The Virtual Foundry
211 S Water St
Stoughton WI 53589, USA
www.thevirtualfoundry.com

Compare and Contrast:
Ultrafuse by BASF and Filamet™ by The Virtual Foundry

The Similarities

BASF (with brand name Ultrafuse) and The Virtual Foundry (with brand name Filamet™) both offer sinterable metal-filled 3D printing filaments that work in common FFF/FDM 3D printers.

Both Ultrafuse and Filamet™ materials are loaded with over 80% metal and are available in 1.75mm and 2.85mm diameters.

Ultrafuse and Filamet™ both follow the same basic three-step process… Print * Debind * Sinter

The resulting part from both companies is pure metal and in this state, any standard metal process can be performed on the part: welding, polishing, machining, etc.

Both BASF and The Virtual Foundry recommend considering this process a near-net-shape activity when tight tolerances are required. Threads should be tapped after sintering, for example.

The Differences

BASF - Ultrafuse	The Virtual Foundry - Filamet™
Material Selection	
Ultrafuse offers two different materials: 316L and 17-4 PH.	Filamet™ comes in 13 different stock materials (which include ceramic and glass) with custom options making the material selection unlimited. So that we're looking at an even comparison, only 316L and 17-4 will be discussed in this paper.

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3D Printer	
BASF suggests using a 3D printer with a closed and heated chamber and heated bed capable of at least 100°C to print Ultrafuse. The print bed should be glass with Dimafix bed adhesive (preferred).	Any FFF/FDM 3D printer that accepts third party materials can print Filamet™. Dual gear extrusion will perform better than single gear, and a direct drive extruder will be easier to use than a bowden tube system. Convenient nozzle changing is helpful.
Print Settings	
Heated Bed Temperature: 100 - 120°C Hotend Temperature: 215-235°C Nozzle Diameter: 0.4mm Nozzle Material: Hardened steel No Part Cooling: Layer cooling can cause warping during printing Recommended Layer Height: 0.10 - 0.25mm [.15 or lower for higher density] Recommended Speed: 15 - 40 mm/s Infill: 100% - Recommend either Lines or Concentric pattern depending on your geometry to give you the most uniform and solid infill. Any gaps or voids in your infill could lead to failure during the debinding and sintering process.	Select your slicer's generic PLA profile. Flow Rate: 135% Hotend Temperature: 225°C Nozzle Diameter: 0.6mm Nozzle Material: Hardened steel No Part Cooling Required: Can be used with no adverse effects Recommended Layer Height: 0.10 - 0.30mm Infill: Solid infill not required but should be at least 30% Warming: Use a Filawarmer to ease the path from spool to printer

BASF - Ultrafuse	The Virtual Foundry - Filamet™
Design Considerations	
BASF suggests that you create one flat side and make sure your part has a consistent thickness. Avoid thin walls and overhangs. Keep your parts within a 100mm^3 volume. Using a height-to-width ratio of less than 3 to 1 will prevent part collapse during debind and sintering. Parts need to be scaled +120% of the required final dimension in X/Y, and +126% of the required final dimension in Z.	The Virtual Foundry advises that thinner walls will perform better than thick parts. Think of shapes like those generated through topological optimization and generative design. Because parts are supported with a ballast material during debinding and sintering, you are not limited to any height-to-width ratios nor overhang limitations. The upper limits of size capability have not yet been discovered, but part size will be limited by your print volume and sintering equipment. To scale your print, consider the final density you want to achieve. You can scale up 10%, shrink the parts 10% and get about 80-85% density. If you scale up 20% and shrink the parts by 20%, your density will be in the high 90%s. Scale the Z axis slightly more than X and Y. In this case, Z means the axis in the crucible which may be different from the Z axis on the print bed.
Supports and Support Material	
When using Ultrafuse, it is recommended to use a support when exceeding a 45° overhang angle. Use the same material as the support (the support infill structure should be dense, approx. 70 %). Supports can be removed in the green part state or after sintering. The debinding and sintering strategy should be considered before removing the support material from the green part.	When using Filamet™, overhangs can be printed using any support material that you would use with standard PLA, including using actual PLA as your support material. Supports are removed before debinding and sintering.

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Debinding and Sintering	
Ultrafuse debinding requires a catalytic debind process that uses vaporized nitric acid.	Filamet™ debinds thermally with just heat.
Ultrafuse sinters in a pure hydrogen environment using commercial furnace equipment.	Filamet™ sinters in common, open-atmosphere kilns and furnaces.
You'll need to send your printed part to a service provider for debinding and sintering. Print and clean your part, mail it off, and wait for it to return after a scheduled run. Currently, parts are processed two times per month. † Details about these processes are listed at the end of this article.	You will bury your print in a refractory ballast material (Sapphire3D Steel Blend), then cover that with Sintering Carbon to manage oxygen. You'll program your kiln with a time and temperature profile provided by The Virtual Foundry. Once the crucible is loaded and placed in the kiln, start the program and remove the part once the program is complete and the kiln is cooled. You can perform the entire Filamet™ process in your house, lab, office or shop.
Sintered Part Density	
316L: 7850 kg/m^3 / 490.1 lb/ft^3 17-4 PH: ≥ 7g/cm^3	You have options and control here. You can shrink the parts 7-10% and get about 80-85% density. Sintering with enough heat and time will cause the parts to shrink by 20%. At this level of shrinkage, your density will be in the high 90%s.

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BASF - Ultrafuse	The Virtual Foundry - Filamet™
Pricing - Material (USD)	
Ultrafuse 316L 1.75mm or 2.85mm 3kg: $465 (prices from matterhackers.com)	316L Filamet™ 1.75mm or 2.85mm 1kg: $273 0.5kg: $142 (prices from shop.thevirtualfoundry.com)
Ultrafuse 17-4 PH 1.75mm or 2.85mm 3kg: $349 1kg: $129 (prices from matterhackers.com)	17-4 Filamet™ 1.75mm or 2.85mm 1kg: $183.60 0.5kg: $98.40 (prices from shop.thevirtualfoundry.com)
Pricing - Debinding and Sintering	
Each spool of filament comes with one free Processing Ticket which covers one debinding and sintering run of up to 1kg of 3D printed Ultrafuse green parts. Additional processing tickets can be purchased for $50 USD or €60,00 – €180,00 and cover the same conditions. The parts are processed at DSH Technologies in North America, and Elnik Systems and AMPC Solutions in Europe. DSH Technologies charges $1500 per cycle if you contact them directly for debinding and sintering services.	Your sintering kiln must meet two requirements to be effective. 1. It has a programmable controller (preferable digital) 2. It can maintain the sintering temperature for several hours (1260°C/2300°F) These kilns range in price from a few hundred dollars to hundreds of thousands of dollars. The Virtual Foundry sells kilns ranging from $2980 - $7920. Once the equipment is acquired, each sintering run will require these items: Crucible: $48.00 - $100.80 Refractory Ballast: $62 for 1kg. A portion is used and this can be reused Sintering Carbon: $36 for 0.5kg. A portion is used and this will be consumed Debinding and sintering your first 1kg of Filamet™: $146 plus the kiln price Subsequent kgs: $36 for Sintering Carbon

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BASF - Ultrafuse	The Virtual Foundry - Filamet™
To Purchase	
forward-am.com/solutions-partners/distributors/	thevirtualfoundry.com/where-to-buy/

References

The information in this article was obtained from:

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† Debinding and Sintering Ultrafuse by BASF

Catalytic debind decomposes the primary polymer in a gaseous acid environment at temperatures in the low hundreds (°C). Debinding according to the BASF process at 120°C with HNO_3 > 98%. Based on a 50 liter debinding furnace, a nitric acid feed of typically 30 ml/h and a purging gas with a throughput of 500 l/h proves to lead to safe processing. Reaction products are then burnt in a natural gas flame at much higher temperatures of above 600°C and your green part is now officially a brown part. The debinding process is finished when a minimal debinding loss of 10.5% is reached. This is done within an enclosed, controlled system designed specifically for this entire process.

Once the now brown part has finished the debinding process, next is sintering—the process of turning the leftover powdered metal in the brown part into solid metal through heat. In a specially designed furnace, temperatures are set right below the melting temperature of the metal in order to remove the secondary binder from the brown part. With this binder gone, the metal particles are now able to fuse together.

Sintering should be done in an atmosphere with 100% clean and dry hydrogen. A typical sintering cycle consists of a ramp from:

1. Room temperature - 5 K/min - 600°C, hold 1h
2. 600°C - 5 K/min - 1380°C, hold 3h
3. Furnace cooling