3D-Printing Safe Work Practices

INTRODUCTION

Additive Manufacturing or Three-dimensional (3D) printing involves the layering of successive layers of material to create or replicate 3-dimensional 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 holds considerable potential and has become common in university labs and classrooms. The following information is based on current research and evaluations regarding the risk to human health and safety.

TYPES

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

Material Extrusion [Fused Deposition Modeling (FDM)] – FDM printers use a thermoplastic filament, which is heated to its melting point, to create a 3-dimensional object. This is the most common type of 3D printer.

Vat Polymerization [Stereolithography (SLA)] – Vat polymerization 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 – 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 3-dimensional object.

Binder Jetting – Binder Jetting distributes a layer of powder onto a building platform and then applies a liquid bonding agent to bond the particle layers together.

Powder Bed Infusion [Selective Laser Sintering (SLE)] – Plastic, metal, ceramic, or glass powders are fused together using lasers or other energy sources to form the structure.

Directed Energy Deposition (DED) – A metal powder or wire is melted at the same time it is being deposited by a moving print head.

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

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HAZARDS

3D printing involves the heating/melting of:

- Plastics [Acrylonitrile Butadiene Styrene (ABS), Polylactic Acid (PLA), etc.]
- Metals (steel, aluminum, titanium, etc.)
- Composites
- Photopolymers.

Exposure to emissions from the heating/melting of print media may lead to negative health effects. The known hazards are as follows:

Chemical Vapors – Plastic filaments have been shown to produce Volatile Organic Compounds (VOCs) when heated in 3D printing processes. Exposure to VOCs can cause headache, nausea, and eye, nose, and throat irritation. Organic solvents used in post-processing vapor baths such as alcohol and acetone vaporize readily and pose an inhalation and fire hazard.

Nanoparticle Emissions – When heated, filaments produce inhalable nanoparticles (NPs) during 3D printing. Additionally, the use of NP-containing media can emit inhalable NPs into the surrounding atmosphere. The health effects of NPs are not well understood, but preliminary research suggests that inhalation is associated with cardiovascular and pulmonary diseases.

Corrosive Baths – Support material can be removed by placing prints in a heated corrosive bath containing sodium hydroxide or other caustic chemicals. Exposure to these chemicals can cause serious chemical burns, scarring, and vision damage.

Vapor Baths – ABS objects can be smoothed or "polished" by placing them in a closed vessel filled with a small quantity of acetone or other organic solvent, which vaporizes and reacts with the ABS plastic. These solvents are usually flammable and can cause symptoms when inhaled such as headache, nausea, and respiratory tract irritation.

Biological Material – Printers using biological material can produce aerosols which may be inhaled or deposited onto nearby surfaces.

Heat – Components such as UV lamps, motors, heat beds, and print heads become hot during operation and can cause burns when touched.

Flammability – Fine metal powders such as aluminum, steel, and titanium can spontaneously combust under normal atmospheric conditions (known as pyrophoricity). Organic solvents like acetone used in vapor polishing can combust when exposed to a heat source. Chemicals used in bed preparation such as hairspray are flammable.

Inert Gas – 3D printers sometimes use inert gases such as nitrogen or argon to create a noncombustible atmosphere in the printing chamber. Some aerosol jet printers use an inert

gas as part of the aerosolization and deposition process. If inert gas is introduced into the surrounding atmosphere, it can displace oxygen and present an asphyxiation hazard.

Electric Shock – Unguarded electrical components and damaged power cords can result in electric shock.

Mechanical Hazards – Hands and fingers can get pinched by moving printer components while in operation. CNC post-processing of metal parts presents mechanical and noise hazards.

Ultraviolet Light/Lasers – Eye exposure to the UV lights used in SLA printers can cause temporary or permanent vision loss. Directed Energy Deposition and Powder Bed Fusion printers often use powerful Class 4 lasers which can cause permanent eye injury from direct or reflected light.

CONTROL OF HAZARDS

To minimize the various hazards associated with 3D Printing, the following controls are highly recommended.

Training

- Employees working in labs with 3D printers are required to complete *General Lab Safety Training* through EHS. Employees working in non-lab areas with 3D printers are required to complete *HAZCOM RTK* training through EHS. Students working with 3D printers in university-sanctioned spaces must be provided a copy of these guidelines to ensure awareness of the hazards.
- 3D printers using class 3B, 3R, or 4 laser systems must be registered with the EHS Laser Safety Officer and identified in the EHS Safety Management System (SMS). Laser safety training should also be added to those working with the printer.

Engineering Controls

- Purchasing units that are fully enclosed with filtration systems is highly encouraged. Filtration should include both HEPA (for particulate) and carbon (for VOCs) filters.
- Use printers in well-ventilated areas. EHS recommends 5-10 air changes per hour.
- Processes using inert gases must be evaluated by the EHS Industrial Hygiene group. Contact (540) 231-8294 to schedule.
- Assure that there is no exposed electrical wiring operating at greater than 50 volts.
- Assure that nip/pinch points and rotating parts are adequately guarded.
- Assure that any 3D printer that uses a laser system completely shields the user from the laser beam and that the system has interlocks to disable the laser if the unit is opened.
- If corrosive baths or vapor baths are used, this should only be performed within a chemical fume hood or using other exhaust controls.

Safe Practices

- *Install, use, and maintain* 3D Printers according to the manufacturer's instructions.
- Safety Data Sheets (SDS) must be kept for all media and chemicals used with the printing process.
- Conduct a Hazard Assessment of the process and review SDS(s) to capture and understand the hazards of your printer.
- The Hazard Assessment should indicate any PPE necessary for safe operation of the printer. This may include, but is not limited to the use of safety glasses, gloves, chemical resistant gloves, apron, etc.
- Respiratory protection may be necessary when working with certain metal and ceramic powders. Contact the Industrial Hygiene group for a formal assessment and review by calling (540) 231-8294.
- Do not work in proximity of the printer while it is in operation (unless fully enclosed with filtration system in use).
- Do not place flammable or combustible materials near the printer while it is in operation.
- If vapor baths are used, assure that there are no sources of ignition in the vicinity.
- Limit the number of printers in the area. Ventilation rates may need to be adjusted.
- Store print media and chemicals properly.
- An eyewash station is *required* if corrosive chemicals are in use.
- Eating and drinking are not permitted in the lab.

Other Requirements

- 3D printers that use inert gases or pyrophoric materials or that create or release flammable vapors must be reviewed and approved by EHS *before* they are installed and put into service. Permits may be required from the University Building Official and/or the State Fire Marshal.
- 3D printers that create or release flammable vapors must be intrinsically safe.
- 3D printers must be listed and labeled in accordance with UL 2011, UL 60950-1 or UL 6238-1. Please contact EHS if your existing 3D printer is not so listed and labeled.

The following items are prohibited from 3D printing: *(reference section 2.2 of Campus and Workplace Violence Prevention Policy, No. 5616)*

a. Firearms, or parts for firearms;
b. Pellet, flare, tranquilizer, stun, spear, and dart guns;
c. Knives with blades larger than that of a folding pocket knife;
d. Switchblades;
e. Daggers;
f. Striking instruments, including clubs, truncheons, blackjacks, metal knuckles, and sap gloves;
g. Martial arts weapons, including nunchakus, tonfas, staffs, and throwing stars;
h. Bow and arrow combinations; and
i. Explosive devices, including hand grenades, bombs, black powder, smokeless powder, percussion caps, friction primers, and pyrotechnic fuses.

If any of the above items are considered for, in the process of, or have been manufactured, contact Virginia Tech Police at 540-231-6411.

Additional Resources / References

3D Printers and Air Quality

Guidance Document on the Safe Use of 3D Printers for Institutions of Higher Learning (UL 200B)

3D Printer Emission Research