

3D Printing Guidance

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1. The purpose of this document

This guideline supports the University of Lincoln's Health and Safety Policy, Risk Assessment Policy, Dangerous Substances and Explosive Atmospheres (DSEAR) Policy and Control of Substances Hazardous to Health (COSHH) Policy, providing assistance for the safe operation of 3D printers within the University. It applies to the use of all types of 3D printers currently utilized at the University of Lincoln.

2. What is 3D printing

3D Printing is an additive manufacturing (AM) process of making three dimensional objects from digital files. The AM process involves laying down successive layers of a material until the object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the object. Each 3D printer has been designed to print with certain types of materials which have their own hazards and may become more hazardous when subjected to the printing process. In addition to printing, a 3D print job may include pre - and post-processing work which can consist of support removal, surface finishing, and curing.

3. Printing technologies

At the University of Lincoln, our workshops and labs are equipped with the 3D printing technologies to support the creative and research endeavours of our staff and students. The primary technologies available are Fused Deposition Modelling (FDM)/Fused Filament Fabrication (FFF) and Stereolithography (SLA).

a. FDM/FFF Printing

FDM, also known as FFF, is a widely used 3D printing technology within our university. This process involves heating thermoplastic filament to a molten state and extruding it through a precision nozzle. The printer lays down the melted material layer by layer onto the build platform, where it cools and solidifies, forming a three-dimensional object. This method is favoured for its efficiency, ease of use, and the strength of the printed objects, making it ideal for prototyping, educational models, and functional parts.

b. SLA Printing

SLA printing represents a different approach, utilizing a UV laser to precisely cure and solidify a photosensitive resin. The build platform incrementally moves, allowing each layer to be cured by the UV laser, based on the digital model's specifications. This technology excels in producing high-resolution objects with intricate details, making it particularly useful for applications requiring fine features, such as intricate research models and detailed prototypes.

4. Printing materials

4.1 Thermoplastics in 3D Printing

At the University of Lincoln, the printing materials currently utilized are thermoplastics and photopolymers, which represent two distinct types of materials each tailored for specific printing technologies and applications.

Thermoplastics are plastic materials that become mouldable upon heating and solidify when cooled. These materials are repeatable in this process, which makes them versatile for 3D printing applications, particularly in Fused Deposition Modelling (FDM) or Fused Filament Fabrication (FFF). The most common thermoplastics used in 3D printing include:

- **Polylactic Acid (PLA):** Known for its ease of use, PLA is a biodegradable material derived from renewable resources like cornstarch or sugarcane. It's widely used in educational settings due to its low warping, pleasant smell during printing, and variety of colours. PLA is ideal for printing models, prototypes, and non-functional items.
- **Acrylonitrile Butadiene Styrene (ABS):** ABS is a strong, durable material with high heat resistance, making it suitable for functional prototypes and end-use parts. It requires a heated print bed and enclosed printing environment due to its tendency to warp and emit fumes during printing.
- **Polyethylene Terephthalate Glycol (PETG):** PETG combines the ease of use of PLA with the durability of ABS. It is strong, flexible, and moisture-resistant, making it ideal for printing functional parts and food-safe containers.
- **Nylon (Polyamide):** Nylon is known for its strength, flexibility, and wear resistance. It is ideal for creating functional parts that need to endure stress and friction. However, it requires higher printing temperatures and often a heated bed.
- **Thermoplastic Polyurethane (TPU):** TPU is a flexible, elastic material used for parts that require rubber-like properties. It is more challenging to print due to its flexibility but is excellent for creating items like gaskets, seals, and flexible hinges.
- **Polycarbonate (PC):** Polycarbonate is a high-strength, impact-resistant material with high temperature resistance. It is suitable for printing mechanical parts and applications requiring durability and stability under stress.
- **High Impact Polystyrene (HIPS):** HIPS is another butadiene-styrene copolymer like ABS. It is often used as a support material because it is soluble in limonene, making it easy to remove. HIPS is also durable and impact-resistant, but it can emit styrene fumes during printing, which requires proper ventilation.

Note:

New technologies and materials are continuously being introduced, so the list of filaments provided is not exhaustive. For any materials used in the 3D printing process, always refer to their Safety Data Sheets (SDS) for detailed information and guidance.

4.2 Photopolymers in 3D Printing

Photopolymers are light-sensitive resins that solidify when exposed to a specific light source, such as UV light, in a controlled layer by layer process. This material class is primarily used in Stereolithography (SLA) and Digital Light Processing (DLP) 3D printing technologies. Key aspects include:

- **High Resolution and Detail:** Photopolymers are capable of producing parts with very fine details and smooth surface finishes, making them ideal for applications requiring high precision, such as dental models, jewellery, and intricate prototypes.
- **Material Properties:** Photopolymers can vary widely in terms of mechanical properties, from rigid and tough to flexible and soft. Innovations in photopolymer chemistry have expanded their applications to include functional parts and biocompatible products.
- **Post-Processing Requirements:** Parts printed with photopolymers typically require cleaning with solvents to remove any uncured resin and may also need post-curing under UV light to achieve their final material properties.

5. Hazards associated with 3D printing.

3D printing, while revolutionary for design, prototyping, and manufacturing, involves processes that can pose various health and safety hazards. It is essential to conduct general and COSHH risk assessments to determine which specific hazards are relevant to the type of printing being undertaken. The Safety Data Sheets (SDS) must be used to understand the COSHH implications.

Below is a list of potential hazards and harmful effects associated with Fused Filament Fabrication (FFF)/Fused Deposition Modelling (FDM) and Stereolithography (SLA) 3D printing techniques, along with short descriptions for each:

5.1. FFF/FDM 3D Printing Hazards

1. **Fumes and VOCs (Volatile Organic Compounds):** Heating thermoplastic materials can release fumes and VOCs, which can cause respiratory irritation and long-term health issues if inhaled in significant quantities. ABS for example, is known for emitting styrene, a potentially harmful VOC.
2. **Ultrafine Particles (UFPs):** The heating process generates UFPs, which can penetrate deep into the lungs and contribute to respiratory and cardiovascular diseases.
3. **High Temperatures:** The extruder nozzle and heated bed reach high temperatures, posing burn risks to users during operation and maintenance.

4. **Mechanical Hazards:** Moving parts, such as the print bed and extruder, can cause injuries if fingers or objects come into contact with them.

5.2. SLA 3D Printing Hazards- Toxic Resins: Photopolymer resins used in SLA printing can be toxic if inhaled or come into contact with the skin, leading to allergic reactions, skin irritation, or more severe health issues.

1. **UV Exposure:** The UV light used to cure resin can cause eye and skin damage if proper protective measures are not taken.
2. **Chemical Waste:** Uncured resin and cleaning solvents are hazardous wastes that require proper disposal to prevent environmental damage and exposure risks.
3. **Resin Spills:** Spills can lead to slips, falls, and skin contact with toxic materials, necessitating careful handling and cleanup procedures.
4. **Chemical Exposure:** Handling solvents for cleaning uncured resin can expose individuals to potentially hazardous chemicals, which may cause skin irritation, allergic reactions, or respiratory issues if inhaled.
5. **Fire and Explosion Hazard:** Some solvents used in post-printing processes, such as isopropyl alcohol (IPA), are flammable and pose a risk of fire and explosion. When using solvents, refer to the COSHH risk assessment to ensure that adequate control measures, such as the use of a suitable Local Exhaust Ventilation (LEV) system, have been identified and implemented. Many solvents are flammable, posing a risk of fire if used or stored near ignition sources.

There are alternatives available on the market that can be considered due to their reduced volatility, higher flashpoints, and overall lower risk of fire and explosion compared to traditional solvents like IPA. Examples include Tripropylene Glycol Monomethyl Ether (TPM), Propylene Carbonate, and Ethyl Lactate.

5.3. General Hazards for Both Techniques

1. **Electrical Safety:** As with any electrical equipment, there is a risk of electric shock or fire if devices are improperly used or maintained.
2. **Noise Pollution:** Some 3D printers operate at noise levels that could contribute to hearing damage over prolonged exposure periods.
3. **Ergonomic Hazards:** Improper setup and long hours of monitoring or interacting with 3D printers can lead to ergonomic issues, such as eye strain and musculoskeletal injuries.

6. 3D Printer Safety and Operational Considerations.

When integrating 3D printing technologies into the workplace, it is crucial to undertake a comprehensive assessment of the potential risks and requirements. This assessment ensures that the technology enhances productivity and learning without compromising on safety or compliance with legal and institutional policies.

The Health and Safety Executive (HSE) report "Measuring and Controlling Emissions from Polymer Filament Desktop 3D Printers" provides valuable insights and recommendations for managing emissions and ensuring safety in environments using 3D printing technology. This report details the potential hazards associated with polymer filament 3D printers, including the emission of harmful particles and volatile organic compounds (VOCs). It emphasizes the importance of proper ventilation, the use of enclosures with filtered ventilation, and selecting filaments with lower emission rates to mitigate health risks. It is recommended that this report be referenced during the risk assessment process for the procurement and use of 3D printing equipment to ensure safe and effective implementation of these technologies.

Additionally, the CLEAPSS (Consortium of Local Education Authorities for the Provision of Science Services), in collaboration with HSE, has endorsed guidance that adopts a sensible and proportionate approach to managing the health and safety aspects of 3D printing technologies in educational settings.

The following considerations and recommendations are designed to guide the selection, installation, and use of 3D printers, focusing on mitigating risks associated with their operation, materials used, and the environment in which they are housed.

1. **Safety Standards:** Ensure printers carry a CE or UKCA mark to verify compliance with current safety standards.
2. **Ventilation Requirements:** For printer installation, select an area with good ventilation. It is advisable to install local exhaust ventilation (LEV) systems to reduce particulate and chemical emissions, as well as the accumulation of explosive vapours that might be produced during post-processing activities, such as washing prints with IPA. Ensure all actions are in accordance with HSE guidance and the University's LEV Policy.
3. **Safety Features:** Select fully enclosed printers equipped with built-in filters to minimize emissions and safeguard against access to moving and hot components.
4. **Power Supply Management:** Confirm the compatibility of the printer and any LEV systems with the available power supply, ensuring they remain unaffected by emergency power shut offs. This means checking that: The equipment can safely power down without causing harm or creating additional hazards. Critical safety systems, such as ventilation for removing hazardous fumes, remain operational or have a safe shutdown procedure.
5. **Electrical Safety:** Opt for printers that feature a dedicated, clearly labelled, and lockable power supply for enhanced safety during maintenance and in emergencies.
6. **Pause and Component Splitting Capability:** For extensive printing tasks, consider printers capable of pausing or breaking down jobs into segments to efficiently manage time and resources.
7. **Material Considerations:** Preferentially use PLA filament to reduce fume and particulate emissions and ensure optimal storage conditions to maintain material integrity.

8. **Maintenance and Cleaning:** Regular maintenance by qualified personnel and the establishment of safe cleaning protocols are essential, avoiding the use of harsh chemicals.
9. **Substitute Harmful Chemicals:** Opt for safer alternatives to hazardous chemicals used in the printing or post-processing stages.
10. **Operator Training:** Provide comprehensive training for all operators on the safe operation and use of 3D printers.
11. **Safety Data Sheets (SDS) Access:** Ensure access to UK-compliant SDS for all filaments and chemicals used in printing and support material removal.
12. **Chemical Storage:** Refer to the SDS for proper storage instructions for all chemicals involved in the printing process.
13. **Appropriate PPE:** Review SDS to confirm that the correct Personal Protective Equipment is provided and used.
14. **Correct Print Temperature:** Consult the SDS and the printer's user guide to use the correct print temperature for the materials.
15. **Waste Disposal:** Ensure all waste is disposed of according to local environmental guidelines and within the allocated budget.
16. **Safe Work Procedures (SWPs):** Develop and enforce SWPs for the operation of all types of 3D printers to ensure safety and compliance.
17. **Prohibited Items for 3D Printing:** In accordance with the University of Lincoln's Weapons Policy, certain items are prohibited from being 3D printed. For further details, please refer to the University of Lincoln's Weapons Policy.

7. Relevant documents/Links

- 7.1. Health and Safety Executive: Managing and controlling emissions from polymer filament desktop 3D printers, Samantha Hall, Ian Pengelly, James Staff, Neil Plant and Gareth Evans. <http://www.hse.gov.uk/research/rrhtm/rr1146.htm>
- 7.2. CLEAPSS Design and Technology: 3D Printing in Schools and Colleges: Managing the Risks. <https://dt.cleapss.org.uk/Resource-File/3D-printing-in-schools-and-colleges-managing-the-risks.pdf>
- 7.3. UoL's COSHH policy
- 7.4. UoL's COSHH Guidance
- 7.5. UoL's Risk Assessment Policy
- 7.6. UoL's Dangerous Substances and Explosive Atmospheres (DSEAR) Policy -
- 7.6. – DSEAR Guidance

7.7. UoL's LEV Policy

7.8. – LEV Guidance

7.9. UoL Chemical Storage

7.10. UoL's Weapons Policy