1. Purpose of this document

This document will serve as guidance for the safe operation of makerspaces and labs with 3D printers. Hazards that may not be immediately apparent include dust accumulation, reactive chemicals, inhalation of fine particles, laser, and radioactivity.

NIOSH defines 3D printing as “the process of taking a design created in software or by a 3D object scanner and then using hardware to create that object out of various materials.” This process can use powder, spooled filament, or liquid resins as the material and may use electrically produced heat, lasers, or UV light to bind the material into the 3d shape. This process can create fine dust, toxic dusts, or chemical fumes as a waste product and hazards may not be adequately outlined in other documentation

2. Makerspace Inventory

Though there are many locations with plastic filament feed type 3d printers, the following areas have been identified as Makerspaces:

- Emerging Technologies Studio (Tech Hub)
- Additive Manufacturing Lab (ES 1500)

3. Types of Printers and Materials

3.1. Printers

Category	Feedstock Materials	Feedstock Form	Binding/Fusing	Most Prominent Potential Hazards
Material Extrusion	Thermoplastics (may include additives)	Spooled filament, pellet, or granulate	Electrical heating element-induced melting/cooling	Inhalation exposure to VOCs, particulate, additives; burns
Powder Bed Fusion	Metal, ceramic, or plastic	Powder	High-powered laser or electron beam heating	Inhalation/dermal exposure to powder, fume; explosion; laser/radiation exposure
Vat Photo Polymerization	Photopolymer	Liquid resin	Ultraviolet-laser induced curing	Inhalation of VOCs; dermal exposure to resins and solvents, ultraviolet exposure
Material Jetting	Material jetting Photopolymer or wax	Liquid ink	Ultraviolet-light induced curing	Inhalation of VOCs; dermal exposure to resins and solvents, ultraviolet exposure

Binder Jetting	Metal, ceramic, plastic, or sand	Powder	Adhesive	Inhalation/dermal exposure to powder; explosion; inhalation of VOCs, dermal exposure to binders
Sheet Lamination	Metal, ceramic, or plastic	Rolled film or sheet	Adhesive or ultrasonic welding	Inhalation of fumes, VOCs; shock, laser/radiation exposure
Directed Energy Deposition	Metal	Powder or wire	Laser/electron beam heating	Inhalation/dermal exposure to powder, fume; explosion; laser/radiation exposure

3.2. Common Print Materials

Plastics	Metals*
• ABS (acrylonitrile butadiene styrene)	• Stainless Steel
• PVA (polyvinyl alcohol)	• Inconel
• PLA (polylactic acid)	• Titanium
• HIPS (High Impact Polystyrene)	• Aluminum Alloy (AlSi10Mg)
• TPU (thermoplastic polyurethane)	• Copper

*Note: Available in many different particle sizes

4. Hazards

4.1. Combustible Dusts

4.1.1 Dust fires occur when combustible dusts are allowed to accumulate. These are a simple combustion process, requiring only oxygen, fuel, and an ignition source. The ignition source may be supplied by static spark, the spark of a vacuum cleaner or compressor motor, or even a light switch. Simple dust fires can be fought with a fire extinguisher, usually a Class ABC but sometimes a Class D.

4.1.2 Dust deflagrations happen when a dust in an enclosed space ignites. These are more rare, but much more hazardous.

4.1.3 Static shock discharges may spark combustible dusts, so where needed an electrostatic dissipative floor must be installed.

4.1.4 A Class D metal fire extinguisher may be required and will be supplied by Environmental Health and Safety.

Figure 1: The dust deflagration pentagon. Note the three legs of the combustion triangle.

Figure 2: The 2008 Imperial Sugar explosion caused by excess sugar buildup. 14 people died, many more injured

4.2 Metal Powders

4.2.1 Metal powders may react with other metal powders and create an exothermic reaction.

4.2.2 When using a metal deposition printer, fully clean the printing chamber and supply side when changing from one metal to another.

4.2.3 Waste products from one metal powder must not be combined with waste products of another metal powder. Exceptions can only be made by the manufacturer of the machine and must be submitted to EHS in advance.

4.2.4 Thermites are metal powder fuels mixed with metal powder oxides. See the examples below:

4.2.4.1 Thermite Fuels: Al, Mg, Ti, Zn, Si, B

4.2.4.2 Oxidizers: Boron Oxide, Silicon Oxide, Chrome Oxide, Manganese Oxide, Iron Oxide, Copper Oxide, Lead Oxide, etc..

4.2.4.3 Reactive Metal Pairs[1]:

Al + Ni	Zr + B	Ce + Si	Mn + Si
Al + B	Si + Zr	Ti + B	Si + Ti
Al + Ti	Ni + Si	Co + Si	

4.3 Lasers

4.3.1 Lasers used for laser cutting or sintering must be part of a system that keeps the beam shielded and protected by an interlock device.

4.3.2 No modifications may be made to 3d printer laser configurations without consent from the Laser Safety Officer in EHS.

4.3.3 Laser containing equipment is regulated by the Laser Safety Program. Many devices have embedded Class 4 lasers used for metal welding, but may have integrated safety features that render the unit a Class 1 Laser system.

4.4 Ultraviolet Light

4.4.1 Some makerspace devices may use UV Light to cure or harden the printed product. UV light is damaging to the skin and eyes and any UV emitting light source should be in a cabinet surrounded by glass that will filter the UV light before it reaches the user. If these engineering controls are not in place the user should contact the manufacturer to purchase them.

4.4.2 All elements of Policy and Procedure 1006 "Hazards of Ultraviolet Light" must be adhered to.

4.5 Chemical Exposure

4.5.1 A comprehensive list of chemical exposure hazards can be found in Section 5.4 of the Chemical Hygiene Plan.

4.5.2 Makerspaces may contain some organic solvents for cleaning and various other tasks. Gloves and safety glasses must be worn when using these compounds. If spilled on skin or in eyes, proceed immediately to the nearest eyewash or sink and drench the exposed area. Call EHS (607-777-2211) for non-emergency exposures, call University Police (607-777-2222) for emergency exposures.

4.5.3 Appropriate PPE should be selected to protect from both powder and chemical hazards.

4.6 Sharps

4.6.1 Metal scrapers, knives, and prying utensils may be employed to remove a 3d printed product from its assembly plate.

4.6.2 Always cut away from you- never move a knife, scraper, or prying utensil toward you.

4.6.3 Always stabilize the working surface by clamping it to the bench or otherwise securing it. Never pry a product off an assembly plate that is not secured. Never secure the assembly plate with just your hand.

4.6.4 Bare blades should not be used. Use a retractable razor or scraper instead.

4.7 Gases

4.7.1 Inert gases may be used to create an inert atmosphere in the chamber.

4.7.2 Inert gases may be heavier than air and may displace oxygen at lower levels and thus appropriate metering may be recommended by EHS.

4.7.3 Cryogenic liquids may be used to create large amounts of inert gas. Precautions for handling cryogenic liquids are addressed in section 13.10 of the Chemical Hygiene Plan and must be followed.

5. Hazard Prevention and Mitigation

5.1. Dust Accumulation and Cleanup

5.1.1. Dust collection protocols must be in place. Accumulation of dust only 1/32" over 5% of the surface area of a room is a hazard. In terms of a lab space; if your 3d printing lab is 1500 sq. ft, an accumulation of 1/32" on two standard benchtops is a hazard. Furthermore, dust accumulated on ceiling fixtures and beams can be disturbed by a small deflagration, fueling a much larger explosion.

5.1.2. A dedicated and approved combustible powder vacuum is necessary to clean powder. Generic shop vacuums or HEPA vacuums may provide that spark as they are not intrinsically safe.

5.1.3. Vacuum cleaners designed for combustible powders must be properly maintained and logs of this maintenance must be kept by the user.

5.1.4. Vacuumed dust may be rendered nonreactive only by means approved by the manufacturer. Many manufacturers recommend mixing with a surfactant or other materials. This may also be referred to as "passivating". Equipment capable of passivation must have instructions posted.

5.1.5. Compressed air must not be used to clear off equipment or surfaces, as this merely stirs the dust up and does not remove it.

5.2. Powder Handling

5.2.1. During delicate powder handling operations, care must be taken to not disturb the mass of powder and instead to gently handle it.

5.2.2. Extraneous personnel and personnel traffic should be removed from the lab space to avoid drafts and unwanted dispersion.

5.2.3. Procedures should be created to prohibit entry to a makerspace during delicate powder handling operations.

5.2.4. Bonding and grounding must be employed when powder sieving or vacuuming.

5.2.5. Airborne dust formation should be avoided by any means. Dry sweeping methods, vacuuming, or gentle handling methods should be developed.

5.3. Storage Limitations

5.3.1. Most buildings are classified by NYS OFPC as Type B Occupancy, meaning mixed use/business. Table 5003.1.1(1) of Chapter 50 governs storage limitations for all hazardous materials and must be consulted prior to starting operations and prior to ordering materials.

5.3.2. Exceeding storage amounts in control areas must be avoided. EHS can assist with interpreting the above referenced table and defining storage limitations and control areas.

5.4. Ventilation

5.4.1. 3d Printers may produce gases such as volatile organic compounds (VOCs) or ultra-fine powders (UFPs) as a waste product during the printing or powder handling process.

5.4.2. The presence of VOCs can often be detected by their distinct odor. Odors should be controlled by an engineering control device such as a shroud or snorkel that captures the emissions.

5.4.3. The presence of UFPs may not be noticeable as there is no distinct odor and they are usually too small to see. UFPs are less than 100 nm in size and when inhaled can enter the deepest part of the lungs, where they may enter tissues and cells. Similar to VOCs, they should be captured at the point of generation. Unlike VOCs they can become concentrated in ductwork and form explosive concentrations.

5.4.4. Air monitoring may be installed to determine background dust and accumulation amounts or the displacement of oxygen by heavy inert gases that may be used.

5.4.5. Inert gases should be removed using appropriate building ventilation. EHS and Physical Facilities can be consulted.

5.5. Personal Protective Equipment

5.5.1. Hand Protection can be utilized to prevent skin contact.

5.5.2. Body protection can be utilized to protect the users from dust exposure to clothing.

5.5.3. Respiratory protection may be required in some applications. Consultation with EHS will determine if participation in the Respiratory Protection Program is required.

5.5.4. Eye protection should be utilized to avoid dust exposure to the eyes.

6. Training

Training Topic	Responsibility
Lab Safety	EHS
Flame Resistant Clothing	PI
Respiratory Protection	EHS
Specific use of printer	PI
Safe operation of vacuum	PI/Vendor
Ancillary equipment	PI

7. Regulations and Resources

- NFPA 484-2012 Standard for Combustible Metals
- NFPA 68, Standard on Explosion Protection by Deflagrating Venting
- NFPA 69, Standard on Explosion Prevention Systems

- NFPA 654, Standard for the Prevention of Fires and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids
- NFPA 61, Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities
- NFPA 655, Standard for Prevention of Sulfur Fires and Explosions
- NFPA 664, Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities
- UL 3400, "Outline of Investigation for Additive Manufacturing Facility Safety Management"
- https://www.safetyandhealthmagazine.com/articles/19406-niosh-announces-partnership-aimed-at-enhancing-safety-and-health-in-3d-printing
- https://www.ehs.harvard.edu/programs/makerspace-safety
- https://3dinsider.com/3d-printer-types/
- https://blogs.cdc.gov/niosh-science-blog/2019/04/09/am/
- https://www.sciencedirect.com/science/article/pii/S0160412018323663

Footnotes

[1] https://www.osti.gov/servlets/purl/1242062