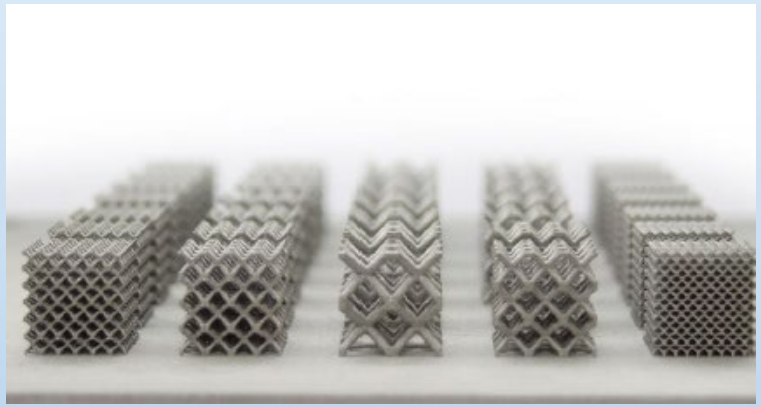
Additive Manufacturing: Types, Materials, and Processes



Additive Manufacturing Process

Definition: the process of joining materials to make objects from 3D models, usually layer upon layer, with a 3D printer. Subtractive manufacturing use techniques such as milling, cutting, or turning to create an object from a single piece of material.

Types of Materials:

Plastics: polylactic acid filament is the most commonly used material for 3D printing

Metals: brass, bronze, titanium alloy, stainless steel

Other: wood, carbon fiber, bio or organic material

Overview of Additive Manufacturing

Basic 3D Printing Flow

- YouTube: The Ultimate Beginner's Guide to 3D Printing

Types of Additive Manufacturing

- Fused Deposition (FDA)
- Resin Stereolithography (SLA)
- Selective Laser Melting (SLM)
- Electron Beam Melting (EBM)
- Electron Beam DED (EBAM)
- Binder Jet
- Laminated Object Manufacturing (LOM)

Slicing Software G-Code

Slicing software takes a CAD model and converts it into G-code.

- G-code is the programming language used to operate the machine. The code helps operate startup, shutdown, heat temperatures, build plate movement, and extruder head movement.
- Slicing software will allow users to set a variety of settings depending on the machine.
- Most slicing software will not show the G-code because of the sheer length of the program.

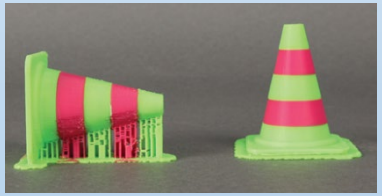
Considerations for Additive Manufacturing Parts

Wall thickness: total distance from the outside of the object to the infill structure.

Infill: percentage of the amount of material on the inside of the structure that supports the exterior faces of the object; (low infill = faster print times with low strength; high infill = longer print times; high strength; note: metal prints are 100% infill).

Orientation on build plate: rotational direction on *x*, *y*, *z* axis and impacts the following:

- Plate balance
- Support material
- Print time
- Print resolution



Scale:

- A quality resolution may be more difficult to achieve with smaller parts.
- Larger parts may not fit on the build plate and may need to be sectioned into smaller components; deformation also presents an issue because of variances in heating.

Layer Height:

- A lower layer height will result in better resolution, but longer print time.
- A higher layer height will result in lower resolution, but shorter print time.

Considerations for Additive Manufacturing

- Support and Support Structure:
  - Unsupported surfaces on the build plate will need a support structure. Different materials will have different specifications for the angle that needs to be supported based on the distance or angle of the overhang. For example, the object that is parallel with the build plate, but does not touch the build plate, will need to be supported.

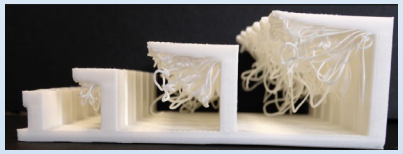


Image 1: Unsupported material

Image 2: Support material

Image 3: High density support material

  - Bridged surface: a surface that is supported from its endpoints be walls of the object.

Image 4: Bridge structure

  - Controllable support placement:
    - Typical most CAD slicing software generates support based on input values.
    - More advanced software allows the user to draw a defined support structured.

  - Types of support material
    - Plastic or metal: usually the same as the printed object; removing the support material using a subtractive manufacturing process must be done with care as to not damage the object.
    - Dissolvable support: these support materials allow the material to dissolve using a special solvent.

Additive Manufacturing with Plastic Fused Deposition Modeling (FDM)

Process:

- Extruder head has a gear inside that feeds the filament through a thermocouple.
- Within the thermocouple; plastic filament (typically rolled) is heated filament melting point, around 190-240°C depending on the machine and material.
- The filament is pushed into a extrusion nozzle.
- The extruder head traverses across the build platform on the x and y axis; the extruder head sits close build plate—about the width of a piece of printer paper—providing minimal friction, which helps spread the filament out onto the flat surface.
- For each layer of the part, the process is repeated.

Advantages:

- Quick print time
- Printer can output complex geometry
- Materials are inexpensive
- Fast print time

Disadvantages:

- Object strength
- Potential for warping or deformation

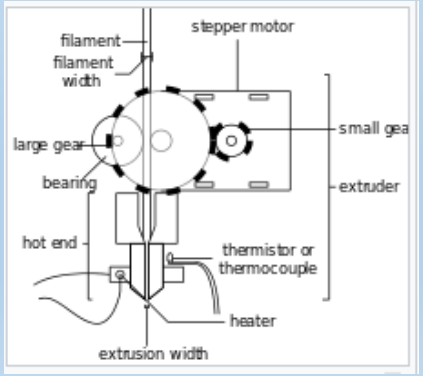


Image 1: Cutaway of extruder and motor

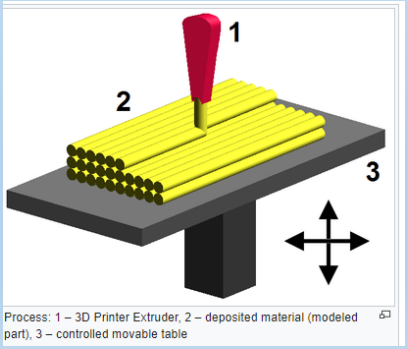


Image 2: Example of layering

Resin Printing (SLA)

Process:

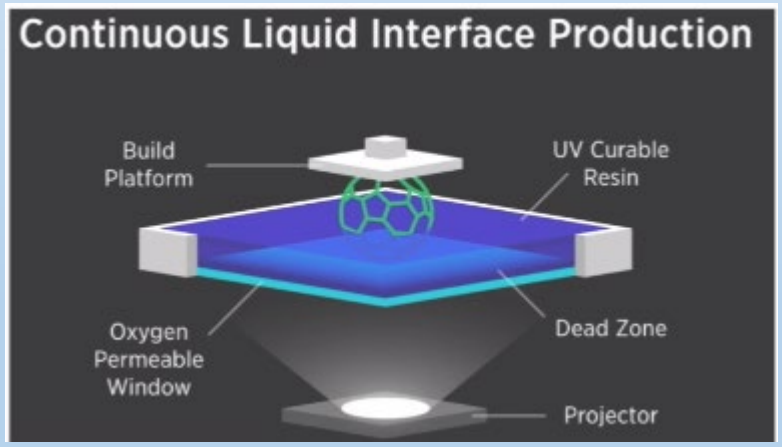
- Starts on a bed of UV curable resin
- Build plate sits on top of the resin bed
- A laser is used to cure resin based on the object's G-code
- Object prints upside down

Advantages:

- High print quality
- Smooth surfaces
- Small layer thickness

Disadvantages:

- Machine cost
- High cost of material
- Difficulty handling material



Additive Manufacturing : Electron Beam Melting (EBM)

Process:

- Material: a powder titanium-aluminum alloy.
- Material sits on build plate via a rake that moves left and right placing new material on the previous height after the build plate moves along the plate axes.
- A high powered laser heats the titanium-aluminum alloy to sinter (harden the material) to the previous layer.
- Once fully printed, the product is taken to a powder recovery system to remove excess material (sintered powder that is not part of the object) from the print.

Completed Print with Excess Powder Material attached to Object

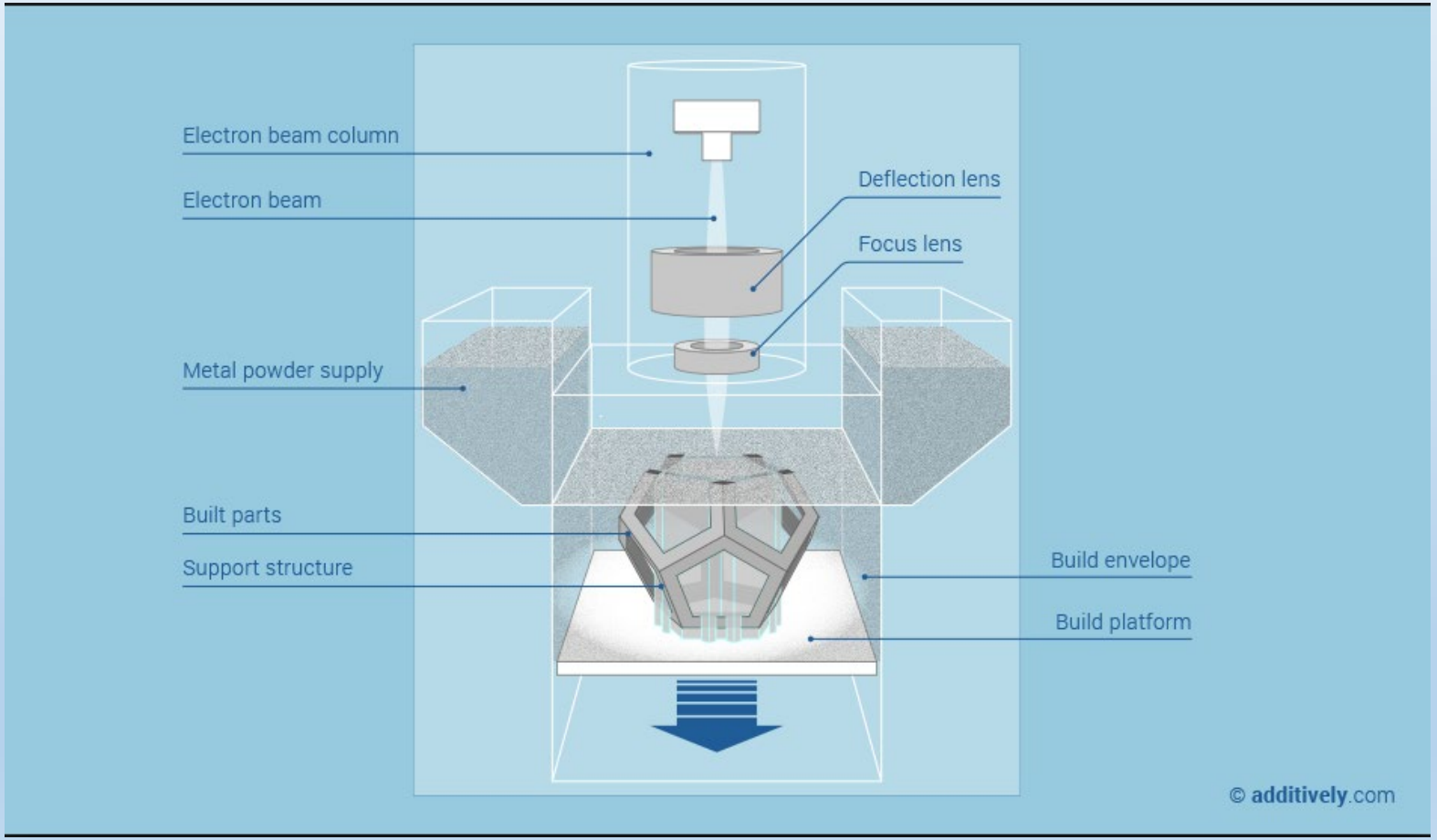
Advantages:

- Creates a solid structure with no infill
- Can create complex geometry structures
- Complete parts have properties similar to wrought parts
- Faster than other additive modeling that use metal material

Disadvantages:

- Purity of material
- Machine setup
- Secondary process needed to remove support structure and smooth final surface
- Raw materials have to be used delicately because of the small size of each granule
- Small print volume

Additive Manufacturing : Electron Beam Melting (EBM) Process Illustration



Additive Manufacturing : Electron Beam DED (EBAM)

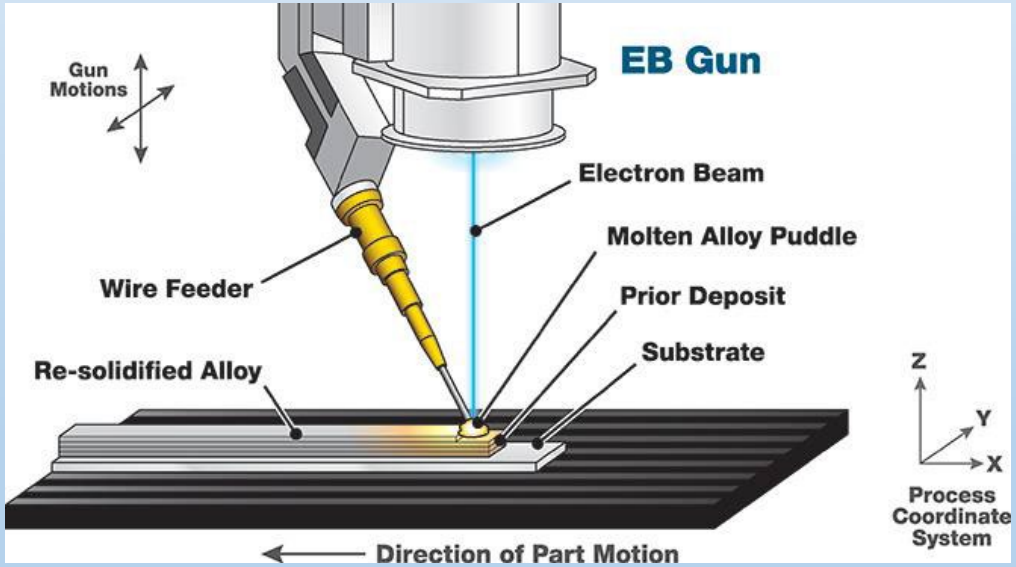
Process uses a laser and wire-fed metal material onto a build plate; similar to FDM. The process takes place inside a vacuum.

Advantages:

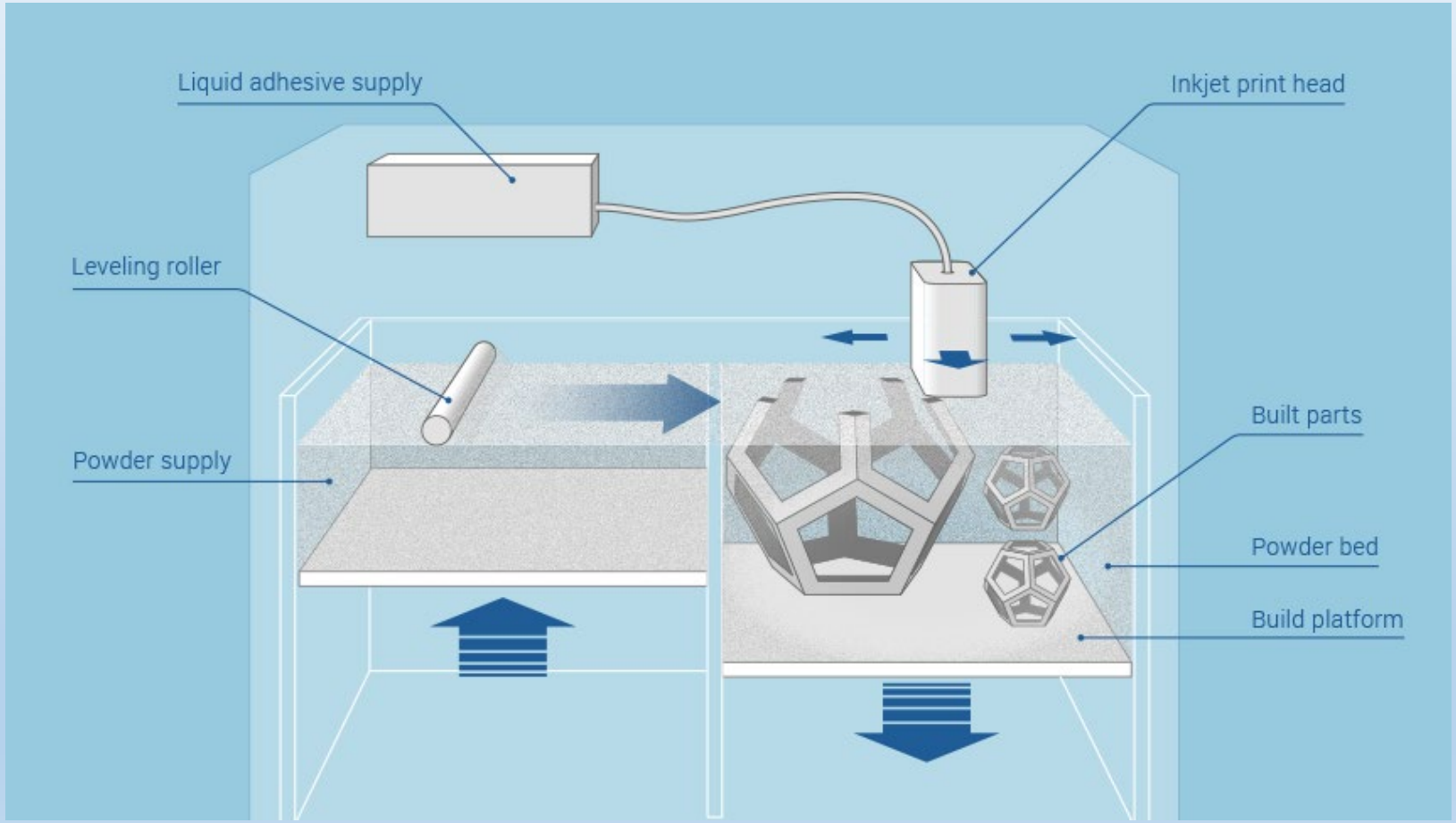
- Creates a solid structure with no infill
- Can create complex geometry structures
- Complete parts have properties similar to wrought parts
- Large print volume

Disadvantages:

- Purity of material
- Machine setup
- Secondary process to remove support structure and smooth final surface



Additive Manufacturing : Binder Jet Printing Process Illustration



Additive Manufacturing : Binder Jet Printing

Process:

- Similar to an inkjet printer.
- A layer of powder is placed over the build plate via a blade.
- A carriage places droplets of binding agent in specific locations that define the boundaries of the object; the binding agent bonds the powder particles together.
- After the final layer, the product is encapsulated by powder and the binding agent is left to cure.

Advantages:

- Fast print process
- Inexpensive material cost
- Variety of materials including metals

Disadvantages:

- Limited mechanical properties due to post processes that can burn off binding agent
- Limits mechanical properties without post secondary processes

Post-Process:

- Removal of excess powder via high powdered air.
- Metal parts will need to be sintered (heat-treated) to harden the structure.