MICHIGAN STATE UNIVERSITY | Environmental Health and Safety

3D PRINTING/ADDITIVE MANUFACTURING SAFETY

May 2020

Environmental Health & Safety
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PURPOSE

3D printing, also known as Additive Manufacturing, is the process by which a three-dimensional object is built from a computer model by laying down successive layers of material. At MSU, students and researchers are finding a growing number of 3D Printing applications including electronics prototyping (https://www.egr.msu.edu/eceshop/testingfacility/optomec), anatomical modeling (https://iq.msu.edu/3d-printing-core), and an innovative Makerspace learning space (https://lib.msu.edu/makerspace).

Production processes and materials vary greatly between 3D printing applications, each having its own unique set of health and safety hazards. EHS has provided safety guidelines which are detailed in this document.

3D PRINTING OVERVIEW

3D Printer Types

3D printing methods are typically organized into seven categories based on the way the material is joined:

- **Material Extrusion** – The most common form of Material Extrusion is **Fused Deposition Modeling (FDM)**, in which a thermoplastic filament such as PLA or ABS is melted and deposited in layers by a moving nozzle. Most low-cost, consumer-grade desktop printers use FDM.
- **Vat Polymerization** – The most common form is known as **stereolithography (SLA)**. Works by focusing a UV laser on a photopolymer resin, which hardens the resin in successive layers.
- **Material Jetting** – Selectively deposits droplets of feed material, such as inks, onto a build platform. When the droplets cool and solidify, the next layer is deposited on top.

- **Binder Jetting –** A liquid binder is sprayed onto a bed of ceramic or metal powder, causing it to solidify. The process is repeated in successive layers to build the 3D object.
- **Powder Bed Fusion** – Most common form is **Selective Laser Sintering (SLS)**. Plastics, metals, ceramics, or glass powders are fused together using lasers or an adhesive to form a solid 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 other sharp blade to cut and bond thin-layered materials (e.g., paper, aluminum foil) together layer-by-layer.

3D Printing Hazards

The hazards of 3D printing are as varied as its applications:

- **Chemical Vapors** – ABS and PLA filaments have been shown to produce Volatile Organic Compounds (VOCs) when heated in 3D printing processes. Exposure to VOCs can 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 hazard.
- **Nanoparticle Emissions** – ABS, PLA, and other filaments produce inhalable nanoparticles (NPs) when heated 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 blindness.
- **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 non-combustible 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.

SAFETY PROVISIONS

General Safety Provisions

- Before operating a 3D printer, ensure you are familiar with the correct, safe operation of the printer.
- Always follow the manufacturer's instructions on printer setup and usage.
- Safety Data Sheets (SDS/MSDS) for materials used with 3D printers should be reviewed prior to use. Printed copies should be kept onsite and made available to employees.
- Never bypass safety controls or defeat interlocks once the printing process has started.
- Do not place flammable liquids near 3D printers. The heated components of 3D printers can cause the flammable liquid to catch fire.
- If the manufacturer offers enclosures or exhaust ventilation kits, they should be purchased if possible. This will decrease the risk of exposure to hand/finger pinches from moving parts and reduce air contamination.
- Never work alone (https://ehs.msu.edu/lab-clinic/chem/working-alone.html) when using hazardous chemicals. It is permissible to work alone if using consumer-grade printers that use solid media.
- Know the locations of emergency equipment relevant to the hazards of your printer, such as fire extinguishers and eyewash stations.

ABS vs PLA

Most consumer-grade FDM printers use either ABS (acrylonitrile butadiene styrene) or PLA (polylactic acid) filament. Both ABS and PLA produce toxic nanoparticles and volatile organic compounds. The emissions of PLA are less hazardous than ABS, so PLA is the preferred filament when feasible.

Post-Processing Baths

Support material may be removed by submerging prints into a bath which can contain water or a caustic solution. All liquids used in these baths should be disposed of as hazardous waste via EHS, including water. Special safety precautions should be taken when using caustic baths to remove support material. The alkaline chemicals used in caustic baths can cause chemical burns and permanent blindness. The following PPE should always be worn when using the caustic bath:

- Long pants
- Closed-toe shoes
- Laboratory coat
- Nitrile gloves that cover the cuffs of the lab coat
- Splash goggles
- Chemical-resistant apron

Ensure that PPE is kept in good condition. Regularly check PPE for cracks, holes, and signs of wear.

A functioning eyewash station must be kept within 25 feet of the alkaline bath. Keep the eyewash station unobstructed and easily accessible. Do not use the bath if a functioning eyewash station is not present. Plumbed eyewashes should be tested weekly and recorded. Portable eyewash stations may be purchased if a plumbed station is not available. Ensure that portable eyewash stations are compliant with the ANSI (American National Standards Institute) Z358.1 standard. Portable stations do not need to be tested.

Use instruments such as tongs when adding and retrieving objects from the bath. Never add or remove objects with your hands, even with gloves on. It is permissible to add and remove objects while the bath is being agitated if no splashing is observed and all PPE is worn. It is permissible for the bath to operate unattended.

Never use the caustic bath alone. In the event of an eye exposure, use the eyewash immediately and have another employee call 911. In the event of a skin exposure, wash for 15 minutes under tepid water and have another employee call 911.

Caustic powder/liquid concentrates should be kept in a dedicated chemical storage cabinet with "Chemical Storage Area" and "Corrosive Material" labels placed conspicuously on the outside of the cabinet. Labels can be ordered from EHS from EHS' Info Safety Portal (https://db.ehs.msu.edu/label_request/new_request.htm).

EHS recommends using Techni Print brand cleaning concentrate (https://www.technic.com/applications/3d-printing/3d-printing-chemistry) because of its less-hazardous properties, but any other caustic agent is acceptable provided that safety practices are followed.

Place used liquid in EHS-provided plastic containers (carboys), complete the Waste Pickup Tag, and contact EHS for waste pickup (https://db.ehs.msu.edu/chem-waste/new.htm). Never pour caustic solution down the drain. When mixing a new caustic bath, fill the container with water first and slowly add the caustic powder/liquid second. EHS can provide equipment such as siphons if needed.

Using Organic Solvents

Organic solvents are flammable chemicals that readily vaporize at room temperature. Examples include acetone and alcohols. They are sometimes used with FDM printers for bed preparation and surface finishing.

Do not use organic solvents or hairspray on printers whose components are heated. Always ensure a functioning ABC fire extinguisher is nearby in the case of a fire.

Do not store organic solvents in refrigerators. This can result in explosion.

Secondary containers containing less than 750mL, such as these wash bottles (https://www.grainger.com/search/lab-supplies/labware/labware-bottles-and-jars/wash-bottles), may be kept on working surfaces outside of the designated Chemical Storage Area. Secondary containers should be labeled with the chemical's name and hazard statements and NFPA diamond found on its SDS. Store large containers of solvents in the Chemical Storage Area.

Use organic solvents inside of a fume hood if possible. If a fume hood is not available, contact EHS for assistance at 517-432-5631 or email mccordty@msu.edu.

Dispose of all waste via EHS waste pickup request (https://db.ehs.msu.edu/chem-waste/new.htm).

Metal Powders

Please contact EHS prior to starting a new work process involving metal powders at 517-432-5631 or email mccordty@msu.edu. All metal powders of any composition and particle size should be treated as hazardous, including alloys and mixtures containing non-metallic substances. Metal powders should be used with great caution. Personal exposure can cause chronic health effects, and improper handling can result in fire or explosion.

The following safety practices should be followed for any operation handling or producing metal powders:

- Conduct activities in a manner minimizes the release of airborne dust and the possibility of spillage.

- Keep a Class D fire extinguisher within reach.
- Only use vacuums designed for use with metal powders. Conventional vacuums can cause fire or explosion. Vacuums should be electrically grounded.
- Never let machines operate unattended.

The following Personal Protective Equipment should be worn when handling metal powders:

- Long pants
- Closed-toe shoes
- Laboratory coat
- Nitrile, butyl, or neoprene gloves that cover the cuffs of the lab coat
- Safety glasses, safety goggles, or full-face respirator
- Half-face or full-face respirator with P100 filters

Closed containers may be handled without PPE. Contact Lillian Brezzell for respirator fit-testing at 517-355-3879 or email brezzell@msu.edu.

Signage

Rooms containing any quantity of hazardous chemicals should have the following signage posted on the door:

- The Michigan Right-to-Know law poster, listing the location of SDSs for all hazardous chemicals used in the laboratory.
- Emergency contact numbers (two names, preferably the P.I., head technician or a graduate student) should be posted on the external doorway to the lab. Names and numbers should be updated when personnel change. In case of an emergency, responders need this information to contact knowledgeable personnel about hazards present in the lab.
- Label chemical storage areas with a Chemical Storage Area sticker, as well as stickers denoting the hazard(s) of the stored chemicals.
- If a laboratory has 10 gallons or more of a flammable or corrosive liquid or toxic gas(es), the main doorway to the lab should have a hazard warning sticker visibly posted on it to indicate the hazard.

Signs can be ordered from EHS' Info Safety Portal (https://db.ehs.msu.edu/label_request/new_request.htm). Right-to-Know notice can be downloaded from Michigan Occupational Safety & Health Administration (https://www.michigan.gov/documents/dleg/wsh_cet2105_219990_7.pdf).

Chemical Storage

Chemicals should be stored in a designated, labeled chemical storage cabinet. **Do not store flammable substances like resin polymers, rubbing alcohol, and acetone in refrigerators/freezers. This can cause an explosion**. Large bottles of chemicals should be stored no more than two feet from floor level.

If multiple types of chemicals will be stored in the same cabinet, refer to page 18 of the MSU Waste Disposal Guide (https://ehs.msu.edu/_assets/docs/waste/msu-waste-disposal-guide.pdf) to determine if they are compatible for storage. If chemicals are determined to be incompatible, contact EHS 517-432-5631 or email mccordty@msu.edu for further guidance. Place labels denoting the hazards of the chemicals on the outside of the cabinet. Labels can be ordered from EHS' Info Safety Portal (https://db.ehs.msu.edu/label_request/new_request.htm).

Spill Procedures

Keep a chemical spill kit in locations using chemicals. FDM printers using solid media do not require a spill kit. Spills under one liter may be cleaned up using the chemical spill kit. For spills over one liter, contact EHS for cleanup at 517-355-0153.

TRAINING

All individuals operating 3D printers should receive the following training, and training should be documented (topics covered, date, employee names and signatures)

- Chemical Hygiene and Hazardous Waste Initial / Refresher
- Site Specific Training with PI or lab manager
- Laser Safety (If handling un-enclosed lasers, such as during assembly and maintenance)