



**UNIVERSIDAD DE OVIEDO**

**CENTRO INTERNACIONAL DE POSTGRADO**

**MÁSTER EN INGENIERÍA INDUSTRIAL**

**TRABAJO FIN DE MÁSTER**

**“ADECUACIÓN DE MATERIALES EN FDM PARA  
DISTRACTOR MECÁNICO Y DISPOSITIVO  
ENDOBAG”**

**LÓPEZ CERNUDA, Cristina**

**ANEXO II. MATERIALES**

## **ÍNDICE DE MATERIALES**

NYLON 12

PC (POLICARBONATO)

PC-ISO (POLICARBONATO ISO)

ABS M30-i



# FDM Nylon 12

## PRODUCTION-GRADE THERMOPLASTIC FOR FORTUS 3D PRINTERS

FDM Nylon 12™ is the first material in Stratasys' family of nylon offerings, complementing the current portfolio of FDM® materials and enabling new applications requiring: repetitive snap fits, high fatigue resistance, strong chemical resistance and press (friction) fit inserts. FDM Nylon 12 is primarily used in aerospace, automotive and consumer goods industries to take on everything from tooling, jigs and fixtures to covers, panels and vibration resistant components. For use with Fortus 380mc™, 450mc™ and 900mc™ 3D Printers, FDM Nylon 12 offers unparalleled toughness and a simple, clean process – free of powders.

CONDITIONED*					
MECHANICAL PROPERTIES <sup>1</sup>	TEST METHOD	ENGLISH		METRIC	
		XZ AXIS	ZX AXIS	XZ AXIS	ZX AXIS
Tensile Strength, Yield (Type 1, 0.125", 0.2"/min)	ASTM D638	4,600 psi	4,100 psi	32 MPa	28 MPa
Tensile Strength, Ultimate (Type 1, 0.125", 0.2"/min)	ASTM D638	6,650 psi	5,600 psi	46 MPa	38.5 MPa
Tensile Modulus (Type 1, 0.125", 0.2"/min)	ASTM D638	186,000 psi	165,000 psi	1,282 MPa	1,138 MPa
Elongation at Break (Type 1, 0.125", 0.2"/min)	ASTM D638	30%	5.4%	30%	5.4%
Elongation at Yield (Type 1, 0.125", 0.2"/min)	ASTM D638	2.4%	2.7%	2.4%	2.7%
Flexural Strength (Method 1, 0.05"/min)	ASTM D790	9,700 psi	8,800 psi	67 MPa	61 MPa
Flexural Modulus (Method 1, 0.05"/min)	ASTM D790	185,000 psi	171,000 psi	1,276 MPa	1,180 MPa
Flexural Strain at Break	ASTM D790	No Break	>10%	No Break	>10%
IZOD impact - notched (Method A, 23 °C)	ASTM D256	2.5 ft-lb/in	1 ft-lb/in	135 J/m	53 J/m
IZOD impact - unnotched (Method A, 23 °C)	ASTM D256	31 ft-lb/in	3.7 ft-lb/in	1,656 J/m	200 J/m
Compressive Strength, Yield (Method 1, 0.05"/min)	ASTM D695	7,400 psi	7,900 psi	51 MPa	55 MPa
Compressive Strength, Ultimate (Method 1, 0.05"/min)	ASTM D695	24,200 psi	800 psi	167 MPa	6 MPa
Compressive Modulus (Method 1, 0.05"/min)	ASTM D695	730,000 psi	155,000 psi	5,033 MPa	1,069 MPa

UNCONDITIONED (DRY)**					
MECHANICAL PROPERTIES	TEST METHOD	ENGLISH		METRIC	
		XZ AXIS	ZX AXIS	XZ AXIS	ZX AXIS
Tensile Strength, Yield (Type 1, 0.125", 0.2"/min)	ASTM D638	7,700 psi	6,900 psi	53 MPa	48 MPa
Tensile Modulus (Type 1, 0.125", 0.2"/min)	ASTM D638	190,000 psi	180,000 psi	1,310 MPa	1,241 MPa
Elongation at Break (Type 1, 0.125", 0.2"/min)	ASTM D638	9.5%	5%	9.5%	5%
Elongation at Yield (Type 1, 0.125", 0.2"/min)	ASTM D638	6.5%	5%	6.5%	5%
Flexural Strength (Method 1, 0.05"/min)	ASTM D790	10,000 psi	8,600 psi	69 MPa	60 MPa
Flexural Modulus (Method 1, 0.05"/min)	ASTM D790	190,000 psi	180,000 psi	1,300 MPa	1,250 MPa
Flexural Strain at Break	ASTM D790	No Break	>10%	No Break	>10%
IZOD impact - notched (Method A, 23 °C)	ASTM D256	2.8 ft-lb/in	0.9 ft-lb/in	150 J/m	50 J/m
IZOD impact - unnotched (Method A, 23 °C)	ASTM D256	>37.4 ft-lb/in	5.1 ft-lb/in	>2,000 J/m	275 J/m

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# FDM Nylon 12

## PRODUCTION-GRADE THERMOPLASTIC FOR FORTUS 3D PRINTERS

### At the core:

#### Advanced FDM Technology

FDM (fused deposition modeling) technology works with engineering-grade thermoplastics to build strong, long-lasting and dimensionally stable parts with the best accuracy and repeatability of any 3D printing technology. These parts are tough enough to be used as advanced conceptual models, functional prototypes, manufacturing tools and production parts.

#### Meet production demands

FDM systems are as versatile and durable as the parts they produce. Advanced FDM 3D Printers boast the largest build envelopes and material capacities in their class, delivering longer, uninterrupted build times, bigger parts and higher quantities than other additive manufacturing systems, delivering high throughput, duty cycles and utilization rates.

#### Opening the way for new possibilities

FDM 3D Printers streamline processes from design through manufacturing, reducing costs and eliminating traditional barriers along the way. Industries can cut lead times and costs, products turn out better and get to market faster.

#### No special facilities needed

FDM 3D Printers are easy to operate and maintain compared to other additive fabrication systems because there are no messy powders or resins to handle and contain, and no special venting is required because FDM systems don't produce noxious fumes, chemicals or waste.

THERMAL PROPERTIES <sup>1</sup>	TEST METHOD	ENGLISH	METRIC
Heat Deflection (HDT) @ 66 psi annealed	ASTM D648	207 °F	97 °C
Heat Deflection (HDT) @ 66 psi unannealed	ASTM D648	167 °F	75 °C
Heat Deflection (HDT) @ 264 psi annealed	ASTM D648	180 °F	82 °C
Heat Deflection (HDT) @ 264 psi unannealed	ASTM D648	131 °F	55 °C
Melting Point	-----	352 °F	178 °C

OTHER	TEST METHOD	VALUE
Specific Gravity	ASTM D792	1.00



SYSTEM AVAILABILITY	LAYER THICKNESS CAPABILITY	SUPPORT MATERIAL	COLOR
Fortus 380mc	0.013 inch (0.330 mm)	SR-110	■ Black
Fortus 450mc	0.010 inch (0.254 mm)		
Fortus 900mc	0.007 inch (0.178 mm)		

<sup>1</sup>Conditioned = 20 °C and 50% RH for 72 hours  
<sup>\*\*</sup>Unconditioned (Dry) = Direct from FDM system  
— Annealed = 2 hours @ 140 °C  
— Unannealed = direct from FDM system

The information presented are typical values intended for reference and comparison purposes only. They should not be used for design specifications or quality control purposes. End-use material performance can be impacted (+/-) by, but not limited to, part design, end-use conditions, test conditions, etc. Actual values will vary with build conditions. Tested parts were built on Fortus 400mc™ @ 0.010" (0.254 mm) slice. Product specifications are subject to change without notice.

The performance characteristics of these materials may vary according to application, operating conditions, or end use. Each user is responsible for determining that the Stratasys material is safe, lawful, and technically suitable for the intended application, as well as for identifying the proper disposal (or recycling) method consistent with applicable environmental laws and regulations. Stratasys makes no warranties of any kind, express or implied, including, but not limited to, the warranties of merchantability, fitness for a particular use, or warranty against patent infringement.

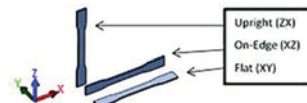
<sup>1</sup>Literature value unless otherwise noted.

Orientation: See Stratasys Testing white paper for more detailed description of build orientations.

XZ = X or "on edge"

XY = Y or "flat"

ZX = or "upright"



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#### HEADQUARTERS

7665 Commerce Way, Eden Prairie, MN 55344  
+1 888 480-3548 (US Toll Free)  
+1 952 937-3000 (Intl)  
+1 952 937-0070 (Fax)

1 Holtzman St., Science Park, PO Box 2496  
Rehovot 76124, Israel  
+972 74 745-4000  
+972 74 745-5000 (Fax)

# PC (polycarbonate)

Production-Grade Thermoplastic  
for Fortus 3D Production Systems



A true industrial thermoplastic, PC (polycarbonate) is widely used in automotive, aerospace, medical and many other applications. PC offers accuracy, durability and stability, creating strong parts that withstand functional testing. A PC part manufactured on a Fortus® 3D Production System is 5 to 60 percent stronger than a part made on previous FDM® systems. It also has superior mechanical properties to ABS and a number of other thermoplastics. When combined with a Fortus system, PC gives you parts for conceptual modeling, functional prototyping, manufacturing tools and end-use-parts.

Mechanical Properties <sup>1</sup>	Test Method	English	Metric
Tensile Strength (Type 1, 0.125", 0.2"/min)	ASTM D638	9,800 psi	68 MPa
Tensile Modulus (Type 1, 0.125", 0.2"/min)	ASTM D638	330,000 psi	2,300 MPa
Tensile Elongation (Type 1, 0.125", 0.2"/min)	ASTM D638	5%	5%
Flexural Strength (Method 1, 0.05"/min)	ASTM D790	15,100 psi	104 MPa
Flexural Modulus (Method 1, 0.05"/min)	ASTM D790	324,000 psi	2,200 MPa
IZOD Impact, notched (Method A, 23°C)	ASTM D256	1 ft-lb/in	53 J/m
IZOD Impact, un-notched (Method A, 23°C)	ASTM D256	6 ft-lb/in	320 J/m

Thermal Properties <sup>2</sup>	Test Method	English	Metric
Heat Deflection (HDT) @ 66 psi	ASTM D648	280°F	138°C
Heat Deflection (HDT) @ 264 psi	ASTM D648	261°F	127°C
Vicat Softening	ASTM D1525	282°F	139°C
Glass Transition (Tg)	DMA (SSYS)	322°F	161°C
Melting Point	-----	Not Applicable <sup>3</sup>	Not Applicable <sup>3</sup>

Electrical Properties <sup>4</sup>	Test Method	Value Range
Volume Resistivity	ASTM D257	2.0x10 <sup>14</sup> - 6.0x10 <sup>13</sup> ohms
Dielectric Constant	ASTM D150-98	3.0 - 2.8
Dissipation Factor	ASTM D150-98	.0006 - .0005
Dielectric Strength	ASTM D149-09, Method A	360-80 V/mil



Other <sup>2</sup>	Test Method	Value
Specific Gravity	ASTM D792	1.2
Flame Classification	UL94	HB
Coefficient of Thermal Expansion	ASTM E831	3.8 <sup>-05</sup> in/in/°F
Rockwell Hardness	ASTM D785	R115
UL File Number	-----	E345258

System Availability	Layer Thickness Capability	Support Structure	Available Colors
Fortus 360mc™	0.013 inch (0.330 mm)	Breakaway, Soluble	□ White
Fortus 380mc™	0.010 inch (0.254 mm)		
Fortus 400mc™	0.007 inch (0.178 mm)		
Fortus 450mc™	0.005 inch (0.127 mm) <sup>5</sup>		
Fortus 900mc™			

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<sup>1</sup>Build orientation is on side long edge.

<sup>2</sup>Literature value unless otherwise noted.

<sup>3</sup>Due to amorphous nature, material does not display a melting point.

<sup>4</sup>All Electrical Property values were generated from the average of test plaques built with default part density (solid). Test plaques were 4.0 x 4.0 x 0.1 inches (102 x 102 x 2.5 mm) and were built both in the flat and vertical orientation. The range of values is mostly the result of the difference in properties of test plaques built in the flat vs. vertical orientation.

<sup>5</sup>PC can attain 0.005 inch (0.127mm) layer thickness when used with SR-100™ soluble support. 0.005 inch layer thickness is not available on the Fortus 900mc.

## Stratasys | [www.stratasys.com](http://www.stratasys.com) | [info@stratasys.com](mailto:info@stratasys.com)

7665 Commerce Way  
Eden Prairie, MN 55344

+1 888 480-3548 (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)

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## At the core: Advanced FDM Technology

Fortus systems are based on Stratasys® FDM® (fused deposition modeling) technology. FDM is the industry's leading additive manufacturing technology, and the only one that uses production-grade thermoplastics, enabling the most durable parts.

Fortus systems use a wide range of thermoplastics with advanced mechanical properties so your parts can endure high heat, caustic chemicals, sterilization and high-impact applications.

## No special facilities needed

You can install a Fortus 3D Production System just about anywhere. No special venting is required because Fortus systems don't produce noxious fumes, chemicals or waste.

## No special skills needed

Fortus 3D Production Systems are easy to operate and maintain compared to other additive fabrication systems because there are no messy powders to handle and contain. They're so simple, an operator can be trained to operate a Fortus system in less than 30 minutes.

## Get your benchmark on the future of manufacturing

Fine details. Smooth surface finishes. Accuracy. Strength. The best way to see the advantages of a Fortus 3D Production System is to have your own part built on a Fortus system. Get your free part at: [stratasys.com](http://stratasys.com).

# PC-ISO

## Production-Grade Thermoplastic for Fortus 3D Production Systems



PC-ISO™ (polycarbonate-ISO), an industrial thermoplastic, which in its raw state, is biocompatible (ISO 10993 USP Class VI) and can be gamma or EtO sterilized. PC-ISO is commonly used in food and drug packaging and medical device manufacturing because of the material's strength and medical compatibility. When combined with a Fortus® 3D Production System, PC-ISO gives you parts that can be used for conceptual modeling, functional prototyping and end-use parts.

Mechanical Properties <sup>1</sup>	Test Method	English	Metric
Tensile Strength (Type 1, 0.125", 0.2"/min)	ASTM D638	8,300 psi	57 MPa
Tensile Modulus (Type 1, 0.125", 0.2"/min)	ASTM D638	289,800 psi	2,000 MPa
Tensile Elongation (Type 1, 0.125", 0.2"/min)	ASTM D638	4%	4%
Flexural Strength (Method 1, 0.05"/min)	ASTM D790	13,100 psi	90 MPa
Flexural Modulus (Method 1, 0.05"/min)	ASTM D790	310,400 psi	2,100 MPa
IZOD Impact, notched (Method A, 23°C)	ASTM D256	1.6 ft-lb/in	86 J/m
IZOD Impact, un-notched (Method A, 23°C)	ASTM D256	1 ft-lb/in	53 J/m

Thermal Properties <sup>2</sup>	Test Method	English	Metric
Heat Deflection (HDT) @ 66 psi	ASTM D648	271°F	133°C
Heat Deflection (HDT) @ 264 psi	ASTM D648	260°F	127°C
Glass Transition (T <sub>g</sub> )	DMA (SSYS)	322°F	161°C
Vicat Softening	ISO 306	282°F	139°C
Melting Point	-----	Not Applicable <sup>3</sup>	Not Applicable <sup>3</sup>

Electrical Properties <sup>4</sup>	Test Method	Value Range
Volume Resistivity	ASTM D257	1.5x10 <sup>14</sup> - 8.0x10 <sup>13</sup> ohms
Dielectric Constant	ASTM D150-98	3.0 - 2.8
Dissipation Factor	ASTM D150-98	.0009 - .0005
Dielectric Strength	ASTM D149-09, Method A	370 - 70 V/mil



Other <sup>2</sup>	Test Method	Value
Specific Gravity	ASTM D792	1.2
Flame Classification	UL 94	HB

System Availability	Layer Thickness Capability	Support Structure	Available Colors
Fortus 380mc™	0.013 inch (0.330 mm)	Breakaway	<input type="checkbox"/> White
Fortus 400mc™	0.010 inch (0.254 mm)		<input checked="" type="checkbox"/> Translucent
Fortus 450mc™	0.007 inch (0.178 mm)		Natural
Fortus 900mc™			

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The performance characteristics of these materials may vary according to application, operating conditions, or end use. Each user is responsible for determining that the Stratasys material is safe, lawful, and technically suitable for the intended application, as well as for identifying the proper disposal (or recycling) method consistent with applicable environmental laws and regulations. Stratasys makes no warranties of any kind, express or implied, including, but not limited to, the warranties of merchantability, fitness for a particular use, or warranty against patent infringement.

\*It is the responsibility of the finished device manufacturer to determine the suitability of all the component parts and materials used in their finished products.

<sup>1</sup>Build orientation is on side long edge.

<sup>2</sup>Literature value unless otherwise noted.

<sup>3</sup>Due to amorphous nature, material does not display a melting point.

<sup>4</sup>All Electrical Property values were generated from the average of test plaques built with default part density (solid). Test plaques were 4.0 x 4.0 x 0.1 inches (102 x 102 x 2.5 mm) and were built both in the flat and vertical orientation. The range of values is mostly the result of the difference in properties of test plaques built in the flat vs. vertical orientation.

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7665 Commerce Way	2 Holtzman St.,
Eden Prairie, MN 55344	Science Park, PO Box 2496
+1 888 480-3548 (US Toll Free)	Rehovot 76124, Israel
+1 952 937-3000 (Intl)	+972 74 745-4000
+1 952 937-0070 (Fax)	+972 74 745-5000 (Fax)

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Fortus systems use a wide range of thermoplastics with advanced mechanical properties so your parts can endure high heat, caustic chemicals, sterilization and high-impact applications.

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# ABS-M30i

Production-Grade Thermoplastic  
for Fortus 3D Production Systems



ABS-M30i™ is a high strength material well suited for the medical, pharmaceutical and food packaging industries. Parts manufactured with ABS-M30i material are biocompatible (ISO 10993 USP Class VI)\* and can be gamma or EtO sterilized. When combined with Fortus® 3D Production Systems, ABS-M30i gives you biocompatible parts with excellent mechanical properties that are well suited for conceptual modeling, functional prototyping, manufacturing tools and end-use-parts.

Mechanical Properties <sup>1</sup>	Test Method	English		Metric	
		XZ Axis	ZX Axis	XZ Axis	ZX Axis
Tensile Strength, Yield (Type 1, 0.125", 0.2"/min)	ASTM D638	4,550 psi	3,750 psi	31 MPa	26 MPa
Tensile Strength, Ultimate (Type 1, 0.125", 0.2"/min)	ASTM D638	4,650 psi	4,050 psi	32 MPa	28 MPa
Tensile Modulus (Type 1, 0.125", 0.2"/min)	ASTM D638	320,000 psi	310,000 psi	2,230 MPa	2,180 MPa
Tensile Elongation at Break (Type 1, 0.125", 0.2"/min)	ASTM D638	7%	2%	7%	2%
Tensile Elongation at Yield (Type 1, 0.125", 0.2"/min)	ASTM D638	2%	1%	2%	1%
Flexural Strength (Method 1, 0.05"/min)	ASTM D790	8,700 psi	7,000 psi	60 MPa	48 MPa
Flexural Modulus (Method 1, 0.05"/min)	ASTM D790	300,000 psi	250,000 psi	2,060 MPa	1,760 MPa
Flexural Strain at Break (Method 1, 0.05"/min)	ASTM D790	4%	3.5%	4%	3.5%

Mechanical Properties	Test Method	English	Metric
		XZ Axis	XZ Axis
IZOD Impact, notched (Method A, 23°C)	ASTM D256	2.4 ft-lb/n	128 J/m
IZOD Impact, un-notched (Method A, 23°C)	ASTM D256	5.6 ft-lb/in	300 J/m

Thermal Properties <sup>1</sup>	Test Method	English	Metric
Heat Deflection (HDT) @ 66 psi, 0.125" unannealed	ASTM D648	204°F	96°C
Heat Deflection (HDT) @ 264 psi, 0.125" unannealed	ASTM D648	180°F	82°C
Vicat Softening Temperature (Rate B/50)	ASTM D1525	210°F	99°C
Glass Transition (Tg)	DSC (SSYS)	226°F	108°C
Coefficient of Thermal Expansion (flow)	ASTM E831	4.90 <sup>-05</sup> in/in/°F	8.82 <sup>-05</sup> mm/mm/°C
Coefficient of Thermal Expansion (xflow)	ASTM E831	4.70 <sup>-05</sup> in/in/°F	8.46 <sup>-05</sup> mm/mm/°C
Melting Point	-----	Not Applicable <sup>2</sup>	Not Applicable <sup>2</sup>

# ABS-M30i



Electrical Properties <sup>3</sup>	Test Method	Orientation	Value Range
Volume Resistivity	ASTM D257	XZ Axis	4.0 <sup>15</sup> - 3.3 <sup>16</sup> ohm-cm
Dielectric Constant	ASTM D150-98	XZ Axis	2.6 - 2.86
Dissipation Factor	ASTM D150-98	XZ Axis	0.0048 - 0.0054
Dielectric Strength	ASTM D149-09, Method A	XZ Axis	100 V/mil
Dielectric Strength	ASTM D149-09, Method A	ZX Axis	360 V/mil

Other <sup>1</sup>	Test Method	Value
Specific Gravity	ASTM D792	1.04
Flame Classification	UL94	HB (0.09", 2.50 mm)
Rockwell Hardness	ASTM D785	109.5

System Availability	Layer Thickness Capability	Support Structure	Available Colors
Fortus <sup>®</sup> 360mc <sup>™</sup>	0.013 inch (0.330 mm)	Soluble Supports	<input type="checkbox"/> Ivory
Fortus 380mc <sup>™</sup>	0.010 inch (0.254 mm)		<input type="checkbox"/> White
Fortus 400mc <sup>™</sup>	0.007 inch (0.178 mm)		<input type="checkbox"/> Black
Fortus 450mc <sup>™</sup>	0.005 inch (0.127 mm) <sup>4</sup>		<input type="checkbox"/> Dark Grey
Fortus 900mc <sup>™</sup>			<input type="checkbox"/> Red
			<input type="checkbox"/> Blue

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<sup>1</sup>Literature value unless otherwise noted.

<sup>2</sup>Due to amorphous nature, material does not display a melting point.

<sup>3</sup>All Electrical Property values were generated from the average of test plaques built with default part density (solid). Test plaques were 4.0 x 4.0 x 0.1 inches (102 x 102 x 2.5 mm) and were built both in the flat and vertical orientation. The range of values is mostly the result of the difference in properties of test plaques built in the flat vs. vertical orientation.

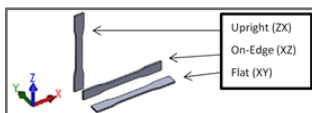
<sup>4</sup>0.005 inch (0.127 mm) layer thickness not available for Fortus 900mc.

Colors: The test data was collected using ABS-M30 Ivory (natural) specimens. ABS-M30 colored material will have similar properties, but can vary by up to 10%. Orientation: See Stratasys Testing white paper for more detailed description of build orientations.

\* XZ = X or "on edge"

\* XY = Y or "flat"

\* ZX = or "upright"



Stratasys | [www.stratasys.com](http://www.stratasys.com) | [info@stratasys.com](mailto:info@stratasys.com)

7665 Commerce Way  
Eden Prairie, MN 55344  
+1 888 480-3548 (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)

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Fortus systems are based on patented Stratasys<sup>®</sup> FDM<sup>®</sup> (fused deposition modeling) technology. FDM is the industry's leading additive manufacturing technology, and the only one that uses production-grade thermoplastics, enabling the most durable parts.

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