

NatureWorks® PLA Polymer 3051D

Injection Molding Process Guide

PLA (polylactide) polymer 3051D, a NatureWorks LLC product, is designed for injection molding applications where the requirements are clarity with heat deflection temperatures lower than 130°F (55°C). See Table 1 for typical properties.

Applications

The variety of products made with PLA 3051D continues to grow rapidly. Applications include cutlery, cups, plates and saucers, and outdoor novelties. And this is just the beginning.

Processing Information

3051D resin can be processed on conventional injection molding equipment. The material is stable in the molten state, provided that proper drying procedures are followed. Mold flow is highly dependent on melt temperature. It is recommended to balance screw speed, back pressure, and process temperature to control melt temperature. Injection speed should be medium to fast.

Amorphous vs. Crystalline Pellets*

Crystalline and amorphous pellets look significantly different. Semi-Crystalline pellets are opaque and amorphous pellets are transparent (See figure below.) Please refer to drying chart on the following page for instructions on drying amorphous PLA pellets.

* *NatureWorks 3051D is delivered as a crystalline pellet.*



Processing Temperature Profile ⁽¹⁾		
Melt Temperature	390°F	200°C
Feed Throat	70°F	20°C
Feed Temperature	330°F	165°C
Compression Section	380°F	195°C
Metering Section	400°F	205°C
Nozzle	400°F	205°C
Mold	75°F	25°C
Screw Speed	100-175 rpm	
Back Pressure	50-100 psi	3.5-6.9 bar
Mold Shrinkage	.004 in/in. +/- .001	

(1) Note: These are starting points and may need to be optimized. Complete Injection Molding Process Guide available at www.natureworkslc.com

Table 1 – Typical Material & Application Properties ⁽²⁾		
	PLA Resin (General Purpose)	ASTM Method
Physical Properties		
Specific Gravity	1.25	D792
Melt Index, g/10 min (210°C/2.16Kg)	10-25	D1238
Relative Viscosity	3.0-3.5	
Crystalline Melt Temperature (°C)	150 – 165 °C	D3418
Glass Transition Temperature (°C)	55-65	D3417
Clarity	Transparent	
Mechanical Properties		
Tensile Yield Strength, psi (MPa)	7,000 (48)	D638
Tensile Elongation, %	2.5	D638
Notched Izod Impact, ft-lb/in (J/m)	0.3 (0.16)	D256
Flexural Strength (MPa)	12,000 (83)	D790
Flexural Modulus (MPa)	555,000 (3828)	D790

(2) Typical properties; not to be construed as specifications.

Process Details ⁽³⁾

Startup and Shutdown

PLA polymer 3051D is not compatible with a wide variety of polyolefin resins, and special purging sequences should be followed:

- Clean extruder and bring temperatures to steady state with low-viscosity, general-purpose polystyrene or polypropylene.
- Vacuum out hopper system to avoid contamination.
- Introduce PLA polymer into the extruder at the operating conditions used in Step

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- Once PLA polymer has completely purged the system, reduce barrel temperatures to desired set points.
- At shutdown, purge machine with high-viscosity polystyrene or polypropylene.

(3) Detailed Purging recommendations available at www.natureworkslc.com

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Drying

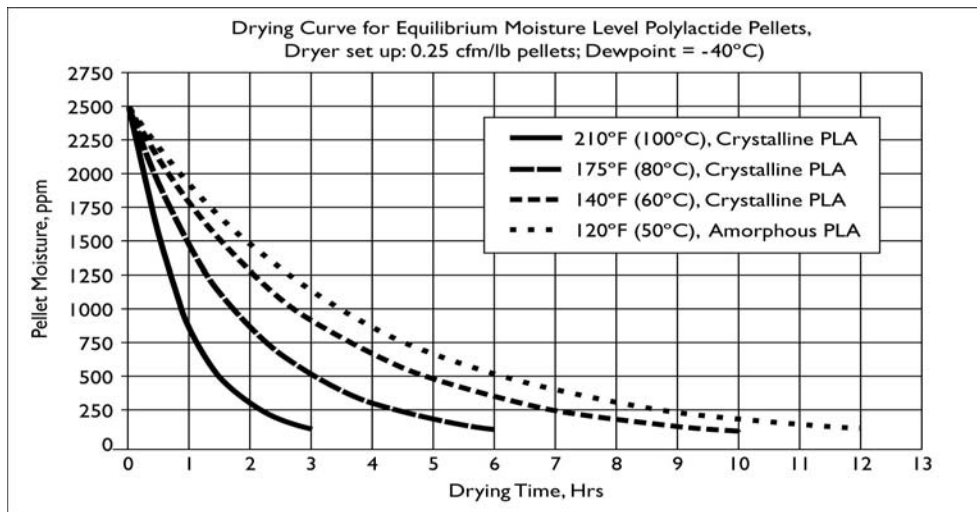
In-line drying is recommended for PLA resins. A moisture content of less than 0.025% (250 ppm) is recommended to prevent viscosity degradation. Polymer is supplied in foil-lined boxes or bags dried to <400 ppm when packaged. The resin should not be exposed to atmospheric conditions after drying. Keep the package sealed until ready to use and promptly dry and reseal any unused material. The drying curves for both amorphous and crystalline resins are shown to the right. It is important to consider accurate initial moisture, when calculating necessary drying time.

Note: Amorphous polymer must be dried below 120F (50C).

Bulk Storage Recommendations

The resin silos recommended and used by NatureWorks LLC are designed to maintain dry air in the silo and to be isolated from the outside air. This design would be in contrast to an open, vented to atmosphere system that we understand to be a typical polystyrene resin silo. Key features that are added to a typical (example: polystyrene) resin silo to achieve this objective include a cyclone and rotary valve loading system and some pressure vessel relief valves. The dry air put to the system is sized to the resin flow rate out of the silo. Not too much dry air would be needed and there may be excess instrument air (-30°F dew point) available in the plant to meet the needs for dry air.

Our estimate is 10 scfm for a 20,000 lb/hr rate resin usage. Typically, resin manufacturers specify aluminum or stainless steel silos for their own use and avoid epoxy-lined steel.



Safety and Handling Considerations

Material Safety Data (MSD) sheets for PLA polymers are available from NatureWorks LLC. MSD sheets are provided to help customers satisfy their own handling, safety, and disposal needs, and those that may be required by locally applicable health and safety regulations, such as OSHA (U.S.A.), MAK (Germany), or WHMIS (Canada). MSD sheets are updated regularly; therefore, please request and review the most current MSD sheets before handling or using any product.

The following comments apply only to PLA polymers; additives and processing aids used in fabrication and other materials used in finishing steps have their own safe-use profile and must be investigated separately.

Hazards and Handling Precautions

PLA polymers have a very low degree of toxicity and, under normal conditions of use, should pose no unusual problems from incidental ingestion, or eye and skin contact. However, caution is advised when handling, storing, using, or disposing of these resins, and good housekeeping and controlling of dusts are necessary for safe handling of product. Workers should be protected from the possibility of contact with molten resin during fabrication. Handling and fabrication of resins can result in the generation of vapors and dusts that may cause irritation to eyes and the upper respiratory tract. In dusty atmospheres, use an approved dust respirator. Pellets or beads may present a slipping hazard. Good general ventilation of the polymer processing area is recommended. At temperatures exceeding the polymer melt temperature (typically 170°C), polymer can release fumes, which may contain fragments of the polymer, creating a potential to irritate eyes and mucous membranes. Good general ventilation should be sufficient for most conditions. Local exhaust ventilation is recommended for melt operations. Use safety glasses if there is a potential for exposure to particles which could cause mechanical injury to the eye. If vapor exposure causes eye discomfort, use a full-face respirator. No other precautions other than clean, body-covering clothing should be needed for handling PLA polymers. Use gloves with insulation for thermal protection when exposure to the melt is localized.

Combustibility

PLA polymers will burn. Clear to white smoke is produced when product burns. Toxic fumes are released under conditions of incomplete combustion. Do not permit dust to accumulate. Dust layers can be ignited by spontaneous combustion or other ignition sources. When suspended in air, dust can pose an explosion hazard. Firefighters should wear positive-pressure, self-contained breathing apparatuses and full protective equipment. Water or water

is the preferred extinguishing medium. Foam, alcohol-resistant foam, carbon dioxide or dry chemicals may also be used. Soak thoroughly with water to cool and prevent re-ignition.

Disposal

DO NOT DUMP INTO ANY SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER. For unused or uncontaminated material, the preferred options include recycling into the process or sending to an industrial composting facility, if available; otherwise, send to an incinerator or other thermal destruction device. For used or contaminated material, the disposal options remain the same, although additional evaluation is required. (For example, in the U.S.A., see 40 CFR, Part 261, "Identification and Listing of Hazardous Waste.") All disposal methods must be in compliance with Federal, State/Provincial, and local laws and regulations.

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Environmental Concerns
Generally speaking, lost pellets are not a problem in the environment except under unusual circumstances when they enter the marine environment. They are benign in terms of their physical environmental impact, but if ingested by waterfowl or aquatic life, they may mechanically cause adverse effects. Spills should be minimized, and they should be cleaned up when they happen. Plastics should not be discarded into the ocean or any other body of water.

Product Stewardship

NatureWorks LLC has a fundamental duty to all those that make and use our products, and for the environment in which we live. This duty is the basis for our Product Stewardship philosophy, by which we assess the health and environmental information on our products and their

intended use, then take appropriate steps to protect the environment and the health of our employees and the public.

Customer Notice

NatureWorks LLC encourages its customers and potential users of its products to review their applications for such products from the standpoint of human health and environmental quality. To help ensure our products are not used in ways for which they were not intended or tested, our personnel will assist customers in dealing with ecological and product safety considerations. Your sales representative can arrange the proper contacts. NatureWorks LLC literature, including Material Safety Data sheets, should be consulted prior to the use of the company's products. These are available from your Nature representative.

NOTICE REGARDING PROHIBITED USE

RESTRICTIONS: NatureWorks LLC does not recommend any of its products, including samples, for use as: Components of, or packaging for, tobacco products; Components of products where the end product is intended for human or animal consumption; In any application that is intended for any internal contact with human body fluids or body tissues; As a critical component in any medical device that supports or sustains human life; In any product that is designed specifically for ingestion or internal use by pregnant women; and in any application designed specifically to promote or interfere with human reproduction.



For additional information in the U.S. and
Canada,

call toll-free 1-877-423-7659

In Europe, call 31-(0)35-699-1344

In Japan, call 81-(0)3-3285-0823

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