ENVIRONMENTAL HEALTH AND SAFETY
University of Nebraska-Lincoln

# Safe Operating Procedure

(Created 11/25)

# 3D PRINTER SAFETY

## Scope

This SOP is directed at small 3-D printers commonly encountered in design labs, research labs, libraries, and similar spaces on campus that use material extrusion or vat photopolymerization technology. Core facilities such as Innovation Studio and Metal Additive Manufacturing in the Department of Mechanical and Materials Engineering are beyond the scope of this SOP.

## Technology Overview

### Material Extrusion

This type of 3D printing technology creates a build layer by layer from bottom up by heating and extruding thermoplastic filament through a heated nozzle. The build bed may be heated as well. Common material extrusion technologies are Fused Deposition Modeling (trademark of Stratasys) and Fused Filament Fabrication.

### Vat Photopolymerization

In this type of 3D printing technology, a vat or tank is filled with a liquid, photosensitive resin and UV light interacts with the resin to selectively polymerize the resin layer by layer to create the desired build. UV light may be generated by lasers or digital light sources depending on the design of the 3D printer.

## Material Extrusion Filament Option

Comon filament materials include the following:

- PLA (polyactic acid)
- ABS (acrylonitirile butadiene styrene)
- Nylon
- HIPS (high-impact polystyrene)
- PETG (polyethylene terephthalate glycol-modified)

Other, less-common, filament types are available.

## Vat Photopolymerization Resin Options

Composition of resins used for vat photopolymerization varies but generally contain hazardous chemicals such as urethanes and acrylate compounds (such as acrylate monomers, methacrylate blends, and epoxy acrylates).

## Emissions

### Material Extrusion

Material extrusion can result in the formation of volatile organic compounds (VOCs) and ultra fine particles (UFPs) that present inhalation hazard. Types and amounts of VOCs and UFPs vary by filament type, 3D printer design, and manufacturer of both printers and filaments. Filament additives and colorants can greatly change a filament's emission profile, both in terms of chemical content and emission rates.

Literature generally reports that styrene is the main VOC emitted during the printing process when using ABS, ASA (acrylonitrile styrene acrylate) and HIPS filaments. The main VOC emitted from nylon and PETG filaments is acetaldehyde. The main VOCs emitted from PLA are lactide and caprolactam.

Emissions of UFPs are lowest with PLA and PETG and relatively high with ABS, ASA, nylon, and HIPS. In consideration of VOC and UFP emissions, PLA is generally the filament of choice to minimize potential exposures.

### Vat Photopolymerization

Resins used in vat photopolymerization 3D printing are typically acrylates, methacrylates, epoxies, or urethanes. Often these materials are skin and respiratory sensitizers, eye and respiratory irritants, and may be reproductive toxins or carcinogenic. Studies have demonstrated that VOC emissions from this type of 3D printing and post-processing (e.g., removal of excess resin, buffing/sanding, etc.) can be more than five times the levels emitted by material extrusion 3D printing and are generally more hazardous.

## Other Safety Hazards

- **UV light:** Vat photopolymerization 3D printers use lasers or LED/Projector sources to produce UV light that cures the resin in the desired pattern. UV is harmful to the skin and eyes. Bypassing safety features (interlocks, guards, etc.) is dangerous.

- **Hot surfaces:** Contact with hot nozzles, build plates, or freshly fabricated materials can result in thermal burns.

- **Fire:** Malfunctions in heated parts of the 3D printer, electrical components, and user error can result in fire.

- **Chemical contact:** Eyes and skin must be protected from chemicals used to clean the 3D printer, set-up the build, or post-print processing of printed builds.

- **Laceration:** Spatulas, razors, scalpels present risk of laceration. Handle safely. Consider cut-resistant gloves.

## Recommendations for Safe Operation

- Provide for local ventilation controls for Vat Photopolymerization 3D printers and post-print processing.

- When practicable, provide local ventilation controls for material extrusion 3D printers. If local ventilation is not feasible:

    - Locate the printer away from areas that are heavily occupied (e.g., do not locate on desks or near workstations) and away from heavy traffic patterns.

    - Locate only in areas with good general ventilation (preferably with 6 air changes per hour while in use). Consider using a portable HEPA/Carbon extraction and filtration device near the 3D printer.

    - Larger rooms are preferred over small rooms.

    - Select filaments that have lower VOC and UFP emissions.

    - Do not remain in the immediate vicinity of the 3D printer while printing is occurring.

    - Minimize the number of 3D printers in any given location, preferably limiting them to one per room.

- Select locations that are equipped with automatic fire sprinklers and fire extinguishers. Users are encouraged to complete EHS fire extinguisher training (both web-based and hands-on portions)

- 3D printers and related equipment should be connected directly to a properly installed and functioning electrical outlet. Do not use extension cords or power strips.

- If there is risk of chemical exposure to the eyes and skin, the location must be equipped with a safety shower and eyewash station.

- Be aware of facility requirements specified by the manufacturer.

- Review the Safety Data Sheets provided by the manufacturer of filaments, resins and post-processing chemicals. Know the hazards of all materials and signs/symptoms of exposure.

- Purchase 3D printers and supplies only from reputable manufacturers and that carry a Nationally Recognized Testing Laboratory (NRTL) certification (UL, TUV, CSA, ETL, FM). Adhere to all manufacturer instructions and observe all warnings. Do not alter a purchased device.

- Restrict access to those who have been properly trained in use of the 3D printer, associated hazards, and risk mitigation strategies.

- Do not allow for unattended operations.

- Wear appropriate Personal Protective Equipment (PPE), based on the hazards present.

    - Eye protection in the form of goggles and face shield if there is risk of chemical splashes to the eye/face. Safety glasses with side shields if there is risk of projectiles (e.g., sanding, scraping). See EHS SOP, **Personal Protective Equipment - Eyes and Face**.

    - A lab coat or similar outer garment must be worn if there is potential for chemical contact. See EHS SOP, **Personal Protective Equipment - Body Protection**.

- Protective gloves are needed when there is risk of chemical contact or thermal burns. Material of construction and thickness must be appropriate to the specific chemicals of concern. See EHS SOP, **Personal Protective Equipment - Hand Protection**.

- Do not wear any type of respirator unless authorized by EHS. Contact EHS for information regarding respirator use. See EHS SOP, **Respiratory Protection, Program Summary**.

- Exercise good personal hygiene. Wash hands after removing PPE and after using a 3D printer.

- Be aware of UNL's Weapons Policy. Contact UNLPD prior to considering building anything that may be banned under the Policy.

- Waste caustics, toxics, solvents, flammables must be disposed of via EHS. See various EHS SOPs, including but not limited to: **Hazardous/Radioactive Material Collection Procedures**; **Disposal of Rags and Wipers**; **Items/Materials Prohibited from Trash Cans and Dumpsters.**

- Sharps must be disposed in accordance with the EHS SOP, **Sharps – Handling and Disposing**.

## References/Resources

3D Printer School Safety: A Guide for Supporting Indoor Air Quality & Human Health, Underwriters Laboratory
https://ehs.osu.edu/sites/default/files/documents/3D-Printer-School-Safety-2020.pdf

UL 200B, Safe Use of 3D Printing for Institutions of Higher Education, Underwrites Laboratory
https://chemicalinsights.ul.org/wp-content/uploads/2023/05/UL-200B_1.pdf

Approaches to Safe 3D Printing: A Guide for Makerspace Users, Schools, Libraries, and Small Businesses, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention
https://www.cdc.gov/niosh/docs/2024-103/pdfs/2024-103.pdf