



3D Printing Health & Safety Guide

3D Printing: What is it?

3D printing is an additive manufacturing technology which has revolutionized rapid prototyping and small-scale manufacturing by making it easier and more accessible. Initially, a virtual design is created and stored by computer-aided design (CAD) with 3D modeling software, and/or by using a 3D scanning device. Once a design model is created, a 3D printer will print the image by laying down definitive, discrete layers, to create the object, layer-by-layer. Studies have indicated that 3D printers are capable of generating potentially harmful concentrations of ultrafine particles (UFP) and chemical vapors during the print process and through processes used post-printing to treat the finished product.

Pomona College's High Performance Computing (HPC) department has two 3D printers designated for the use of research. We have reviewed the use of benchtop Fused deposition modeling® (FDM) /Fused filament fabrication (FFF) and Stereolithograph Apparatus (SLA)/ Digital Light Processing (DLP) type 3D printers.

Main hazards associated with 3D printing?

The hazards associated with 3D printing are related to the processes and technologies applied. These exposures can be hazards associated with ultraviolet light (UV)/ laser beams, burns from molten materials, electrical/shock, electromechanical force, High magnetic field and to health hazards associated with inhalation of ultrafine and/or toxic smoke, fumes and dusts. Setting up 3D printers requires the consideration of various hazards intrinsic to the type technology/application, and the specific work environment where installation is taking place. The American Society for testing and Materials (ASTM) is established to define standards in "Additive Manufacturing". The industry has classified additive manufacturing processes into seven categories. HPC'S 3D printers consist of the following two:



Material Extrusion (ME)	VAT Photopolymerization (VP)
<p>Alternate Names:</p> <p>Fused Filament Fabrication (FFF)</p> <p>Fused Deposition Modeling (FDM™)</p>	<p>Alternate Names:</p> <p>Stereolithography Apparatus (SLA)</p> <p>Digital Light Processing (DLP)</p>
<p>Description:</p> <p>Deliver plastic filament to heated nozzle</p> <p>Filament materials include acrylonitrile butadiene styrene (ABS) resin or polylactic acid (PLA)</p>	<p>Description:</p> <p>Uses a vat of liquid photopolymer resin to construct model layer by layer and then hardened using UV light</p>
<p>Usual Materials:</p> <p>Thermoplastic filaments and pellets (FFF) or liquids and slurries</p>	<p>Usual Materials:</p> <p>UV curable photopolymer resins (includes various fillers)</p>
<p>Health Hazards:</p> <p>ABS emission</p>	<p>Health Hazards:</p> <p>UV Light, chemical Solvents, exposure to wastes</p>

What are some specific hazards associated with 3D printing processes?

Inhalation and related systemic exposure to hazardous agents

Many 3D printing processes use thermoplastics and other materials, which are heated, extruded, and/or fused using high energy sources. These processes emit ultrafine particle clouds and fumes in the nanoparticle range, (i.e. 1/10,000 millimeter or sub-micron range). For example, in NIOSH study, 3D printing via material extrusion by means of polylactic acid (PLA) feedstocks and with relatively low-temperature, desktop applications can generate in excess of 20 billion particles per minute. Higher temperature acrylonitrile butadiene styrene (ABS) feedstocks can release in excess of 200 billion particles per minute. Nanoparticles are of concern because they are very small, have large surface areas (low density) and can readily penetrate, interact with, and/or traverse the body's systems (i.e. skin, lungs, nervous and brain tissues) at the cellular level.

Exposure to high concentrations of nanoparticles

Nanoparticles as it relates to 3D printing has been associated with adverse health effects, including cardio-pulmonary and respiratory effects, cancer, asthma, and nervous system effects. While PLA feedstocks are intended to be non-toxic and compatible with biological tissues, there may be unknown effects at very high concentrations, particularly in poorly ventilated spaces. The thermal decomposition products of ABS feedstock have been shown to have toxic effects on lab rodents. These hazards may be significant; thus installation designs must consider the adequacy of exhaust ventilation or filtration.

Skin or respiratory irritant/sensitizers:

Certain thermoplastics and photopolymers (used in 3D printing) when activated by heat or Ultra Violet (UV) light may contain toxic or hazardous monomers. U/V light may also pose a radiation hazard to the eyes or skin.

There are also hazards associated with support materials

Support materials in the 3D print matrix may contain harmful agents (e.g. phenyl phosphates associated with thermoplastic acrylics). These can be hazardous during use, and downstream waste handling.

- Due to the hazardous nature of these materials and applications, Standard Operating Procedures (SOPs) are required at a minimum especially when used in the

Laboratory. Contact the Facility Coordinator/Laboratory Safety Officer (LSO) or Environmental Health & Safety to verify SOP's are incorporated into department Specific Plans for the research area. Consult the 3D printer manufacturer website to locate Safety Data Sheets (SDS) to identify and evaluate the specific health and safety hazards associated with the 3D print materials used. In addition to health hazards, examples of equipment specific hazards may include:

- Hot surfaces – print head block, heated beds and UV lamp
- High Magnetic Field-High magnetic fields occur around the X and Y axis of specific 3D- printers.
- High voltage/Electric risk – UV lamp connector, electric outlet and ground wire.
- Ultraviolet radiation – UV lamp. Don't look at the lamp; make sure UV screen is intact.
- Moving parts – printing assembly.

Printer Media	Health and Safety Concerns	Control
•ABS	• Ultra fine particulate • Low toxicity • Some odor	• Fume Hood • Appropriate general ventilation • local exhaust
•PLA	• Ultra fine particulate • Low toxicity • Some odor	• Fume Hood • Appropriate general ventilation • local exhaust

table 1. summary 3D media evaluation

General Safety for 3D Printer

- Discuss ALL issues or concerns regarding this 3D Printer with the supervisor prior to its use.

- All printers must be installed according to the manufacturer's requirements and according to NFPA 72 National Electric Code.
- Always follow manufacturer guidelines, be cognizant of all of the SDS and safety information presented in this document.
- Consult LHAT and/or EH&S for a hazard assessment when considering modifications/novel uses.
- Notify coworkers before beginning non-routine and hazardous work. To work alone; facility must have work alone protocol.
- To prevent respiratory irritation, work in a well ventilated room.
- Once a printing job is started, do not open cover, or defeat/override interlock switch.
- Printer should not be left unattended during operation for an extended period of time.
- If interlock safety switch fails, do not use the printer.
- As determined by the hazard assessment, in addition to all pertinent laboratory personal protective equipment (PPE) and chemical protective gloves may be required when accessing the printer stage area after printing.
- Uncured material may be hazardous; wear suitable/ recommended glove protection and if material can splash, wear safety goggles.
- In the event of leak/ spill of printing material cartridges, use solvent-absorbent pads for model/ support material spills. Dispose clean-up materials as chemical waste. Contact UCR EH&S 951-827-5528 when responding to any major spills.
- Keep model and support materials away from areas where cosmetics are applied, or food and drink are stored, prepared or consumed.
- Follow all related SOPs in the laboratory SOP bank (PPE, waste disposal, etc. as appropriately modified by any specific information in the SDS information presented in this document.

Training Requirements

All users working directly with a 3D print chemical/hazardous media outside of the laboratory are required to have hazard communication (HAZCOM) training covering any hazardous materials used in the process. Completion of the training must be documented in writing with the records maintained by the Supervisor of the printing operation.

Personal Protective Equipment (PPE) Requirements

Follow all PPE recommendations found in the Safety Data Sheet (SDS) for the specific printer media used. Eye protection is required during any activity where airborne projectiles may be present (i.e. cutting off rough edges of a printed item). An emergency eyewash will be required in the immediate vicinity of the work. A spill kit capable of neutralizing the caustic components of the alkaline bath shall also be provided.

Hazard Assessment Form/Procedure

It is recommended to perform a risk assessment. This checklist is designed to enable the user of 3D printers, in consultation with their Supervisor, identify hazards associated with and prior to, their intended use of a 3D printer. When planning the use of a 3D printer, the recommended risk controls listed below should be considered and incorporated where relevant to reduce the level of risk. Other controls not already covered that are unique to the functions of 3D printers should also be considered and recorded if the 3D printer