



Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

High performance compounds for FFF printing in the aerospace applications

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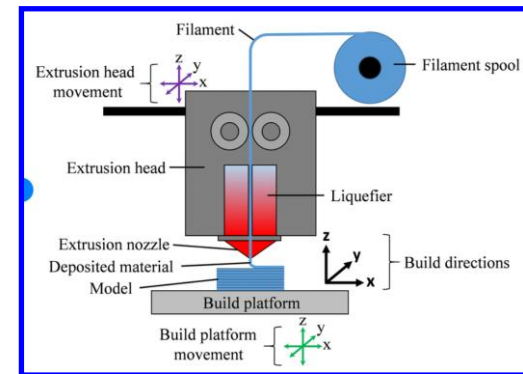


Development of high performance compounds for FFF printing in the aerospace applications

➤ The primary objective of the aerospace world is certainly that of reduce the weights of their aircraft with lighter parts maintain high performance standards of the components produced.

REQUIREMENTS REQUIRED FOR MATERIALS FOR FDM PRINTING OF AIRCRAFT COMPONENTS

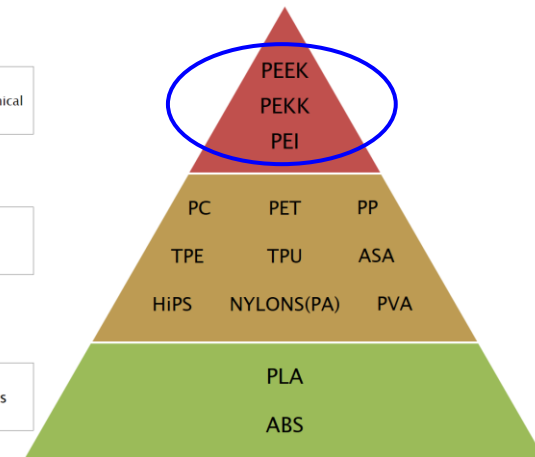
- High mechanical properties
- High resistance to solvents
- Temperature resistance
- Good processability for FDM printing
- High adhesion properties of the composite to metal substrates
- High wear resistance



Advanced Plastics
Mechanical, thermal and chemical high strength application

Engineering Plastics
Structural purpose applications

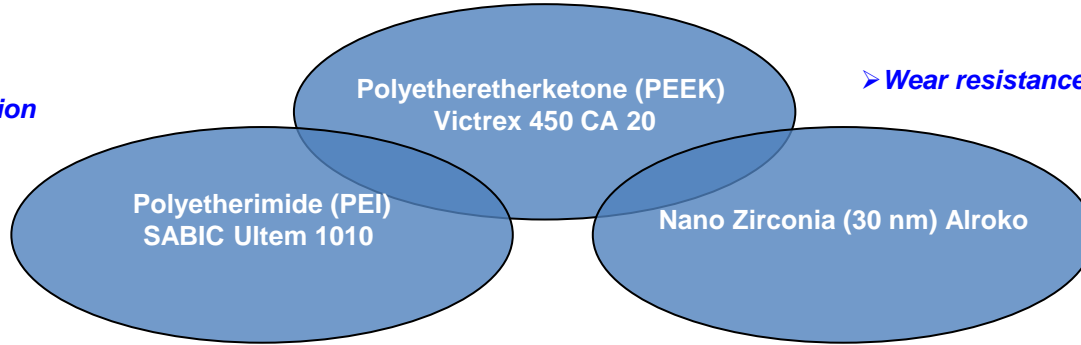
Standard plastics
Non-critical applications



Development of high performance compounds for FFF printing in the aerospace applications

- Mechanical properties
- CF/Matrix adesion
- Composite/Metal adesion
- AM Processability

Blending to increase



➤ Wear resistance

VICTREX™ PEEK 450G™

Product Description
High performance thermoplastic material, unreinforced PolyEtherEtherKetone (PEEK), semi-crystalline, granules for injection-moulding and extrusion, standard flow, FDA food contact compliant, colour white/yellowish.

Typical Application Areas
Applications for higher strength and stiffness suitable for applications for medical and food.

MATERIAL PROPERTIES

Property	Value
Tensile Strength	100 MPa
Tensile Modulus	2.3 GPa
Flexural Strength	100 MPa
Flexural Modulus	2.3 GPa
Impact Strength	40 kJ/m²
Heat Deflection Temperature	230°C
Thermal Conductivity	0.21 W/mK
Specific Heat Capacity	1.5 J/gK
Melting Point	340°C
Glass Transition Temperature	216°C
Thermal Expansion Coefficient	10.5 µm/mK
Water Absorption	0.02%

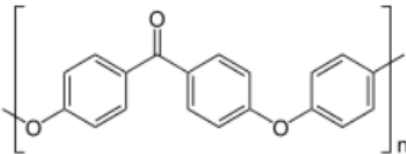
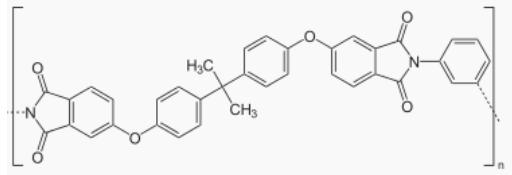
VICTREX® PEEK 450CA20

Product Description
High performance thermoplastic material, 20% carbon fibre reinforced PolyEtherEtherKetone (PEEK), semi-crystalline, granules for injection-moulding and extrusion, standard flow, FDA food contact compliant, colour black.

Typical Application Areas
Applications for higher strength and stiffness in a static or dynamic system. Excellent wear resistance, low coefficient of friction, low coefficient of thermal expansion. Chemically resistant to aggressive environments.

MATERIAL PROPERTIES

PROPERTY	CONDITIONS	TEST METHOD	UNITS	TYPICAL VALUE
Tensile Strength	Stress, 23°C	ISO 527	MPa	130
Tensile Modulus	Stress, 23°C	ISO 527	GPa	2.1
Flexural Strength	Stress, 23°C	ISO 178	MPa	140
Flexural Modulus	Stress, 23°C	ISO 178	GPa	2.4
Impact Strength	Notched, 23°C	ISO 180A	kJ/m²	8.5
Heat Deflection Temperature	Unnotched, 23°C	ISO 1843	°C	40
Melting Point		ISO 11357	°C	343
Glass Transition Temperature		ISO 11357	°C	142
Thermal Expansion Coefficient	Average	Average	µm/mK	10.5
Water Absorption	Average	Average	%	0.02



Data Sheet: ULTEM 1010

Details
This material has the highest heat resistance, chemical resistance and tensile strength compared to other POM thermoplastics. It is available in transparent, opaque and glass filled grade. It has broad application in custom tools for metal or plastic parts fabrication, medical tools and temperature resistant dies.

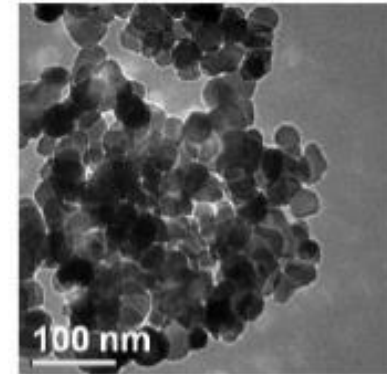
Key Features
High heat resistance - Resistant to chemicals.

Thermal Properties

Property	Value
Heat deflection [°C]	200
Glass transition temperature [°C]	216
Vicat softening temperature [°C]	215
Coefficient of thermal expansion [6.1 - 10.6]	10
Thermal conductivity [W/m·K]	0.21
Specific heat capacity [J/kg·K]	2000
Melting point [°C]	340

Mechanical Properties

Property	Value
Tensile strength [MPa]	105
Modulus of elasticity [GPa]	3.2
Flexural strength [MPa]	160



Main characteristic of the starting material

BENCHMARK: SOLVAY KETASPIRE KT820 CF10



SCHEDA TECNICA

**Ketaspire® CARBON PEEK
Filament**

KetaSpire® PEEK
Design & Processing Guide

Formulation set
PEEK 450 CA 20 / PEI (80/20)
PEEK 450 CA 20 / PEI (70/30)
PEEK 450 CA20 / nano ZrO2 (95/5), 30 nm

	E [GPa]	Tensile Strength (MPa)	Melting point (°C)	Tg (°C)	Melt viscosity (Pa s)
PEEK Solvay Ketaspire CF 10 LS1	11	140	343		
PEEK VICTREX 450 G	4	98	343	143	350
PEEK VICTREX 450 CA 20	19.5	230	343	143	525
PEI Ultem 1010	3.2	110	340	216	25 cm ³ /10 min

		Composizione	
Materiale composito		CF	Filler
		%	%
1	Carbon PEEK Solvay Ketaspire KT820 CF10	10	-
2	Carbon PEEK Victrex 450CA20	20	-
3	C-PEEK 450CA20/PEI:80/20	16	20
4	C-PEEK 450CA20/PEI:70/30	14	30
5	C-PEEK 450CA20/ZrO₂:95/5	≈20	5

Preparation by melt compounding of Hybrid composite based on Carbon PEEK, PEI and nano ZrO₂



Victrex 450 CA20



Nano Zirconia



PEI Ultem

MIXER HAAKE PolyLab QC



PEEK/PEI (70/30)

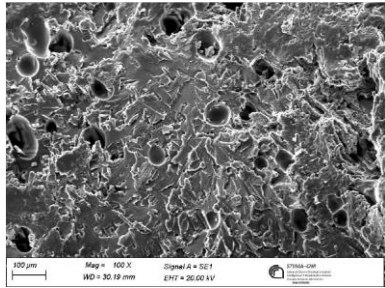


PEEK/nano ZrO₂

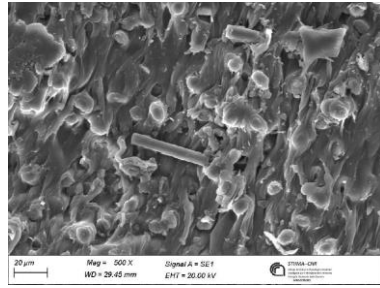


PEEK/PEI (80/20)

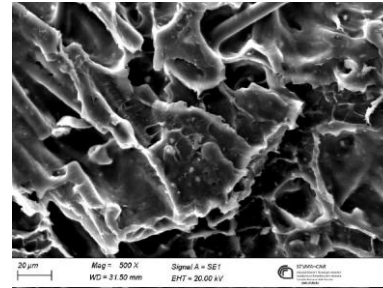
SEM and Calorimetric analysis (DSC) of PEEK/PEI e PEEK/nanoZrO₂ compound



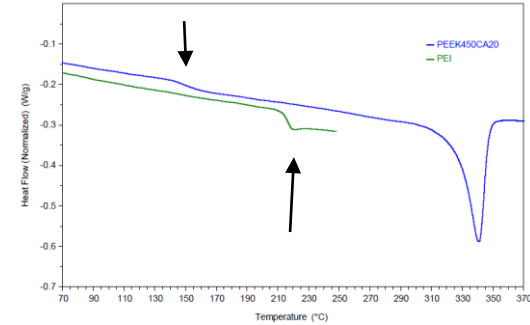
Victrex 450 CA20/PEI 70/30



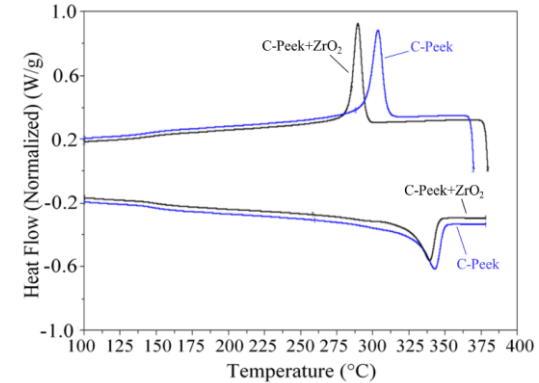
Victrex 450 CA 20



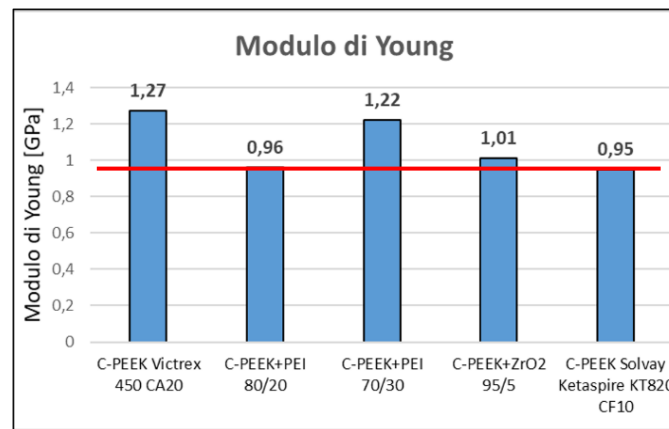
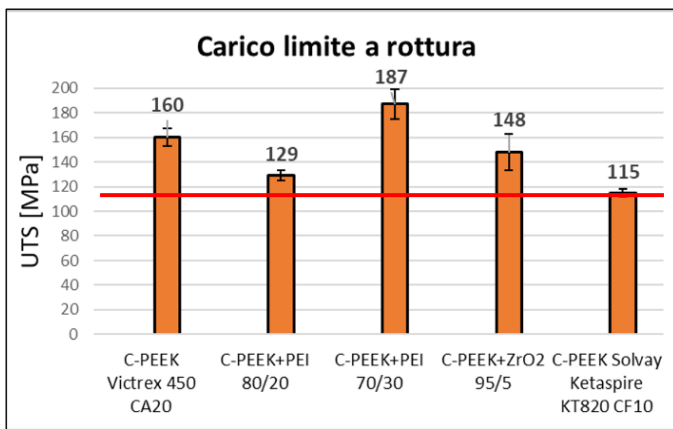
Victrex 450 CA20/nano ZrO₂ 95/5



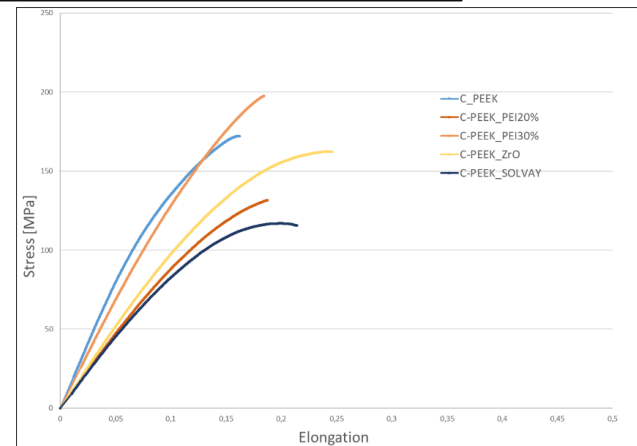
PEEK/PEI/ZrO ₂ (%)	100/0	80/20	70/30	95/0/5
T _g (°C)	149.0	170.9	176.8	216.1
T _c (°C)	303.6	293.6	294.2	289.5
T _m (°C)	343.1	338.4	338.9	339.1
X _c *	30.4	26.2	31.3	26.6



Mechanical characterization of the compound (STIIMA CNR)



Sample ISO527*	E [GPa]			UTS [MPa]		
C_PEEK	1,27	±	0,27	160	±	7
C_PEEK_PEI20%	0,96	±	0,04	129	±	4
C_PEEK_PEI30%	1,22	±	0,11	187	±	12
C_PEEK_ZrO2	1,01	±	0,04	148	±	15
C_PEEK_Solvay	0,95	±	0,06	115	±	3



Preparation by Extrusion of Filament for 3D printing (FFF)



Process parameter	Unit	Value
Feeding	°C	380
Compression	°C	394
Transport	°C	390
Dye	°C	386
Melt	°C	392
Pression of extrusion	Bar	82
Screw speed	RPM	18
extrusion speed	m/min	7



C-PEEK+PEI 30%

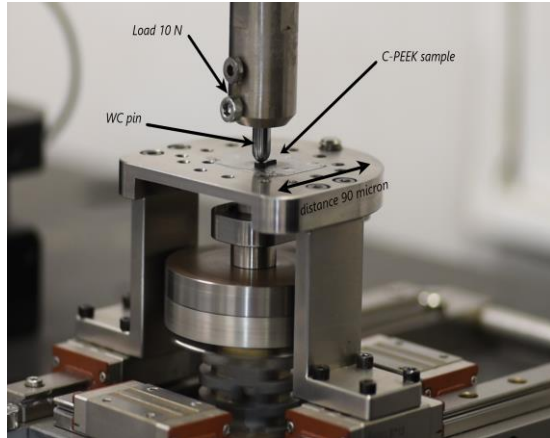


C-PEEK+5% n ZrO₂



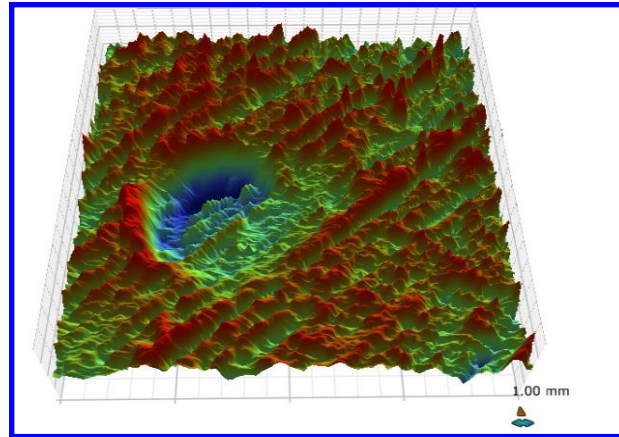
C-PEEK+PEI 20%

Fretting Test on Hybrid Carbon PEEK/nano Zirconia



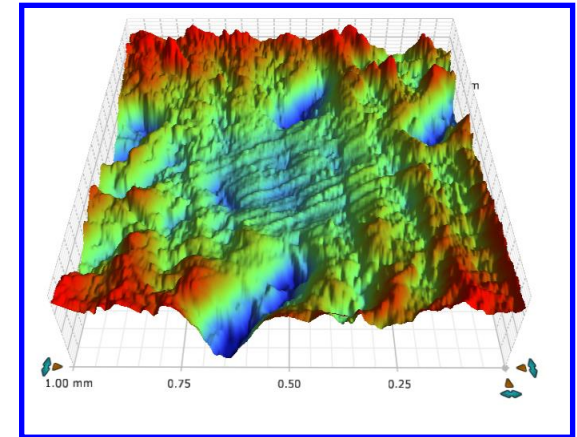
time = 3 h
Load = 10 N
F = 60 Hz
L = 90 μm

Carbon PEEK



$\Delta h = 6,6 \mu\text{m}$
 $\Delta x = 0,5 \text{ mm}$

Carbon PEEK/nano Zirconia



$\Delta h = 0,58 \mu\text{m}$
 $\Delta x = 0,5 \text{ mm}$

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