HARVARD
Campus Services
ENVIRONMENTAL HEALTH & SAFETY

FACT SHEET

Program: Makerspace Safety

3D PRINTERS - ADDITIVE MANUFACTURING

INTRODUCTION

What is 3D printing? 3D printing or rapid prototyping additive manufacturing is a method of manufacture where layers of a material are built up to create a solid object.

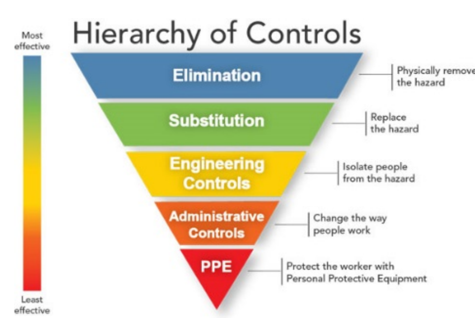
Fused Deposition Modeling (FDM) is the most widely used 3D Printing technology: it represents the largest installed base of 3D printers globally and is often the first technology people are exposed to.

Fused Deposition Modeling (FDM), or Fused Filament Fabrication (FFF), is an additive manufacturing process that belongs to the material extrusion family. In FDM, an object is built by selectively depositing melted material in a pre-determined path layer-by-layer. The materials used are thermoplastic polymers and come in a filament form.

Most of these devices are currently sold as standalone devices without any exhaust ventilation or filtration accessories, **researchers suggest caution should be used when operating in inadequately ventilated or unfiltered indoor environments. If your school or department is planning to install a 3D printer, please contact EH&S for guidance.**

SAFETY

3D printing is still a relatively new technology and there are many gaps in the information available about health and safety implications. As with many innovations, workers are the first groups exposed to potential hazards. Based on prior knowledge from air pollution research and industrial processes (e.g., welding) there are concerns over 3D printing emissions and their potential impact on workers' health.



The Center for Disease Control (CDC) recommends the hierarchy of controls (elimination, substitution, engineering, administration and then personal protective equipment), and would be applicable for all brands of 3D printers and filaments. This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees.

- Engineering controls are favored over administrative and personal protective equipment (PPE) for controlling existing worker exposures in the workplace because they are designed to remove the hazard at the source, before it comes in contact with the user. Well-designed engineering controls can be highly effective in protecting workers and will typically be independent of worker interactions to provide this high level of protection.
- The initial cost of engineering controls can be higher than the cost of administrative controls or PPE, but over the longer term, operating costs are frequently lower, and in some instances, can provide a cost savings in other areas of the process.
- Ventilation is an important engineering control to help control/reduce emissions from 3D printers, and can be manually or electronically switched on when the 3D printers are operated. Examples of ventilation controls could include single unit local exhaust ventilation system, snorkel fume extractors, or for situations where multiple printers are used, operating 3D printers on enclosed ventilated racks. Ventilation options (in order of decreasing effectiveness) include:
    - Directing exhaust outdoors;
    - Connecting the enclosure to a HEPA and activated charcoal filtration unit; or
    - Increasing the room ventilation to at least 4-6 air changes per hour (ACH), only if at most two 3D printers are concurrently operated and the 3D printers are not operated in the immediate vicinity of a workstation occupied by personnel.

  Resources: Enclosures, if not provided by the printer manufacturer, can be fabricated by inhouse machine shops or purchased from external vendors such as PrintedSolid. Filtration units can be purchased from vendors such as BOFA or Sentry Air Systems, and can be connected to the printer enclosures or positioned with the snorkel end close to the printing process.
- More research is needed to identify additional low emitting filaments for use in 3D printers so that filament selections can be made based on low emission rate in addition to other filament properties. Low emitting filaments will reduce energy costs associated with ventilation and filtration controls and may be particularly important for workplaces in leased facilities or other settings where ventilation modifications are not feasible or allowable.
- If your 3D printing process requires a corrosive bath, contact EH&S about any additional training or PPE requirements.

For more information, see the following table summarizing the types of 3D printing and their primary hazards.

Category	Types of Devices/Process	Feedstock Materials	Feedstock Form	Binding/ Fusing	Most Prominent Potential hazard
Material Extrusion is a 3D printing process where a filament of solid thermoplastic material is pushed through a heated nozzle, melting it in the process. The printer deposits the material on a build platform along a predetermined path, where the filament cools and solidifies to form a solid object.	Fused Filament Fabrication (FFF), sometimes called Fused Deposition Modeling (FDM).	Thermoplastics (may include additives)	Spooled filament, pellet, or granulate	Electrical heating element-induced melting/cooling	Inhalation exposure to VOCs, particulate, additives; burns
Vat Polymerization is a 3D printing process where a photo-polymer resin in a vat is selectively cured by a light source.	SLA (Stereolithography) and DLP (Digital Light Processing)	Photopolymer	Liquid resin	Ultraviolet-laser induced curing	Inhalation of VOCs; dermal exposure to resins and solvents, ultraviolet exposure
Powder Bed Fusion is a 3D printing process where a thermal energy source will selectively induce fusion between powder particles inside a build area to create a solid object. Powder Bed Fusion devices also employ a mechanism for applying and smoothing powder simultaneous to an object being fabricated, so that the final item is encased and supported in unused powder.	Selective Laser Sintering (SLS)	Metal, ceramic, or plastic	Powder	High-powered laser or electron beam heating	Inhalation/dermal exposure to powder, fume; explosion; laser/radiation exposure
Material Jetting is a 3D printing process where droplets of material are selectively deposited and cured on a build plate. Using photopolymers or wax droplets that cure when exposed to light, objects are built up one layer at a time. Material Jetting (MJ) works in a similar way to a standard inkjet printer. The key difference is that, instead of printing a single layer of ink, multiple layers are built upon each other to create a solid part.	Material Jetting (MJ), Drop on Demand (DOD)	Material jetting Photopolymer or wax	Liquid ink	Ultraviolet-light induced curing	Inhalation of VOCs; dermal exposure to resins and solvents, ultraviolet exposure

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Binder Jetting is a 3D printing process where a liquid bonding agent selectively binds regions of a powder bed. Binder Jetting moves a print head over the powder surface depositing binder droplets, which are typically 80 microns in diameter. These droplets bind the powder particles together to produce each layer of the object.	Binder Jetting	Metal, ceramic, plastic, or sand	Powder	Adhesive	Inhalation/dermal exposure to powder; explosion; inhalation of VOCs, dermal exposure to binders
Metal Powder Bed Fusion is a 3D printing process, which produces solid objects, using a thermal source to induce fusion between metal powder particles one layer at a time. Most Powder Bed Fusion technologies employ mechanisms for adding powder as the object is being constructed, resulting in the final component being encased in the metal powder. The main variations in metal Powder Bed Fusion technologies come from the use of different energy sources; lasers or electron beams.	Direct Metal Laser Sintering (DMLS); Selective Laser Melting (SLM); Electron Beam Melting (EBM)	Metal	Powder or wire	Laser/electron beam heating	Inhalation/dermal exposure to powder, fume; explosion; laser/radiation exposure

Source: Potential Hazards of Additive Manufacturing
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https://blogs.cdc.gov/niosh-science-blog/2019/04/09/am/