What material should I use in a high temperature environment?

The easiest way to compare how well different materials withstand heat is using the heat deflection temperature. This is a measurement of how hot a material must get before it will start to deform under a specified load. In a practical sense, it is a guideline for how hot the material can get before it becomes too weak to be usable.

Another factor to consider is the glass transition temperature (T_g). Basically, this is the point where the material begins to loose the ability to hold it's shape. Below the glass transition temperature, the material will be rigid and brittle. If you bend it slightly, it will return to it's original shape. Above the glass transition temperature, the material will become progressively more soft and rubbery. If you bend it the deformation will be permanent.

The glass transition temperature has another application in 3D printing. You will notice that this temperature is very close to the recommended bed heating temperature for each material. This is because the material will not warp due to thermal contraction if you can hold it at or above the glass transition temperature.

PLA, the most common 3D printing material, has a very low glass transition temperature. If you leave a PLA print on the dashboard of your car on a hot day, it will start to sag and droop. PET is nearly as easy to print with as PLA, but it remains stable at temperatures you might experience in your everyday life.

Our normal recommendation when people ask for a high temperature material is ABS, because it remains usable (barely) at the boiling point of water. ABS is used extensively in the automotive industry for interior components and engine parts like intake ducting, so you know it can withstand the heat of an engine bay. The difficulty of printing ABS is moderate, and it does not require a specialized printer.

Of the materials that work in standard 3D printers, Polycarbonate has the best resistance to heat by far. However, it is also extremely difficult to print with. It warps more than any other material, and it requires a printer with an all metal hot end in order to reach the exceptionally high printing temperature. We do not recommend polycarbonate to anyone unless you already have a great deal of printing experience.

Nylon is an unusual material because it's glass transition temperature is much lower than it's heat deflection temperature. Nylon acts more like a firm rubber than a rigid plastic. We don't recommend using nylon for parts that need high rigidity, however it's high heat deflection temperature means it will stay durable up to a very high temperature.

Recently we have started carrying two other extremely high temperature materials, PEEK and Ultem (PEI). These materials can NOT be printed in a standard printer. They require extremely high extrusion and bed temperatures, and a heated print chamber. Even with the correct equipment, these materials are not easy to work with.

Material	**Heat Deflection Temperature @ 0.455 MPa (°C)**	**Glass Transition Temperature - T_g (°C)**	**Melting Temperature - T_m (°C)**	**Printing Temperature (°C)**
Polyether ether ketone (PEEK)	260	143	343	450
Polyetherimide (Ultem/PEI)	216	215	Amorphous	380
Polycarbonate (PC)	140	147	Amorphous	290
Polyamide (Nylon)	110	52	217	255

Acrylonitrile Butadiene Styrene (ABS)	98	105	Amorphous	230
Polyethylene Terephthalate (PET)	70	76	207	240
Polylactic acid (PLA)	56	60 - 65	155	205

The glass transition temperature is also interesting because you can use it to gauge how difficult a material will be to print with. The glass transition temperature is the point where the print will begin to undergo internal stress due to thermal contraction. The farther T_g is from room temperature, the more the plastic will shrink. Shrinkage causes the print to warp off of the bed and the layers to split apart from each other. This chart shows how much shrinkage each material will undergo when cooling from T_g to room temperature (20 °C) based on the material's coefficient of thermal expansion (α).

Material	**Coefficient of Thermal Expansion - α (m/(m*K))**	**Shrinkage**
Polyether ether ketone (PEEK)	36×10^{-6}	0.44 %
Polyetherimide (Ultem/PEI)	47×10^{-6}	0.92 %
Polycarbonate (PC)	$65\text{-}70 \times 10^{-6}$	0.83 - 0.89 %
Polyamide (Nylon)	$50\text{-}90 \times 10^{-6}$	0.16 - 0.29 %

Acrylonitrile Butadiene Styrene (ABS)	80×10^{-6}	0.68 %
Polyethylene Terephthalate (PET)	59.4×10^{-6}	0.33 %
Polylactic acid (PLA)	85×10^{-6}	0.36 %

Note: The figures listed above are for generic forms of these materials. Exact specifications may vary from one manufacturer and line of material to another.

References

1. http://taulman3d.com/t-glase-spec.html
2. http://taulman3d.com/nylon-645-spec.html
3. http://www.matweb.com/reference/deflection-temperature.aspx
4. https://www.researchgate.net/figure/278823225_fig8_Fig-8-Coefficient-of-thermal-expansion-of-PLA-hBN-composites
5. http://www.engineeringtoolbox.com/linear-expansion-coefficients-d_95.html
6. http://www.professionalplastics.com/professionalplastics/ThermalPropertiesofPlasticMaterials.pdf
7. MatterHackers Pro Series Nylon TDS
8. http://www.technicalproductsinc.com/pdf/Specs/PEEK%20EPM%20Specs.pdf
9. http://usglobalimages.stratasys.com/Main/Files/Material_Spec_Sheets/MSS_FDM_ULTEM1010.pdf