# Design and Printing Guide

*Tullomer™ FDM Filament*

# Contents

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# 2 About This Guide

This guide outlines the types of part geometries best suited for 3D printing with Z-Polymers' Tullomer™ filament and offers design strategies to improve print success. It walks through the recommended workflow—from selecting appropriate part types for FDM printing with Tullomer™, to designing features, preparing the build setup, and configuring slicer parameters. While it provides practical guidance, it does not cover the broader principles of design for additive manufacturing, and assumes the reader is already familiar with the basics of FDM printing and part design for FDM processes.

# 3 About Tullomer™

Tullomer™ is a high-performance polymer classified as a Liquid Crystal Polymer (LCP). While LCPs have been studied since the 1800s—Kevlar, developed by DuPont in the 1960s, being a well-known example—most are not melt-processable and therefore unsuitable for FDM 3D printing. Z-Polymers developed Tullomer™ as a melt-processable LCP, making it one of the first LCPs compatible with standard FDM printers. **This material exhibits a distinctive combination of properties: exceptionally high strength and stiffness in fiber direction, chemical inertness, thermal stability uncommon for polymers, natural flame resistance, minimal outgassing, biocompatibility, and a low dielectric constant.**

### 3.1 Material Format and Storage

Tullomer™ is supplied as 1.75mm filament in 250g, 500g and 1kg vacuum-sealed spools. While pre-drying is not required, doing so—or storing the filament in a dry box—can improve print consistency. After opening, spools should be kept in a dry environment. If the filament end becomes damaged, trim it cleanly before feeding. Ensure the spool is mounted securely and spins freely during printing to avoid feed issues.

## 4 Properties of Tullomer™

Tullomer™ exhibits exceptional material characteristics, outperforming most conventional polymers across mechanical, chemical, electrical, and safety domains. A brief summary of its key properties is provided below. Further details are discussed throughout this guide.

### 4.1 Mechanical Properties

- Very strong in the **X-Y print direction**
- Highly abrasion resistant
- Excellent creep resistance
- High temperature tolerance
- Low coefficient of thermal expansion

### 4.2 Chemical Properties

- Very good chemical resistance
- Excellent water vapor barrier
- Very low outgassing
- Non-cytotoxicity

### 4.3 Electrical Properties

- 100% radio frequency transparency
- High thermal and electrical resistance
- Low dielectric constant and loss tangent

### 4.4 Safety Properties

- Non-flammable and self-extinguishing
- Bio-compatible
- PFAS-free

# 5 FDM Printing Guidelines

## 5.1 General Considerations

- This guide assumes the use of industrial or high-performance consumer-grade FDM machines with nozzle temperature capabilities between **290–350°C**.
- Like other high-performance 3D printing polymers, this material exhibits challenges in achieving strong interlayer adhesion due to its chemical inertness and limited interdiffusion between layers. Nonetheless, with appropriate thermal management and deposition strategies, interlayer strengths comparable to or better than as-printed PEEK (5–20 MPa as reported in Wu et al., 2023) can be reliably achieved. The influence of each parameter on bonding performance is discussed throughout this document, while Section 6.2 provides a concise summary of the recommended practices.
- Maintain a consistent environment with minimal drafts or ambient temperature swings.

## 5.2 Printing Orientation

- In general, a part should be printed with the **largest surface area in contact with the build plate**. This improves adhesion and reduces the risk of detachment.
- The **lower the aspect ratio in the Z direction**, the better the stability during printing. Tall, thin parts are more prone to tipping, wobbling, or delaminating.
- During slicing, orient the part so that the **largest cross-sectional area faces downward**, directly contacting the bed. This not only improves print success but can also shorten print time.
- As a rule of thumb: the part's **two largest dimensions should lie in the X and Y axes**, with the **shortest dimension along Z**. This orientation typically provides the best combination of strength, stability, and surface finish. The orientation might change for specific parts with designated loading scenarios.

## 5.3 Extrusion and Nozzle Settings

- **Nozzle Temperature:**
  - **Optimal:** 340–350°C. Parts printed around this extrusion temperature will **significantly** ($\sim$ x6) have better interlayer strength in comparison to the ones printed at lower temperatures.
  - **Fallback:** 310–330°C with slower speeds to compensate for reduced heat transfer.
- **Nozzle Size:** Prefer **0.4 mm or potentially larger** to increase volumetric flow, thermal mass of the filament deposited, and heat delivery. High flow nozzles (such as High-Flow HTA) are better for consistent heating of the material. **The recommendation of high-flow nozzles isn't in order to bump up the volumetric flow rate, but to be able to heat the material more effectively during extrusion.**
- **Material Flow Rate:** Ensure the flow rate does not exceed nozzle capacity; under-extrusion may occur otherwise. Expect flow rates lower than conventional 3D printing materials such as PLA, PETG, ABS.

## 5.4 Nozzle Material

- Use high thermal conductivity nozzles (e.g., **copper-core with wear-resistant coatings**, or diamond), especially if you are printing below 340°C.
- Avoid low-conductivity options such as hardened steel if possible, unless you can achieve 350°C or more.
- Higher conductivity improves melt consistency and promotes better heat transfer to the previously deposited layer.

## 5.5 Print Speed

**For Optimal Interlayer Adhesion**

### 5.5.1 Printing Above 340°C

- **Recommended:** 50–100 mm/s for most external geometries.
- 150 mm/s for infill.

### 5.5.2 Printing Below 330°C

- Lower speeds enable greater thermal transfer to the previous layer, promoting better interlayer bonding.
- For printers limited to $< 330$°C: reduce the speed further to 10–20 mm/s to promote better heating of the previously deposited layer, including infill patterns.

**For Optimal XY Strength & Surface Finish**

- Print below 300°C with a low layer height ($< 0.1$mm) and high speed ($\geq 300$mm/s).

## 5.6 Layer Height and Line Width

- **Layer Height:**
  - **Range:** 12.5% - 50% of nozzle diameter.
  - Thinner layers increase the surface area of contact and reduce cooling time between layers. However, too thin layers have very low thermal mass, and may not heat up the previously extruded layer properly. Experimentation shows printing with relatively thin layers above 340°C ($\leq 20\%$) and relatively thick layers below 340°C ($\geq 40\%$) gives the best interlayer adhesion.
- **Line Width:**
  - **Range:** 90–150% of nozzle diameter
  - Wider extrusion lines improve layer bonding by increasing fusion contact area. **This may lead to increasing artifacts on the surface finish.** If surface finish is critical, consider decreasing line width to around 100% or using post-processing techniques like sanding.

## 5.7 Supports

- **Tree-style supports** are generally recommended for Tullomer due to their ease of removal and reduced scarring compared to traditional blocky supports.
- Regardless of the support style, **supported surfaces will exhibit poorer surface finish** due to fusion irregularities during bridging.
- Minimize supports when possible by using design adjustments (e.g., chamfers, bridging, or reorientation).
- For parts where surface quality is critical, consider post-processing methods such as light sanding to restore finish after support removal.

## 5.8 Warping, Height, and Minimum Feature Considerations

Warping in Tullomer™ prints can occur during or after printing and is typically caused by internal stresses accumulating across successive layers.

**Geometry plays a major role**: large, flat parts with high aspect ratios are especially susceptible.

**Key parameters to reduce warping include:**

1. Ensuring strong first-layer adhesion to the build surface (see adhesion guidance in additional tips, Subsection 5.14).
2. Using thicker layer heights, which reduce internal stress buildup.
3. Slowing down print speed, which promotes more uniform deposition and cooling.
4. Printing at the highest reliable extrusion temperature to promote even heat distribution and stronger interlayer fusion.

**Taller parts carry increased risk of delamination**—both during printing and in end-use—simply because they contain more layer interfaces. This structural vulnerability is most pronounced when Z-direction stresses are involved. **However, by following best practices—such as printing at high nozzle temperatures, using slow print speeds, wider line widths, and enabling every-layer ironing—this risk can be significantly reduced.** These settings improve thermal bonding across layers and help stabilize tall geometries, especially when combined with optimal print orientation and appropriate wall thickness.

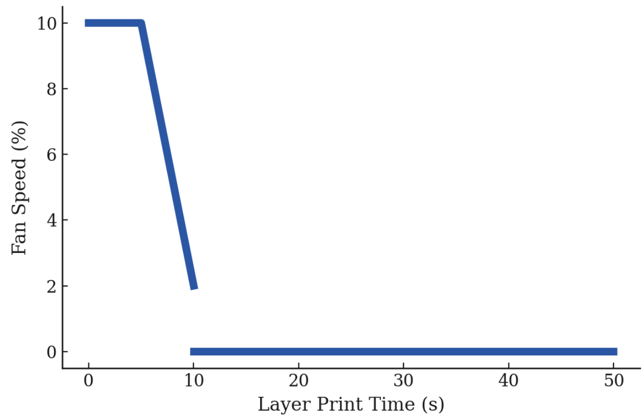
Because of interlayer strength limitations, thin features ($\leq 5$ mm) should be avoided. For prints at temperatures $\leq 330$°C, a minimum wall thickness of 10 mm is recommended.

## 5.9 Every Layer Ironing (Optional)

- Enabling ironing on **every layer** can improve top surface fusion and enhance interlayer contact.
- Significantly increases print time, but may improve strength in Z by promoting heat reflow.
- Use sparingly—only on regions where Z-strength is critical and surface precision is acceptable.
- We recommend ironing all top surfaces to achieve a glossy and smooth surface finish at the topmost surfaces.

## 5.10 Cooling

- **Part Cooling Fan: Disabled** by default.
- If some cooling is necessary for geometric fidelity, restrict use to non-load-bearing sections.
- As an example, at 350°C on the QIDI X Max 3, the following cooling curve works optimally to prevent geometric artifacts (tuning will be required with different machines):




## 5.11 Build Plate Temperature

- **Recommended Range:** 100–120°C
- Higher bed temps help retain thermal energy in the early layers and reduce warping.
- If the contact area is too small at the first layer, consider using a brim (outer and inner). If you have a large flat part, consider using brim ears.
- Rafts aren't recommended.

## 5.12 Infill and Wall Settings

- **Infill Pattern:** Any infill pattern can be used. For best interlayer adhesion; aligned rectilinear with no solid infill direction rotation.
- **Infill Density:** 50% – 100%.
- **Perimeters:** At least 2 walls to support shell integrity.

## 5.13 Layer Time Management

- For narrow cross-sections, consider dynamically increasing print speed or introducing cooling to avoid excessive heating and melt deformation.
- Avoid using `minimum layer time` settings that induce print head idling, which can cause heat accumulation.

## 5.14 Additional Tips and Warnings

- **Build Surface:** For optimal first-layer adhesion, use **glass, PEI, PEX, or an engineering build plate**, combined with a light application of **Magigoo PC adhesive**. Ensure the surface is clean, level, and free from oils or residue.
- **First-Layer Inspection:** On printers that offer automated first-layer inspection (e.g., lidar-based systems), **disable this feature**.
- **Print Speed vs. Strength Directionality:** High print speeds can improve bonding and strength in the **XY plane**, but this comes at the cost of reduced heat transfer between layers. For most applications where Z-strength is critical, **slower printing speeds are recommended**. Only opt for faster speeds if your load paths are exclusively in the XY direction.
- **Shear-Thinning Behavior:** Tullomer is a **highly shear-thinning material**. If the material appears to lose dimensional integrity or shows signs of excessive sagging or pooling, it may be due to overly low viscosity. In such cases, **reduce nozzle temperature or slow down the flow rate** to stabilize the extrusion.
- **Surface Finish:** Elevated temperatures can cause surface rippling due to the material's distinct flow behavior. For applications where surface quality is critical, such as molding, it may be beneficial to reduce the nozzle temperature, though this will compromise interlayer strength.
- **Shrinkage:** This material behaves differently from typical polymers, as it has a negative coefficient of expansion—meaning it expands rather than shrinks as it cools. To offset this unique behavior, set the shrinkage value in the filament profile to around 100.5%. Begin with this setting and adjust as necessary.
- **Chamber Heating:** Chamber heating is shown to help both with preventing warping and also better fusion of layers. You can go up to 120°C, per your printer's capability.

**Table 1:** Summary of how key parameters affect interlayer adhesion and print quality when using Tullomer™ filament.

| **Parameter** | **Effect on Print Performance** |
|---|---|
| Nozzle Temperature | 340–350°C gives best interlayer adhesion; requires slower print speeds to compensate for reduced heat transfer at lower temperatures. |
| Print Speed | Slower speeds improve interlayer bonding; higher speeds improve XY strength and surface finish but will reduce Z strength. |
| Nozzle Material | High thermal conductivity nozzles (e.g., copper, diamond-coated) promote consistent melt and better heat delivery to prior layers. |
| Layer Height | Thin layers ($\leq$20% of nozzle diameter) are preferred above 340°C; thicker layers ($\geq$40%) improve fusion at lower temps. |
| Line Width | Wider lines (120–150% of nozzle diameter) increase bonding area but may compromise surface finish. |
| Cooling | Part cooling fan should be off; enable minimal cooling only for geometric fidelity in non-structural areas and very short layers. |
| Build Plate Temperature | Recommended 100–120°C to prevent warping and support first-layer adhesion. |
| Infill Pattern | Aligned rectilinear without rotation improves Z-bonding; other patterns are acceptable but less optimal. |
| Infill Density | Use 50–100%; higher densities enhance mechanical integrity and interlayer cohesion. |
| Perimeters | At least 2; more perimeter walls improve shell strength and delamination resistance. |
| Supports | Tree-style supports reduce scarring and are easier to remove. |
| Every Layer Ironing | Improves interlayer fusion and surface quality at the cost of longer print times; use selectively. |
| Minimum Feature Size | Avoid features $\leq$ 5 mm in Z; use $\geq$ 10 mm if printing below 330°C. |
| Print Orientation | Print with largest surface on bed; minimize Z-height to reduce instability and delamination. |
| Layer Time Management | Avoid idle time between layers; dynamically increase speed or enable minor cooling on thin sections. |

# 6 Part Applications

Tullomer™ is a high-performance Liquid Crystal Polymer (LCP) developed by Z-Polymers to be compatible with the FDM printing process. Original LCPs are not melt-processable, but Tullomer™ brings the unique advantages of LCPs to extrusion-based 3D printing. This section outlines key properties and the types of applications where Tullomer™ excels. Detailed material data is available in the official Tullomer Technical Data Sheet.

## 6.1 Exceptional X-Y Mechanical Strength

Tullomer™ consists of finely structured crystal domains that align during the printing process, forming highly ordered filaments. These filaments exhibit mechanical properties that surpass those of conventional polymers such as Nylon and PC, and even outperform high-performance materials like PEEK and Ultem. In some cases, the strength of printed Tullomer™ filaments rivals that of continuous reinforcement fibers like carbon, Kevlar, or glass. As a result, when slicer toolpaths are optimized, Tullomer™ parts can demonstrate exceptional mechanical strength in the X-Y plane—especially along the direction of extrusion, where material alignment is maximized.

**Compatible Applications:** High-strength components printed in-plane.
**Examples:** Chain links, hoop-stressed rings, structural members.

## 6.2 Z-Direction Strength

Tullomer™ delivers outstanding strength and dimensional stability in the XY plane, making it well-suited for parts that demand strong in-layer tensile and flexural properties. However, because of its chemically inert and stable structure, the material may exhibit limited interlayer bonding when processed below 340°C. This results in reduced strength in the Z-direction, particularly between print layers and adjacent toolpaths. Z-Polymers is currently developing methods to improve Z-direction performance, with updates expected in the future. In the meantime, parts requiring strength along the Z-axis should be evaluated carefully or redesigned to rely primarily on XY strength.

Below is a summary of the steps for achieving the maximum interlayer adhesion possible based on your machine:

- **Print Temperature:** Use the highest stable extrusion temperature your machine supports — ideally **340–350°C**. This significantly enhances heat transfer to the previous layer and improves bond strength.
- **Print Speed:** Slow down. For printers operating below 330°C, reduce speed to **10–20 mm/s**. At higher temperatures, speeds up to **20–50 mm/s** are acceptable. Lower speeds increase the time available for heat diffusion between layers.
- **Nozzle Material:** Use **high thermal conductivity nozzles** such as copper or diamond-coated variants. These improve melt consistency and increase the heat delivered to the underlying layer.

- **Layer Height:** Tune layer height to balance thermal mass and surface contact:
  - At high temperatures ($\geq$ 340°C): use **thin layers** ($\leq$ 20% of nozzle diameter)
  - At low temperatures ($\leq$ 330°C): use **thicker layers** ($\geq$ 20%)
- **Line Width:** Use **wider extrusion lines** (120–150% of nozzle diameter) to maximize contact area between layers.
- **Every Layer Ironing:** Enable every-layer ironing for critical Z-strength features. This promotes additional heat reflow, though it increases print time.
- **Disable Cooling:** Keep the **part cooling fan off** by default. If minimal cooling is required for geometry, restrict it to non-structural regions and use a carefully tuned cooling curve.
- **Bed and Chamber Heating:** Use a heated bed (100–120°C) and enclosed build chamber when possible to reduce thermal gradients and layer contraction stress.
- **Slicer Strategy:** Orient toolpaths to avoid unsupported Z-direction tension. Maximize perimeter walls and minimize sharp transitions in geometry.
- **Geometry Design:** Avoid thin features ($\leq$ 5 mm) in Z at lower temperatures. Use **minimum 10 mm wall thickness** if printing below 330°C.
- **Environmental Stability:** Avoid open-air environments or fluctuating ambient temperatures during printing.

**Compatible Applications:** Compressive or 2.5D parts with minimal Z loading.
**Examples:** Compression seals, thick flat parts, chain links.

## 6.3 High Temperature Resistance

Tullomer™ is designed for high thermal performance, offering a heat deflection temperature around 230°C and a melting point close to 280°C. As a fully crystalline Liquid Crystal Polymer (LCP), it lacks a conventional glass transition temperature, setting it apart from most polymers. This characteristic allows Tullomer™ to retain its structural integrity in demanding environments, making it ideal for applications operating at or above 200°C.

**Compatible Applications:** Thermal tooling and heat-resistant parts.
**Examples:** Autoclave molds, injection molds, high-temp seals.

## 6.4 Chemical Resistance

Tullomer™, like other Liquid Crystal Polymers (LCPs), is highly stable and chemically inert, offering broad resistance to a wide range of chemical agents. However, extended exposure—especially at elevated temperatures—to certain aggressive substances can lead to degradation over time. The following categories should be considered when designing for chemically demanding environments:

- **Strong Acids:** Highly concentrated acids such as sulfuric acid ($H_2SO_4$), hydrofluoric acid (HF), and fuming nitric acid ($HNO_3$) can cause surface etching, hydrolysis, oxidation, and eventual polymer degradation.

- **Strong Bases (at High Temperatures):** Concentrated bases including sodium hydroxide (NaOH), potassium hydroxide (KOH), and ammonia ($NH_3$) may trigger hydrolysis and degradation, particularly under elevated thermal conditions.

- **High-Temperature Oxidizing Agents:** Oxidizing gases such as chlorine ($Cl_2$) and ozone ($O_3$) may react with LCPs at high temperatures, resulting in structural breakdown after prolonged exposure.

- **Solvents:** Tullomer™ resists most solvents under standard conditions. However, extended contact at elevated temperatures with halogenated solvents (e.g., chloroform, dichloromethane), as well as phenolic compounds like cresols and phenols, may cause swelling, degradation, or dissolution.

**Compatible Applications:** Chemically exposed components.
**Examples:** Seals, solvent-resistant housings, oil contact parts.

## 6.5 Low Creep

Creep describes the slow, progressive deformation of a material when subjected to constant stress over time. The rate of creep is influenced by factors such as applied stress, operating temperature, and the material's internal structure. Like other Liquid Crystal Polymers (LCPs), Tullomer™ offers outstanding resistance to creep, making it well-suited for applications that demand long-term dimensional stability.

Materials with low creep are essential in fields like aerospace, automotive, and medical devices—where components must maintain their structural integrity under sustained mechanical and thermal loading conditions.

**Compatible Applications:** Parts under sustained load and heat.
**Examples:** Mold tooling, structural housings, electronic enclosures.

## 6.6 High Abrasion Resistance

Tullomer™ demonstrates excellent resistance to abrasion, making it ideal for applications involving continuous friction or mechanical wear. In environments where components are subject to rubbing, sliding, or grinding, materials must be durable enough to maintain performance without degrading. Tullomer™ excels under these conditions, preserving its structural integrity while protecting surrounding parts from excessive wear.

**Compatible Applications:** Components exposed to continuous motion or contact.
**Examples:** Bearings, sliders, wear pads.

## 6.7 Ultra-Low Coefficient of Thermal Expansion

The coefficient of thermal expansion (CTE) quantifies how much a material expands or contracts in response to temperature changes. A low CTE is essential in applications requiring dimensional stability—such as electronics packaging, precision tooling, and flexible substrates—where even small thermal distortions can lead to warping, cracking, or mechanical failure.

As a Liquid Crystal Polymer, Tullomer™ exhibits an exceptionally low CTE, with near-zero volumetric expansion. This performance is markedly better than that of typical thermoplastics used in FDM printing, allowing Tullomer™ parts to maintain their geometry across wide temperature swings. In some cases, depending on the degree of molecular alignment during printing, Tullomer™ can even display a negative CTE—behaving like Kevlar—where the material slightly contracts when heated. This unique behavior may influence how a part responds to thermal stress in real-world conditions.

**Compatible Applications:** Precision parts exposed to thermal gradients.
**Examples:** Calibration fixtures, oven jigs, autoclave molds.

## 6.8 RF Transparency

RF transparency describes a material's ability to allow radio frequency signals to pass through with minimal interference or signal loss. Many composites and polymers containing conductive additives, such as carbon fiber, can attenuate or block RF transmissions, making them unsuitable for use in antenna housings, radar systems, or wireless communication devices.

Tullomer™, on the other hand, is a pure polymer with an exceptionally low dielectric constant. This results in minimal interaction with electromagnetic fields, allowing RF signals to pass through virtually unimpeded. Its inherent RF transparency makes Tullomer™ an excellent choice for applications that require clear signal transmission through structural components.

**Compatible Applications:** Communication enclosures.
**Examples:** Drone frames, antenna housings, radar domes.

## 6.9 Excellent Water Vapor Barrier

A water vapor barrier limits the transmission of moisture through a material—an essential feature in applications like electronics, packaging, and construction, where exposure to humidity can compromise performance. Tullomer™ provides an excellent barrier against water vapor, forming tight seals that effectively restrict the diffusion of small molecules. This capability is especially beneficial in electronics enclosures and sealing applications, where moisture control is key to preventing corrosion, electrical failure, or long-term degradation.

**Compatible Applications:** Moisture-sensitive packaging and seals.
**Examples:** Electronics cases, food-safe enclosures, medical housings.

## 6.10 Thermal and Electrical Insulation

Thermal resistance refers to a material's capacity to limit heat transfer, while electrical resistance indicates its ability to block the flow of electric current. Tullomer™ exhibits excellent performance in both areas, providing reliable insulation against extreme temperatures and electrical voltages. This makes it an ideal choice for protecting sensitive components within assemblies from thermal damage or electrical short circuits. Like other Liquid Crystal Polymers, Tullomer™ is well-suited for use in high-performance connector housings and other applications that demand strong thermal and electrical isolation.

**Compatible Applications:** Electrically and thermally isolated components.
**Examples:** Connector housings, electrical panels, thermal breaks.

## 6.11 Flame Retardancy (UL-94 V-0)

Tullomer™ is naturally flame-resistant and certified with a UL 94 V-0 rating. This means it self-extinguishes within 10 seconds when subjected to a vertical flame test and does not emit flaming droplets. Its inherent non-flammability makes it a reliable material for use in safety-critical environments where fire resistance is essential—such as aerospace interiors, electronic housings, automotive systems, and industrial protection components.

**Compatible Applications:** Flame-resistant parts.
**Examples:** Aerospace interiors, electronics packaging, transport housings.

## 6.12 Low Outgassing

Unlike many conventional polymers, Tullomer™ exhibits extremely low permeability and absorption, preventing gases and volatile compounds from becoming trapped within the material. This ensures that under demanding conditions—such as elevated temperatures, vacuum environments, or chemical exposure—Tullomer™ does not release absorbed substances. While other polymers may outgas water, oils, solvents, or VOCs at inopportune times, Tullomer™ avoids this risk entirely. Its stability makes it particularly well-suited for ultra-high vacuum systems, cleanrooms, aerospace hardware, and semiconductor manufacturing, where maintaining contamination-free conditions is critical.

**Compatible Applications:** Clean environments, high-vacuum systems.
**Examples:** Vacuum seals, space systems, solvent-resistant enclosures.

## 6.13 Biocompatibility and Low Cytotoxicity

Tullomer™ is biocompatible and suitable for direct contact with human tissue, showing no adverse effects such as inflammation, immune response, or abnormal tissue growth. It has successfully passed both in vitro and in vivo biocompatibility testing, making it a strong candidate for applications requiring FDA regulatory approval. These characteristics position Tullomer™ as a reliable material for use in medical devices, prosthetics, and other healthcare-related applications where biological safety is essential.

**Compatible Applications:** Medical and biologically safe parts.
**Examples:** Implants, surgical tools, lab fixtures.

## 6.14 PFAS-Free

Virtually all industries can benefit from materials that are free of PFAS "forever chemicals." While some high-performance polymers—such as PTFE and PFA—either contain PFAS or emit them during production, Tullomer™ is completely PFAS-free. It contains no PFAS compounds and does not release them at any stage of its manufacturing process, making it a safer choice for environmentally conscious and regulation-sensitive applications.

**Compatible Applications:** PFAS-restricted environments.
**Examples:** Food handling, medical devices, water filtration components.

## 6.15 Weathering Resistance

Like most plastics, Tullomer™ experiences gradual surface changes when exposed to prolonged weathering, primarily due to UV radiation. Over time, this can result in a white, chalky residue on the surface, along with loss of gloss, color fading, and some decline in mechanical properties.

However, Tullomer™ retains its structural performance well under artificial weathering conditions. After 2,000 hours of accelerated UV exposure, representative samples typically maintain around 90% of their original mechanical strength, indicating strong durability for outdoor or high-exposure applications.

**Compatible Applications:** Outdoor structural parts, UV-exposed mechanical components
**Examples:** Sensor casings, Equipment brackets, Agricultural components

**NOTE:** These guidelines are intended as a baseline. Final tuning may depend on specific part geometry, printer hardware, and slicing software. Always validate through empirical testing.