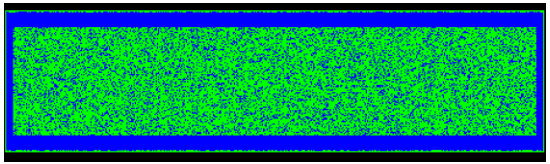
Co je CMYK a co je RGB?

J750 - Color Print

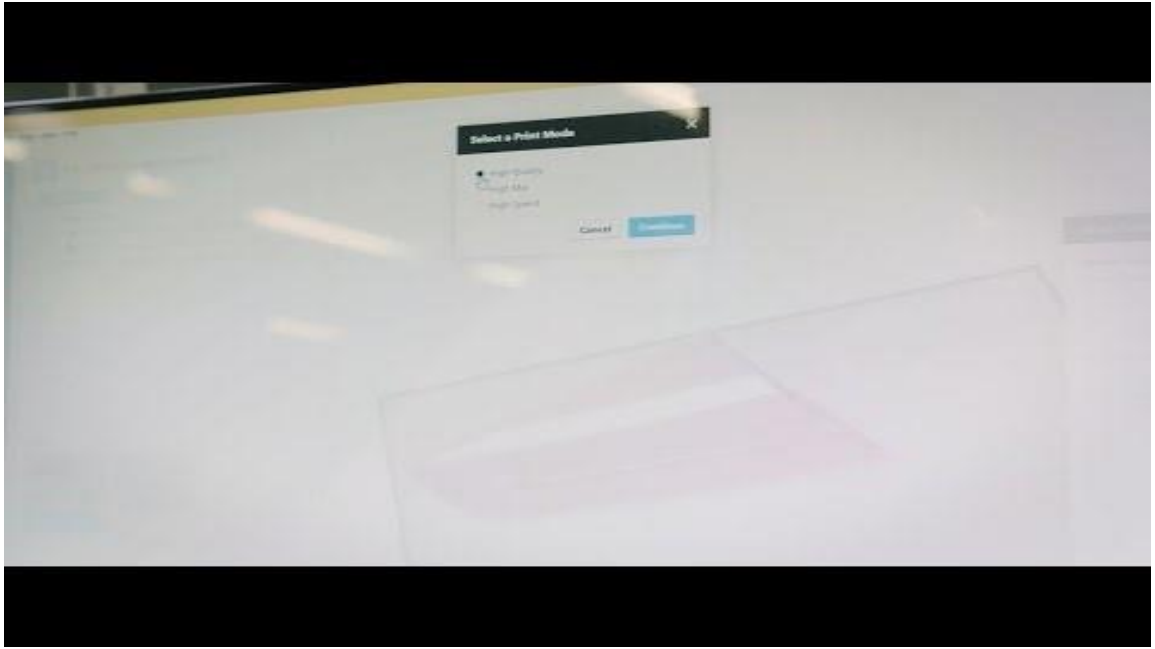




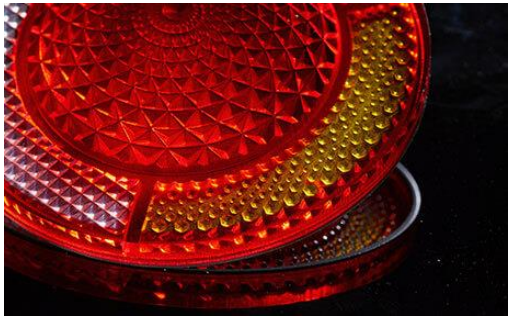
J750 – UltraClear material

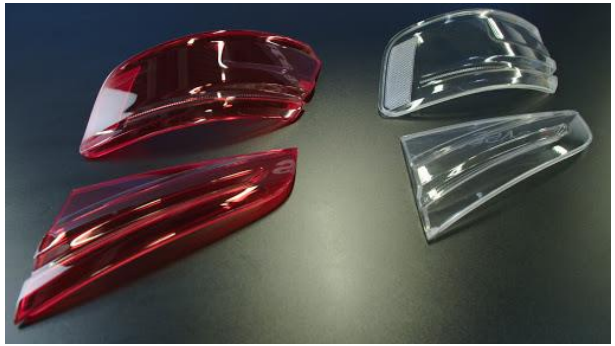


J750 – VIVID Color

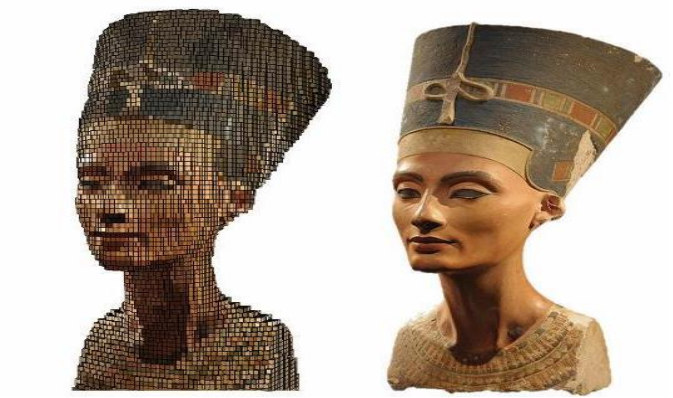


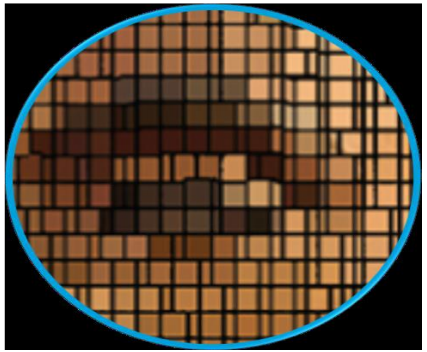
J750 – VIVID Color

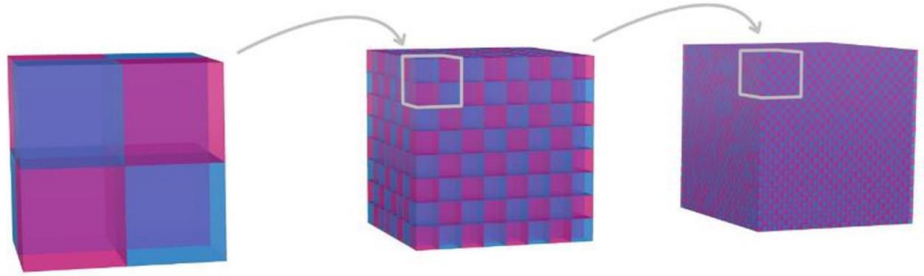




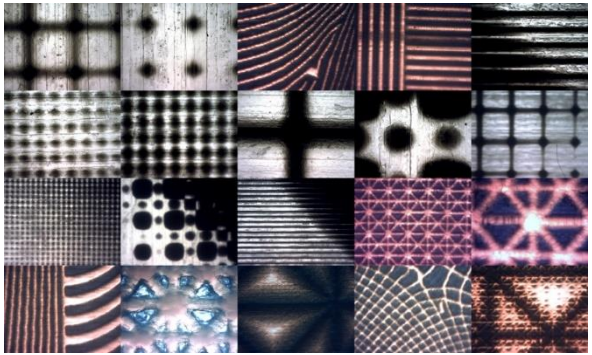
J750 – VOXEL PRINT

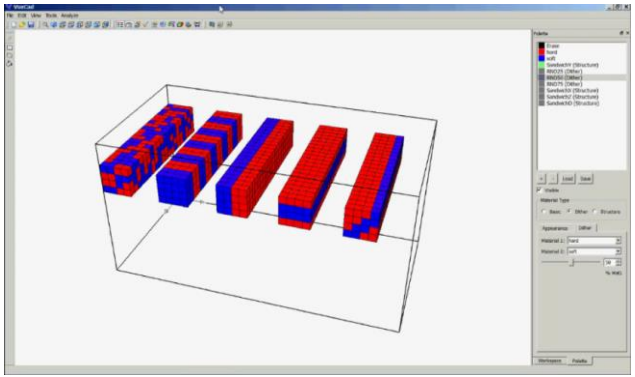




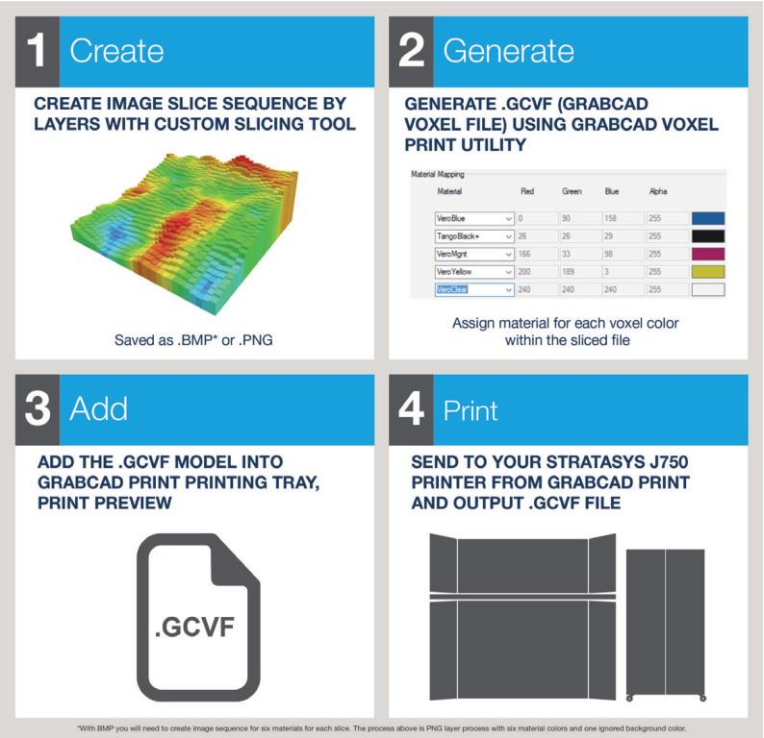


J750 – VOXEL PRINT

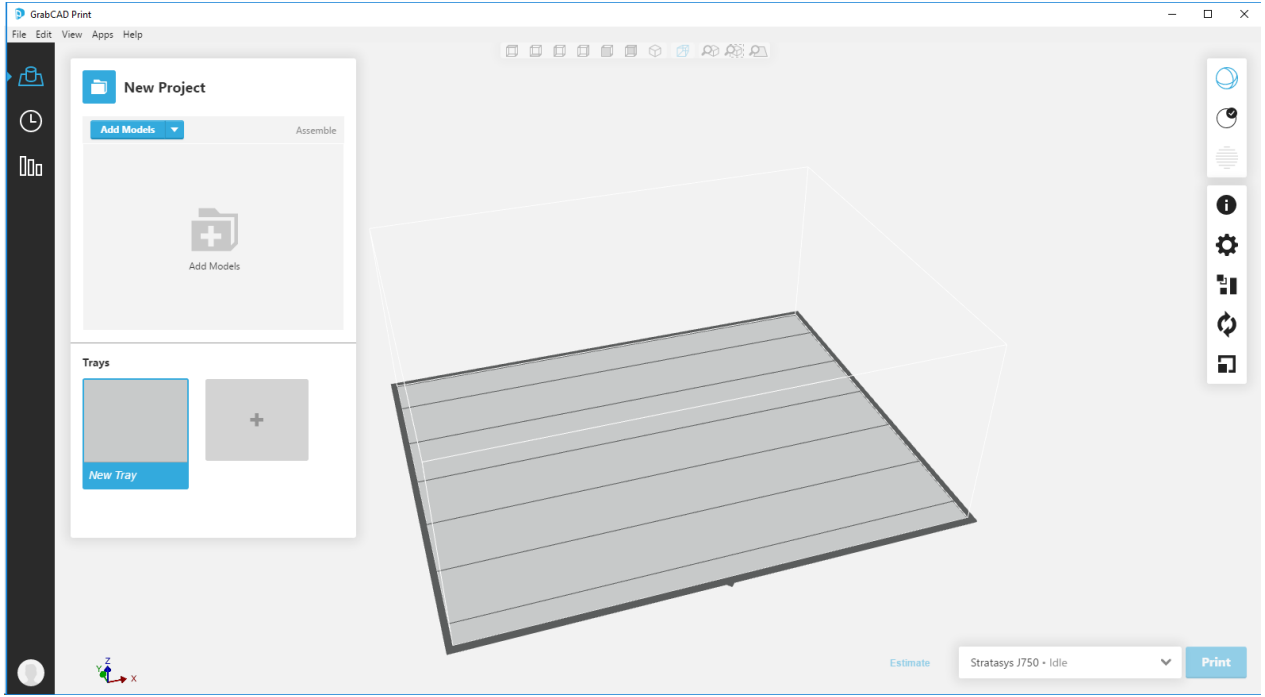




J750 – VIVID Color



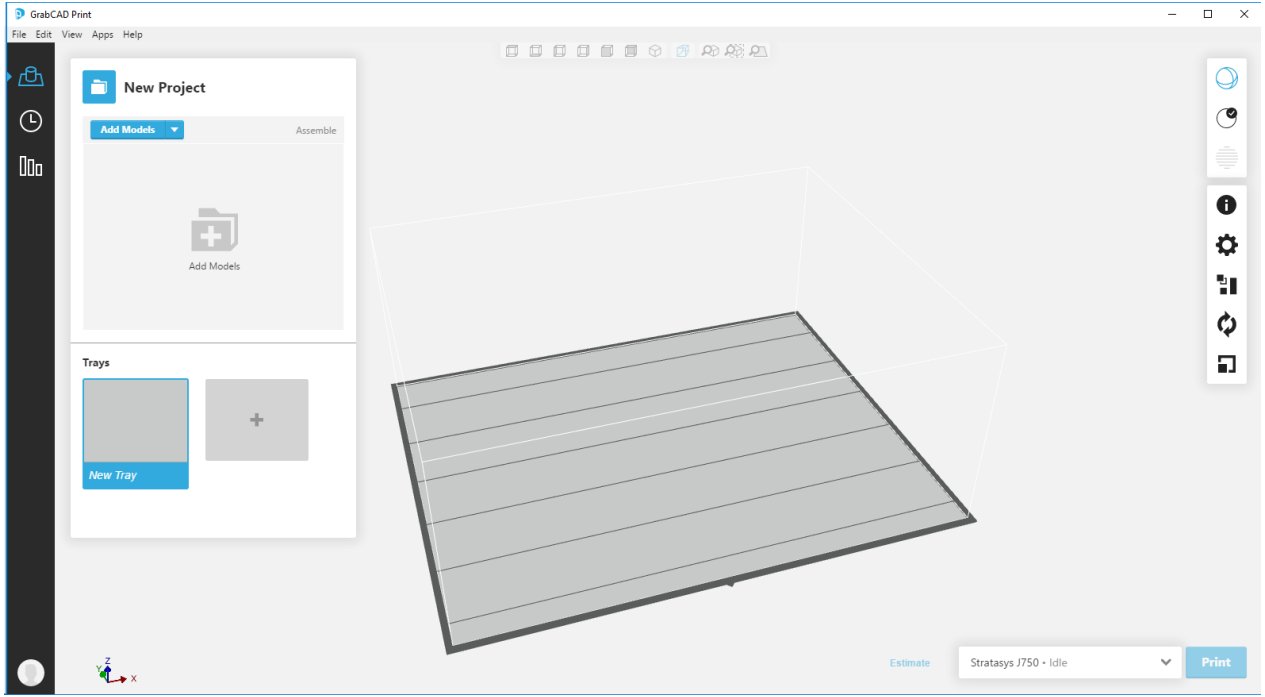
GrabCAD


GrabCAD Print
File Edit View Apps Help
New Project
Add Models
Assemble
Add Models
Trays
New Tray
Estimate
Stratasys J750 • Idle
Print

GrabCAD

GrabCAD

GrabCAD


GrabCAD Print
File Edit View Apps Help
New Project
Add Models
Assemble
Add Models
Trays
New Tray
Estimate
Stratasys J750 • Idle
Print

Děkuji za pozornost