

3D PRINTER SAFETY

3D printing, also called additive manufacturing, is a method of creating a three-dimensional object layer-by-layer using a computer created design. 3D printers are increasing in popularity as they can be used for rapid prototyping and small-scale manufacturing. The following provides guidance on selection, use and installation of 3D printers, as well as information on the hazards associated with these printers and how to control them.



Types of 3D Printing Processes and Associated Health Hazards

Process	Description	Printer Media	Potential Health Hazards	Additional Considerations
Material Extrusion (Fused Deposition Modeling [FDM])	Heated filaments dispense through a nozzle to build a piece by layers	ABS PLA	Inhalation: VOCs, UFP (ultrafine particulates)	Thermal runaway protection; boiling point of filament vs heat setting on 3D printer
VAT Photopolymerization (Stereolithography [SLA])	UV light to fix thermoplastics	Photopolymers	Inhalation: VOCs, UFP UV light exposure Dermal: resins, solvents	Chemicals used to clean finished products; flammable liquid storage
Sheet Lamination (Laminated Object Manufacturing [LOM])	Sheets of material on build platform are bonded with adhesive and cut with laser or blade	Paper Plastic Metal	Inhalation: VOCs Explosive dust	Sanding/finishing processes post-build; laser
Powder Bed Fusion* (Selective Laser Sintering [SLS])	Powder layer melted by a laser	Metal Plastic	Inhalation: powder, VOCs, metal fumes Dermal/Eye: laser	Temperature thresholds for metal fumes
Directed Energy Deposition* (DED, Laser Metal Deposition [LMD])	Metal powder or wire is fed through a muzzle and heading on the build platform	Metal	Inhalation: VOCs, metal fumes Explosive dust	Heat; temperature thresholds for metal fumes; shielding gas
Binder Jetting* (Powder Bed, Inkjet Head)	Binding agent deposited on powder layer	Metal Plastic Ceramic	Inhalation: powder Dermal: binders	Post-processing chemical use
Material Jetting (Multi-Jet Modeling [MJM])	Material deposited on platform is cured with UV light	Wax Photopolymer	Inhalation: VOCs, UV light exposure Dermal: resins, solvents	Post-processing chemical use
Bioprinting (Tissue Printing, Organ Printing [3DBP, Bio-AM])	Biological materials are used to make structures layer-by-layer	Bioinks Living cells Growth factors	Inhalation: aerosols Dermal: biological materials	Post-processing chemicals, UV light exposure

*Metal 3D printing requires evaluation by Yale Fire Marshals Office
Diagrams of each process outlined above are shown in Appendices

Additional Hazards

Biological – With biological 3D printing, there can be a potential exposure to the aerosols generated in the process. Proper disinfection procedures of the 3D printer between prints is also of concern.

Hot Surfaces – The print head block, lasers and UV lamp generate heat. Such surfaces must be guarded, and labeling must warn users of the hazards.

Flammable Dusts – finely divided metal powders can spontaneously combust, causing fires or an explosion.

Fire – the high temperatures necessary to melt materials pose a fire risk if the unit malfunctions or material ignites.

Mechanical – Moving parts must be guarded to prevent accidental contact. Guards must never be bypassed.

Electrical – Contact with energized parts can lead to injury or even death. Before each use, inspect the 3D printer for any damaged wiring and safeguards. Do not use the printer if problems are found. Ensure the printer is properly grounded and plugged directly into an outlet.

Finishing Baths & Washes – Some 3D printers require the use of baths or washes to remove the extra material surrounding each 3D printed item. These baths and washes are commonly composed of corrosive chemicals or solvents. The use of these chemicals must be reviewed and approved by EHS to ensure proper ventilation, procedures, training, emergency equipment and personal protective equipment are provided.

REQUIREMENTS

Contact EHS prior to purchasing a 3D printer to ensure the printer and location meet all EHS requirements.

Administrative

- Ensure 3D printers are purchased with full enclosures and interlocked guards where feasible. Purchase 3D printers with ANSI/CAN/UL 2904 certification and Nationally Recognized Testing Laboratory for electrical and fire code compliance.
- A person must be identified as responsible for ensuring the 3D printer is properly maintained, access is controlled, users are trained and safe work practices are developed and enforced.
- Submit [3D Printer Inquiry Form](#) to EHS. This form collects information for the 3D Printer Inventory managed by EHS and includes printer type, build materials, location, etc. This submission will be reviewed by EHS, and a poster specific to your 3D printer and materials (sample shown in Appendices below) will be provided by EHS upon review.

Location and Ventilation

3D printers have been shown to emit ultrafine particles (UFP) and volatile organic compounds (VOCs) when operating. To manage these emissions, consideration must be given to the ventilation of the space where printers are used. The ventilation in offices, libraries or meeting rooms is inadequate and not appropriate to remove continuous emissions from multiple 3D printers. In general, the ventilation options include:

- Dedicated exhaust to the outdoors, ex: snorkels, fume hood, ventilated enclosure racks
- Connecting the enclosure to a HEPA/charcoal filtration unit
- General, non-recirculating exhaust, with a minimum of 6 air changes per hour

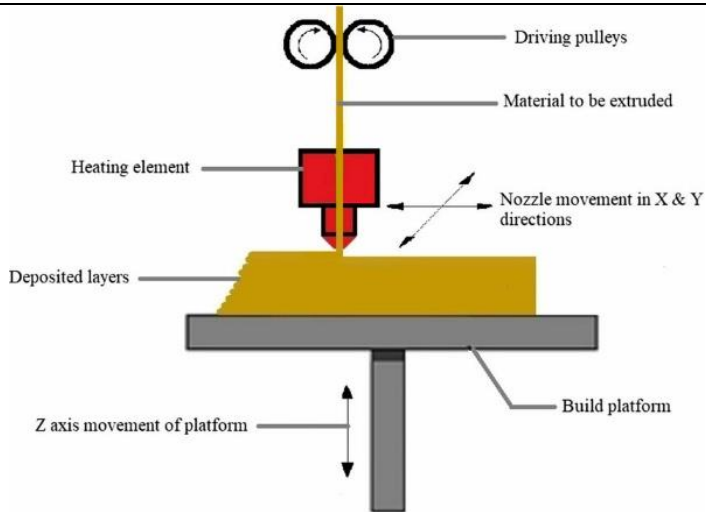
As ventilation requirements are dependent on the number of units in one space, the location of the units in reference to occupants of the space, and the type of process and media used, it is critical to consult with EHS prior to purchasing a 3D printer to ensure that the unit is placed in an area with adequate ventilation.

General

- Complete printer-specific training in addition to [Laboratory Safety Program](#) training if used in a laboratory prior to using the printer. For Bioprinting, ensure to take the [Biosafety Program](#) training and any other applicable [Biological Safety Trainings](#) (BBP, BSL-Enhanced, etc.).
- Review Safety Data Sheets (SDSs) for materials used with 3D printers.
- Wear proper personal protective equipment while using the printers.
- Never bypass interlocks or other safety controls.
- Maintain a distance from the printer while it is in operation to minimize exposure to printer emissions.
- Allow a waiting period after printing to allow cool down and contaminant dissipation before opening the printer to access the finished product.
- Clean surfaces around the printer frequently using a damp cloth. Use HEPA vacuums to clean floors or other areas with particulate.
- Wash hands with soap and water after using the printer.
- Report any concerns to the responsible person or EHS.

ADDITIONAL RESOURCES

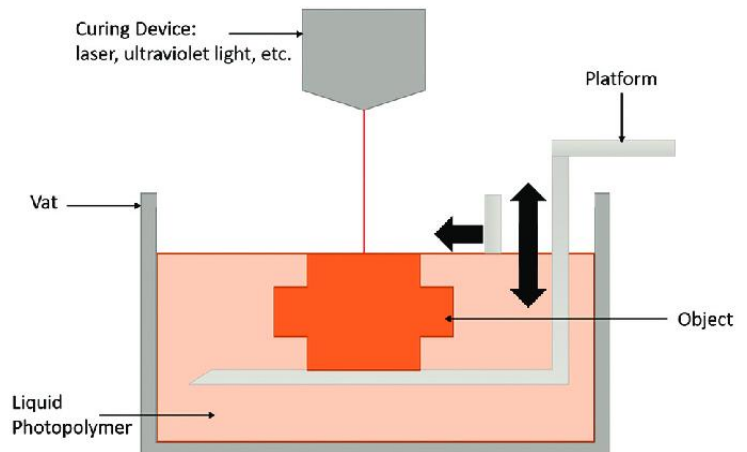
- Chemical Insights – *Tools for Promoting 3D Printer Air Quality Safety* <https://chemicalinsights.org/3D-printing/>
- UL 200B Guidance Document – *Safe Use of 3D Printing for Institutions of Higher Education* https://chemicalinsights.org/wp-content/uploads/2023/05/UL-200B_1.pdf
- Environmental Science & Technology – *Emissions of Ultrafine Particles and Volatile Organic Compounds from Commercially Available Desktop Three-Dimensional Printers with Multiple Filaments* <https://pubs.acs.org/doi/pdf/10.1021/acs.est.5b04983>
- The National Institute for Occupational Safety and Health (NIOSH) - *Approaches to safe 3D printing: a guide for makerspace users, schools, libraries, and small businesses* <https://www.cdc.gov/niosh/docs/2024-103/default.html>

APPENDICES**Diagrams****Material Extrusion**

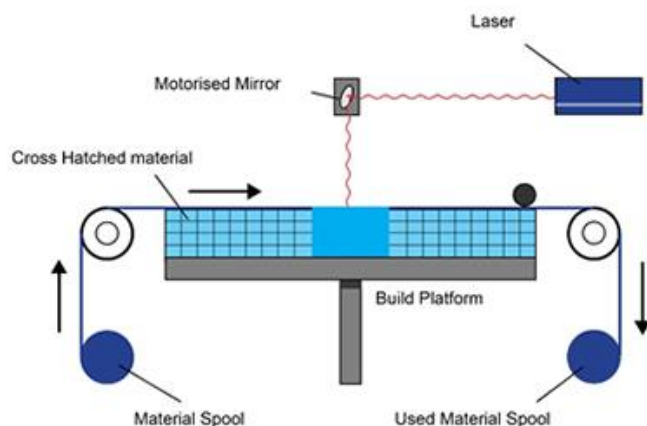
Objects are built by heating and extruding thermo-plastic filament through a nozzle, depositing material layer by layer to form a three-dimensional part.

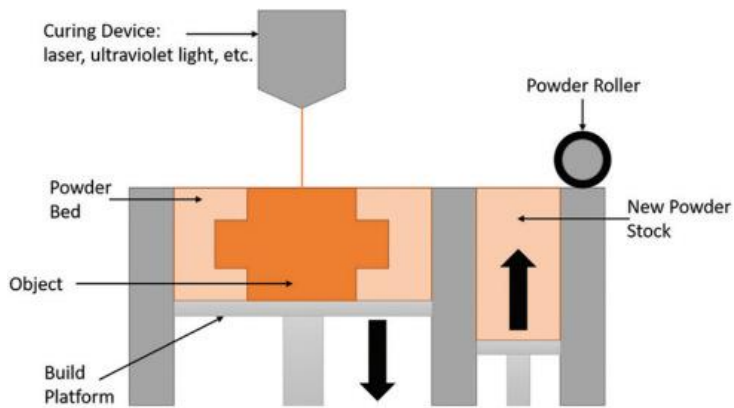
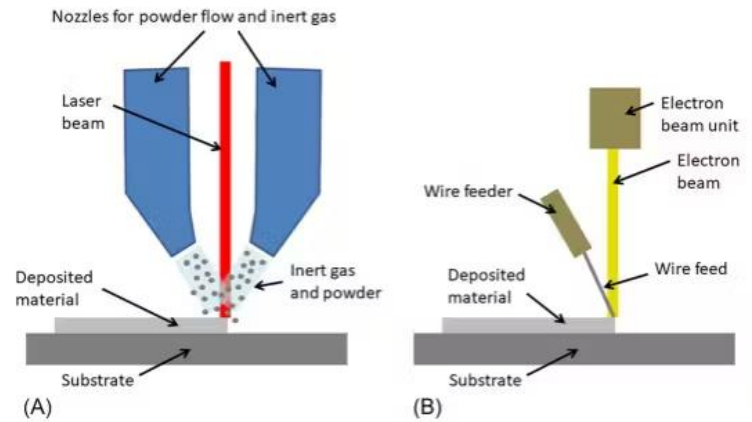
VAT Photopolymerization

Objects are created by selectively curing liquid photopolymer resin with UV light, solidifying the material layer by layer into a three-dimensional part.

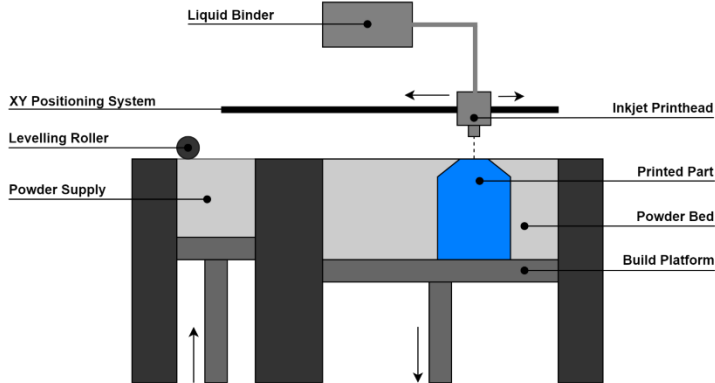
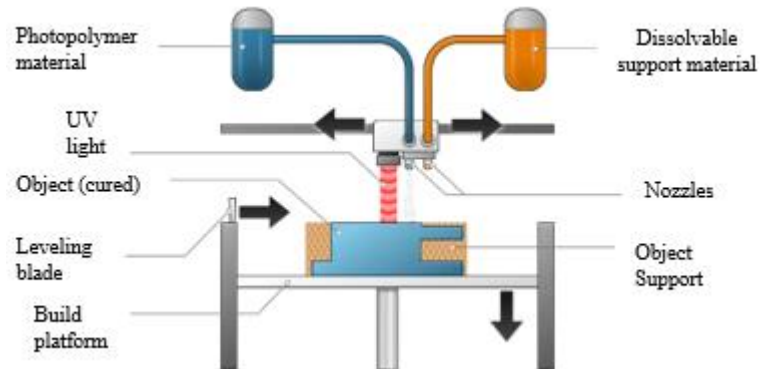
**Sheet Lamination**

Objects are created by bonding sheets of material together layer by layer and cutting each layer to shape, typically by using a laser or blade.

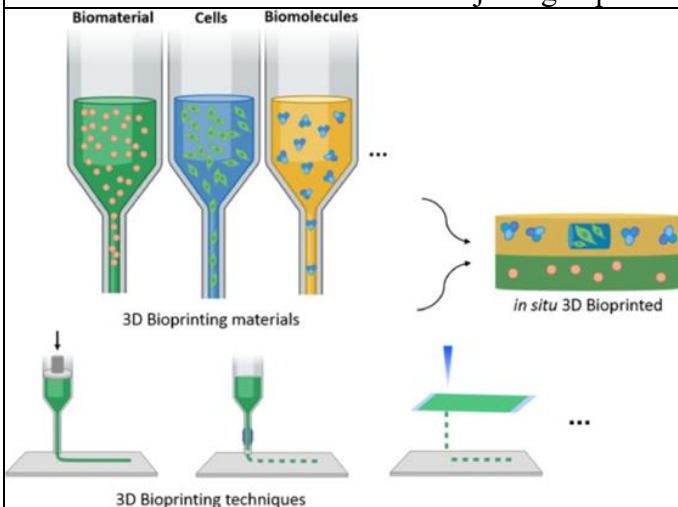


Powder Bed Fusion**Directed Energy Deposition**

Powder bed fusion builds objects by using a laser/energy source to selectively melt thin layers of powder across a build area, while directed energy deposition feeds material directly into a focused laser/energy source to add or repair material locally.

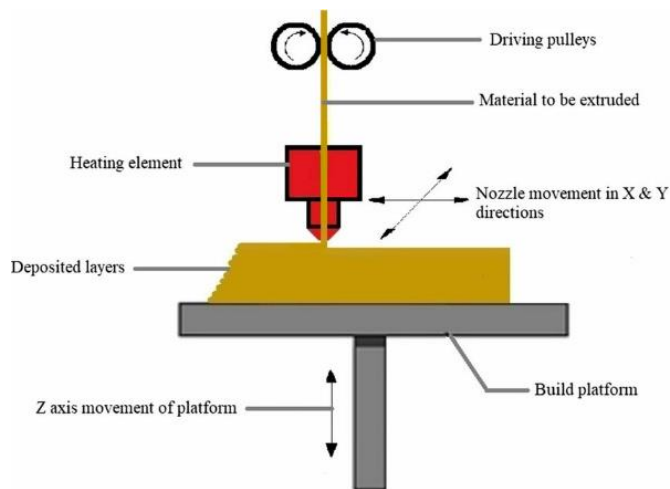
Binder Jetting**Material Jetting**

Binder jetting forms objects by selectively depositing a liquid binder onto a powder bed, while material jetting deposits droplets of build material that are cured in place.

**Bioprinting**

Bioprinting is a form of additive manufacturing that uses living cells, biomaterials, and bioactive molecules to fabricate tissue-like structures layer-by-layer. Bioprinting can be done via many of the printing processes described above.

Sample 3D Printer Poster

3D Printer Safety Guidelines – Material Extrusion**General Safety Requirements**

- Contact EHS prior to using any unapproved/new build materials
- Maintain good housekeeping
- Wash hands with soap and water after handling hazardous materials
- Contact EHS for waste disposal (via EHS Integrator or calling 203-432-6545)

Prior to Use

- Ensure proper EHS & printer-specific training is completed
- Verify local exhaust/ventilation is functioning if applicable
- Wear PPE! (Safety glasses, nitrile gloves during material handling, close-toed shoes & long sleeves/pants)
- Inspect printer (wiring, guards, interlocks, build plate, enclosure, etc.)
- Only use approved filaments per printer-specific SOP

During Use

- Keep area free of clutter and ignition sources
- Be aware of hot ends/build plates and abnormal emissions (smoke, odors, etc.)
- Avoid standing/sitting directly next to printer during operation
- Stop operation if malfunctions occur

After Use

- Allow parts to cool before handling
- Use HEPA vacuum or wet methods for cleaning only (no dry sweeping)
- Use tools to remove parts if still hot
- Maintain guards, interlocks, and filters per manufacturer's specifications