Thermal and mechanical properties of selected 3D printed thermoplastics in the cryogenic temperature regime

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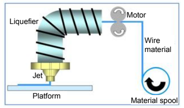
M3PoB

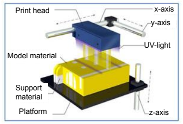
Introduction

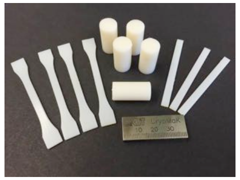
The application of High Temperature Superconductors is actually expanding to a couple of new fields, in particular space and airborne applications. The design and development of future low or zero emission airplanes is a challenge which requires the integration of the technology of superconductivity, which will be applied in different parts of the vehicle as power generator, electrical combustion drives and transfer lines depending on the philosophy of the approach.

The advantage of the high energy density and low losses of superconducting wires and cables allows very compact designs, meets however the disadvantage of a necessary thermal insulation by a containment with vacuum shield, a cryostat, to provide the operation temperature of superconductors and to restrict thermal losses.

3D-printed thermoplastics are so far rarely considered for such cryogenic applications but are promising candidates for complex cryogenic parts and constructions. Rare or no material data on mechanical and thermal properties however are available for this temperature regime. It is the goal of this work to start first investigations of the mechanical properties (tensile stress and compression), the thermal expansion and the thermal conduction on some examples of 3D printed materials to get first data at temperatures in the range of 4-300K



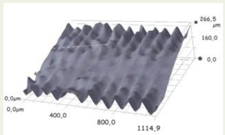


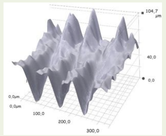


3D Printing Materials

Fused Deposition Modeling (FDM)

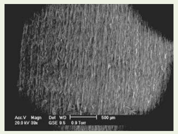
Device	modified Ultimaker-Original
Resolution / sheet thickness	~100 µm
Deposition temperature	~245°C
Material	ABS (Acrylnitril-Butadien-Styrol))

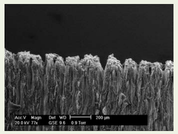




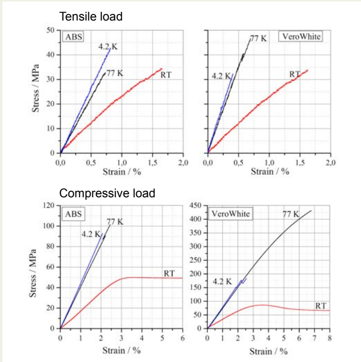
Polyjet Modeling

Device	Stratasys EDEN 260V
Resolution x/y plane	~42 µm
Sheet thickness	~17 µm
Deposition temperature	50-60°C
Material	Acrylate photopolymer hardened by UV (VeroWhite Fullcure830™)





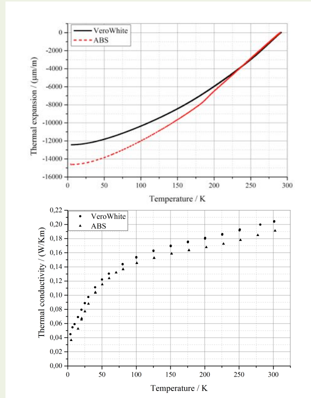
Mechanical Properties



Material	Temp.	Tensile: Youngs Modulus, GPa	Tensile: Yield strength, MPa	Tensile: Ultimate Strength, MPa	Compressive: Compressive Modulus, GPa	Compressive: Yield Strength, MPa	Compressive: Ultimate Strength, MPa
Polyjet-Modeling							
VeroWhite	RT	2.497 (2.5)[a]	32	36 (50)[a]	3.108	81	86
	77K	6.850	-	46	7.813	255	431
	4K	8.876	-	32	7.752	-	183
Fused Deposition Modeling							
ABS	RT	2.583 (2.4)[b]	33	35 (45)[b]	1.591	49	50
	77K	4.476	-	32	4.143	-	101
	4K	5.570	-	43	4.397	-	93

[a,b] Data at RT from manufacturer datasheet

Thermal Properties



Outlook

Within this work the samples investigated were printed in the direction of the flat side. An open question is the existence of an anisotropy of properties with respect to the print direction.
In future the investigations will be extended to a couple of other 3D-printed materials, including investigations on high voltage insulation, thermal cycling, and permeability of gases.