3D Printers

Introduction

Three-dimensional (3D) printing involves the layering of successive layers of material to create or replicate 3D objects. Depending on the printer, 3D objects are created through extrusion, sintering, or curing. 3D printers are now commonly used in many industries including, but not limited to, aerospace, architecture, automotive, consumer products, defense, dentistry, education, and medical fields. 3D printing has also become common in UConn labs and classrooms. Though 3D printing holds considerable potential, the workplace health and safety risks are still being determined.

Types

Multiple types of 3D printers are available to create three dimensional objects. The most common types of 3D printers are listed below:

Common Types of 3D Printers	
Types	**Description**
Material Extrusion [Fused Deposition Modeling (FDM)]	Uses a thermoplastic filament, which is heated to its melting point, to create a 3D object. This is the most common type of 3D printer.
Vat Polymerization [Stereolithography (SLA)]	Uses a liquid photopolymer resin to create a model and then cure each layer of resin using an ultraviolet (UV) laser or digital processing lamp.
Material Jetting	Selectively deposits droplets of feed material onto a build platform, allows the droplets to cool and solidify, and then builds on the solidified droplets to create a 3D object.
Binder Jetting	Distributes a layer of powder onto a building platform and then applies a liquid bonding agent (i.e., a glue) to bond the particle layers together to create a 3D object.
Powder Bed Fusion [Selective Laser Sintering (SLS)]	Deposits a thin layer of plastic powder that is melted by a laser on a building platform. 3D objects are created through layer-by-layer construction in the powder bed.
Directed Energy Deposition (DED)	Uses a laser or electron beam to melt material (usually metal powders or wires) from the nozzle of a multi-axis arm as it is being deposited.

Sheet Lamination	Creates 3D objects by using a laser or other sharp blade to cut and bond thin-layered material (e.g., paper, aluminum foil, etc.) together layer by layer.

Hazards

3D printing involves the melting of plastics [Acrylonitrile Butadiene Styrene (ABS), Polylactic Acid (PLA), Polyvinyl Alcohol (PVA), Polycarbonate (PC), etc.], metals (steel, aluminum, titanium, copper, silver, gold, nickel, etc.), composites, and photopolymers. Exposure to emissions from the melting of print media could lead to negative health effects. The hazards associated with 3D printing are indicated below:

Health Hazards	
Biological	3D printers used to create cells and/or engineered tissues may release biohazardous aerosols.
Sensitizers	3D printer by-products from the melting of thermoplastics and photopolymers can cause allergic reactions upon contact or inhalation.
Toxicity	3D printers using certain print media have been shown to emit volatile organic compounds (VOCs). Some VOCs have been linked to eye, nose, and throat irritation, headaches, damage to the liver, kidney, and central nervous system, and cancer.
Ultrafine Particles (UFPs)	The health effects associated with exposure to UFPs (i.e., particles less than 100 nm) are currently being researched. Past studies have indicated that exposure to UFPs at high concentrations can produce inflammatory responses in cardiovascular and respiratory systems.
Ultraviolet (UV) Radiation	3D printers using lasers to melt print media can emit UV radiation. Exposure to UV radiation may result in acute or chronic effects on the skin, eyes, and immune system.
Physical Hazards	
Flammability	3D printers using finely divided metal powders (e.g., aluminum, titanium, etc.) or other resins can be spontaneously combustible (pyrophoric), leading to fires. Contact UCFD prior to using printers with finely divided metal powders/resins.
Hot Surfaces	Contact with the print head block and/or UV lamp can cause burns.
Electrical	Unguarded electrical components in some 3D printers could pose a risk of electrical shock.
Moving parts	3D printers with ingoing nip points and/or rotating parts can cause pinch or crush injuries.

Training Requirements

1. Employees working in labs with 3D printers are required to complete **Lab Safety & Chemical Waste Management Training** through EHS. Employees working in non-lab areas with 3D printers are required to complete **Hazard Communication Training** through EHS. Students working with 3D printers in UConn-sanctioned spaces must be provided a copy of these guidelines to ensure awareness of the hazards.
2. 3D printers using lasers or electron beams must be registered with the Radiation Safety Office and/or the State of Connecticut by EHS. Laser use and analytical x-ray use must comply with all requirements of the **Laser Safety Manual**, as applicable. Contact the EHS Radiation Safety Manager for further instructions.

Engineering Controls

1. Fully enclose (preferred) or cover 3D printers to limit exposure to VOCs and UFPs.
2. Use 3D printers in well-ventilated areas. EHS recommends keeping 3D printers in rooms with 4-10 fresh air changes per hour.
3. Provide local exhaust ventilation for ABS printers or place in a fume hood. ABS printers have been shown to emit styrene, a possible human carcinogen, by the International Agency for Research on Cancer.

Work Practices

1. Install, use, and maintain 3D printers as indicated by manufacturer specifications.
2. Safety Data Sheets (SDSs) must be present and accessible in the immediate work area for all print media and other chemical products involved in the printing process.
3. Maintain a safe distance from the printer(s) to limit inhalation of emitted particles.
4. Limit the number of printers per room. One printer per standard office space (~150 ft^2) for a non-lab area can be used as a guideline. Multiple 3D printers in the same room may be possible based on the ventilation rate, enclosures, and room size.
5. Store print media and other chemicals associated with the printing process as indicated by the manufacturer.
6. Choose a low-emitting printer and filament, if feasible.
7. Since 3D printers run for extended periods, rooms/labs should avoid altering ventilation rates based on occupancy sensors, unless local exhaust is being used to remove emissions.
8. An emergency eyewash station and safety shower are required in the immediate work area if corrosive materials are present or used in the printing process.
9. Eating or drinking is not allowed in areas where 3D printers are being used.

10. Avoid contact with heated surfaces to prevent burns.
11. Live parts on 3D printers operating at 50 volts or more must be guarded against accidental contact.
12. 3D printers with ingoing nip points and/or rotating parts must be properly guarded (i.e., no exposed belts, gears, pulleys, or other moving parts or points of operation).

Personal Protective Equipment

1. Eye protection recommended by the manufacturer in safety data sheets/printer specifications is required (if applicable).
2. Gloves recommended by the manufacturer must be worn while handling the print media and other chemicals associated with the printing process (if applicable).
3. Respirators may be necessary for use with some 3D printers (e.g., metal and ceramic powders). If employees are required or voluntarily choose to wear respirators, they must comply with the requirements of the UConn **Respirator Program**.

Resources

- *USEPA*. Office of Research and Development Publications. **An Overview of Ultrafine Particles in Ambient Air**.

- *NIOSH*. **Control Measures Critical for 3D Printers**.

- *Environmental Science & Technology*. **Emissions of Ultrafine Particles and Volatile Organic Compounds from Commercially Available Desktop 3D Printers with Multiple Filaments**.

- *Journal of Toxicology and Environmental Health*. **Emission of particulate matter from a desktop 3D printer**.