

## **Metal Printing Process: A Rapid Manufacturing Process Based on Xerography using Metal Powders**

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### **Abstract**

A new method of rapid manufacturing called the Metal Printing Process (MPP) is under development at SINTEF in Norway. This method is using xerography to build objects using powders of metals and ceramics in a layered manner. Each layer is transferred from the photoreceptor onto a punch which is used to press the new layer onto the growing object in a die. The new layers are subsequently consolidated. To build object with a complex shape, a support powder must be used. This support powder must behave similar to the building powder during layer printing, but needs to behave differently (i.e. not sinter) when the part is sintered. By varying the composition of the layers in the z-direction, graded materials can be made.

### **Introduction**

There is an industrial trend towards production methods that reduce time consuming and costly machining operations. The purpose of the Metal Printing Process (MPP) research program is to develop a new and revolutionary production technology to meet this challenge. The MPP is a process that builds components ready for use directly from metal (and ceramic) powders using layer manufacturing principles. The MPP research program aims to develop, build and demonstrate a Metal Printing prototype machine with industrial functionality[1].

### **Metal Printing Process overview**

A potential solution for part-producing industry for on-demand, cost-effective manufacture, re-supply, or low volume production of functional objects is the emerging technology arena known as Rapid Manufacturing. Rapid Manufacturing technologies offer a significant reduction of time and cost to bring new products to the market. The SINTEF Metal Printing Process is aimed at developing the equivalent of a high-speed photocopier that produces three-dimensional objects from powder material. This technique is based upon the commercially proven technology of photocopiers that use photo-masking and electrostatic attraction. The MPP technique uses the same fundamental functions to build solid objects on a layer-by-layer basis[2,3].

**Data capture.** The digital part, a 3D CAD drawing, is represented by a series of individual layers, or slices, which are typically 0.1 millimeter in height. 3D CAD-data of the digital model is used to create slice information. The slice information is transferred to the MPP machine where the layers of powder are generated, deposited, and consolidated into a solid object.

**Layer fabrication.** The layer fabrication process is illustrated in Figs. 1 and 2. To generate the layers, the process uses the laws of electrostatic charge and fields. A photoreceptor is charged to a specified charge density using a scorotron. An electrostatic image of the part slice is created on the photoreceptor by light exposure, using a computer controlled LED printer head. The light exposure causes the photoreceptor to retain the electrostatic charge only for the image of the slice. After that the photoreceptor plate is aligned horizontally over the powder reservoir where the electrostatic force causes the powder to be attracted to the plate in the exact image of the part slice. The layer of powder is then deposited on the building table or directly into the die[4]. By using a second (or third) LED exposing station, a second (or third) powder can be attracted to the same photoreceptor. In this way, one powder layer with several powders can be made. This method, illustrated in Figs. 3 and 4, is similar to the method used in color photocopiers.

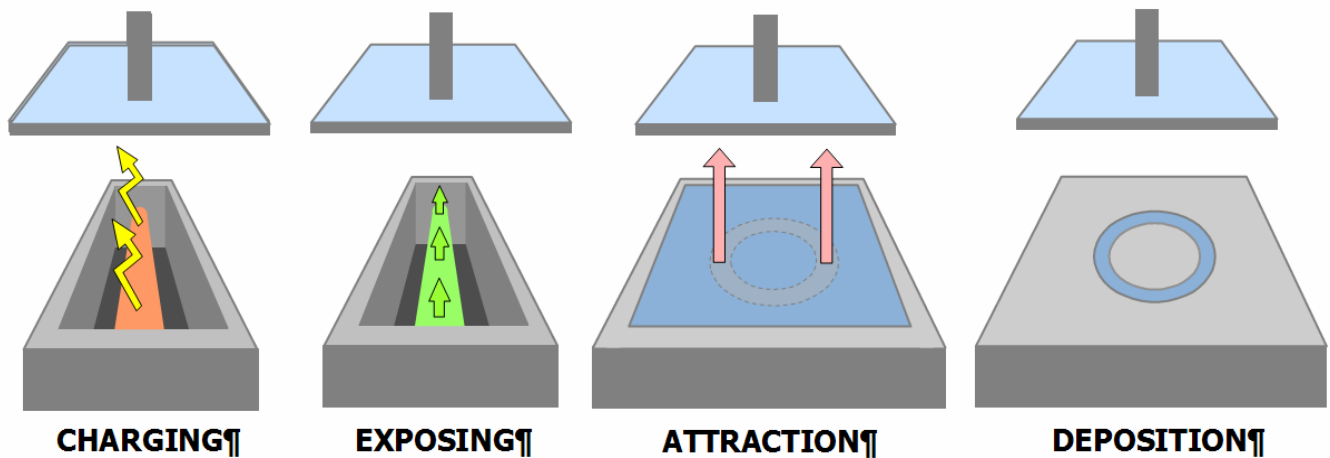


Figure 1. A schematic illustration of the process steps during layer fabrication.

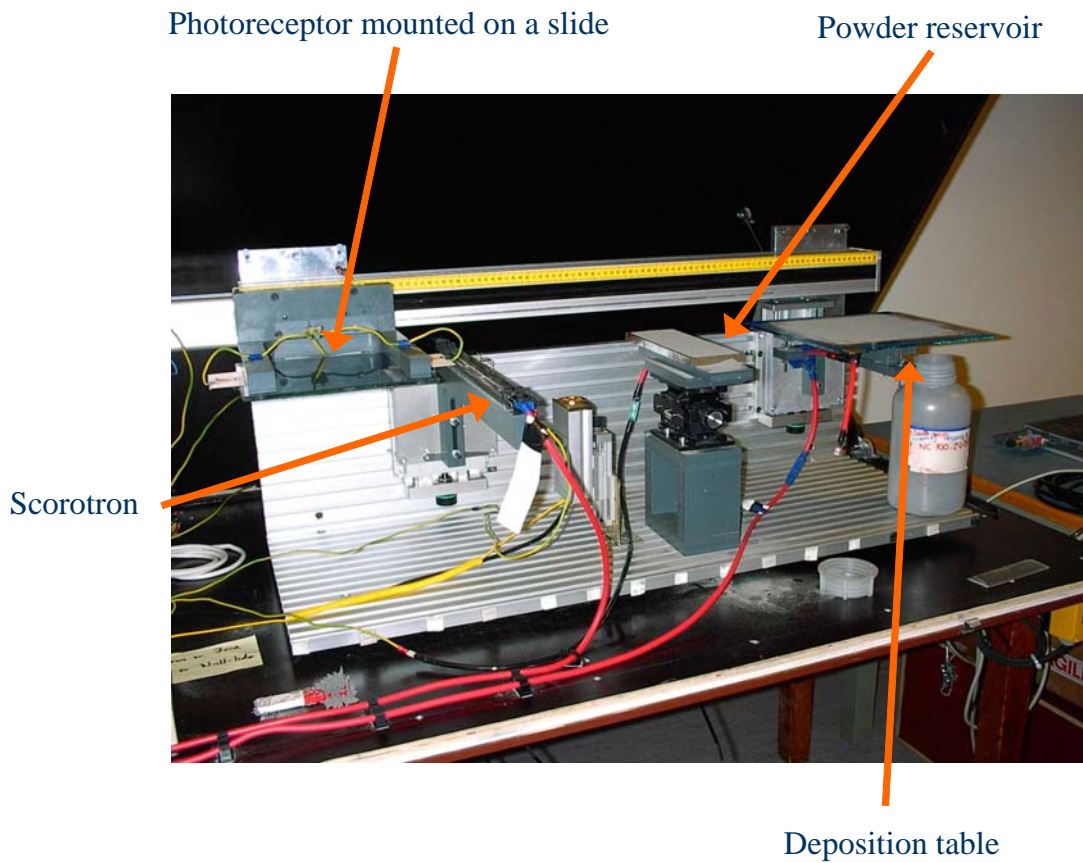


Figure 2. Laboratory set-up of the layer fabrication process sketched in Fig. 1 apart from the LED exposing station.

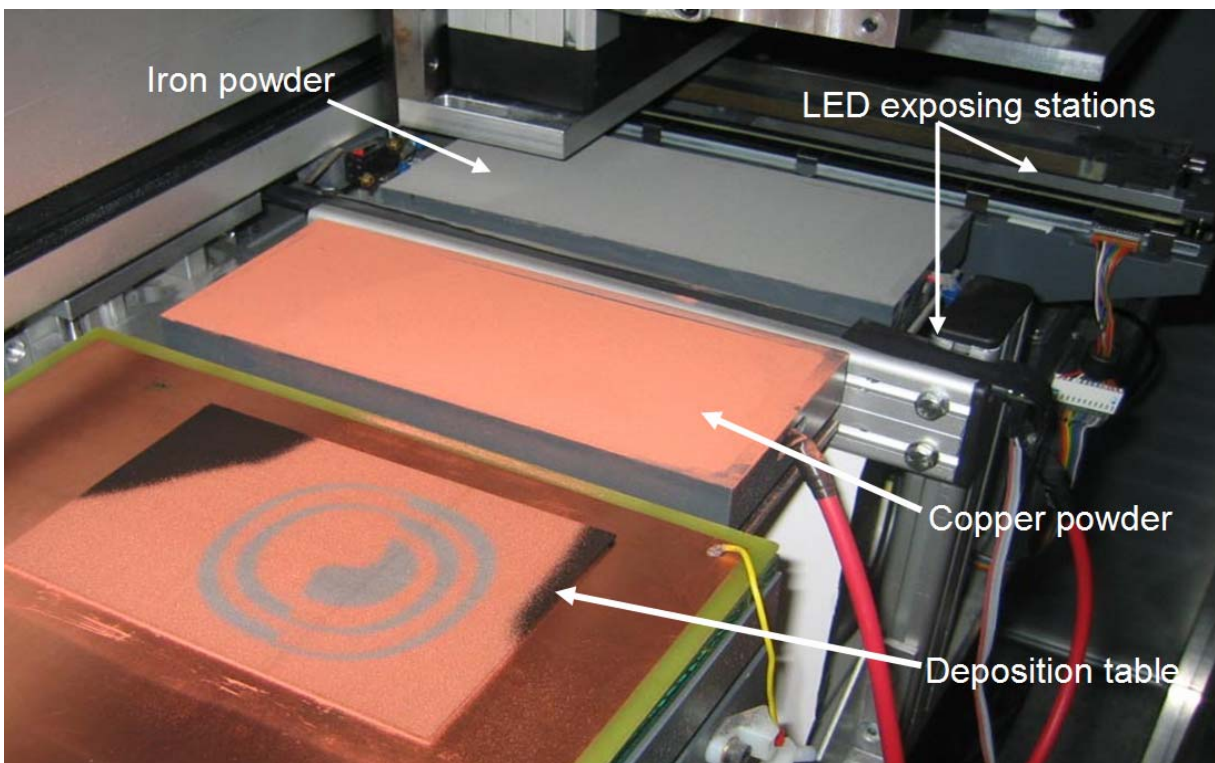


Figure 3. Layer fabrication of two different powders in the same layer.



Figure 4. A graphite sheet with copper and iron powder (dark) deposited on it.

**Consolidation** In the MPP, powder layers are created on the photoreceptor and then transported to the consolidation system. The photoreceptor is illuminated with a strong light source above the die such that it loses its charge and the powder is deposited. The loose powder layer is then cold compacted by a powerful press. This cycle is repeated until the product is finished. After the final layer is deposited, the compact is hot pressed at sintering temperature. The consolidation stage of the MPP is illustrated in Fig. 5. Several heating methods like induction and electric resistance heating have been investigated for the consolidation cycle. Each of these methods has their specific advantages and disadvantages depending on the specimen size, type of powder material and required sintering temperature[5-7].

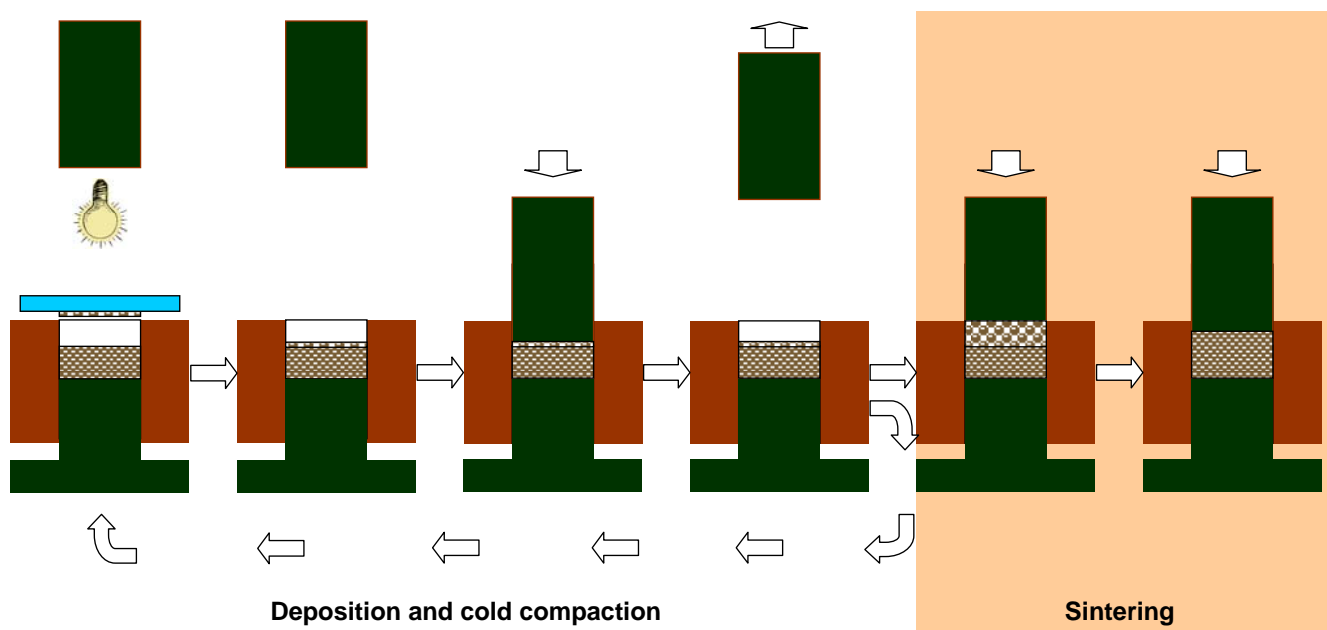


Figure 5. Schematic representation of the compaction cycle and subsequent sintering.

## Potentials of the process

**Shaped components.** As shown in Figs. 3 and 4, a powder layer can consist of two (or more) different powder materials. By choosing two powders with very different sintering temperatures, for example copper and alumina powder, and hot pressing them at a temperature where only the copper is sintered, one can produce a complex shaped component with overhangs and internal passages. The alumina powder functions in this case only as a medium to transfer the pressure and to support the shape of the component. This is illustrated in Fig. 6.

**Graded materials.** By changing the powder in the powder reservoir from layer to layer, graded materials can be produced. An example of such for a copper-iron graded material is shown in Figs. 7 to 9. In this case, pure iron powder is first inserted into the machine, after which it is exchanged by mixtures of iron and copper powder with gradually increasing weight fraction of copper until there is only pure copper powder used. This example demonstrates the possibility to produce functionally graded materials or mix elementary powders which react to intermetallic compounds during sintering via MPP.

**Controlled porosity.** By sintering after the deposition of a small number of layers, the porosity of the material can be locally controlled. This gives the possibility to produce filters or membranes which integrate various materials with different local porosity.

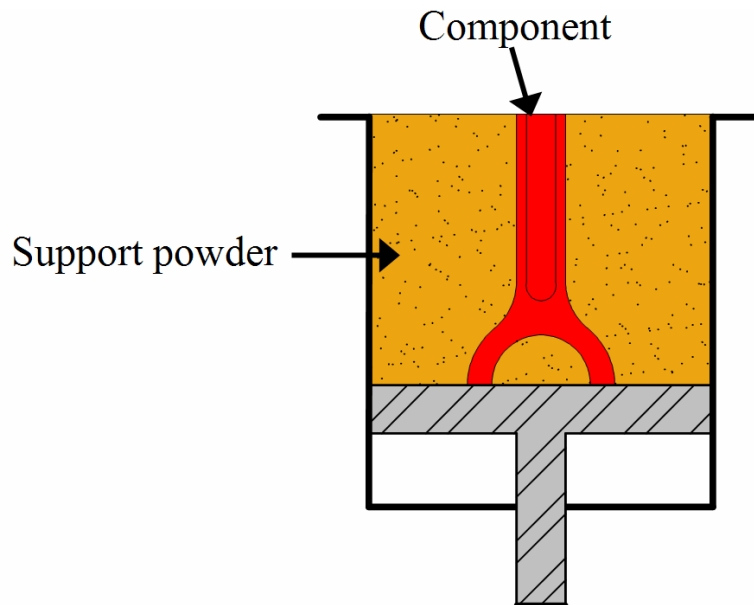


Figure 6. Method with which shaped components can be build using two different powders.



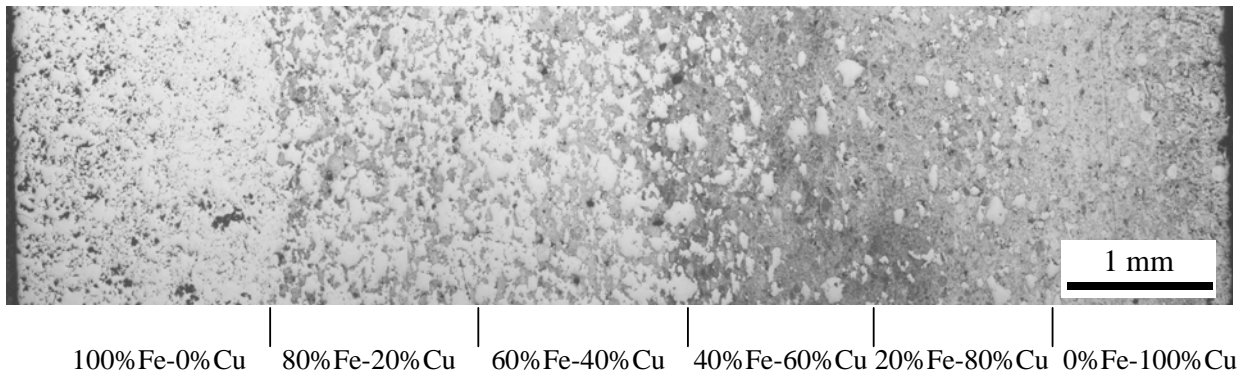


Figure 7. Sintered structure with a progressive change from iron to copper.

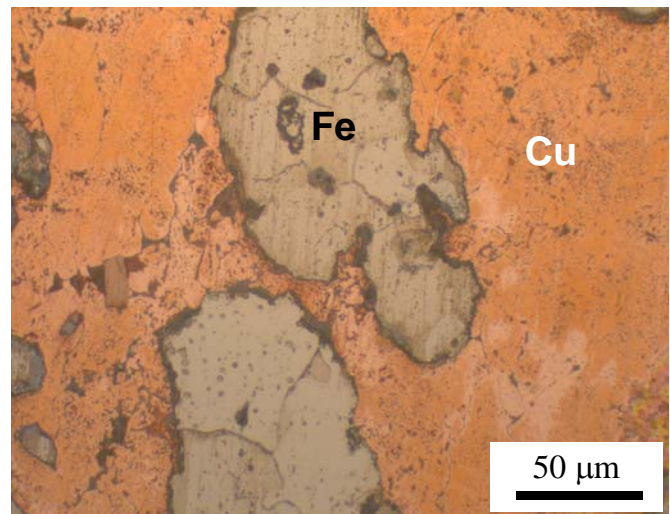
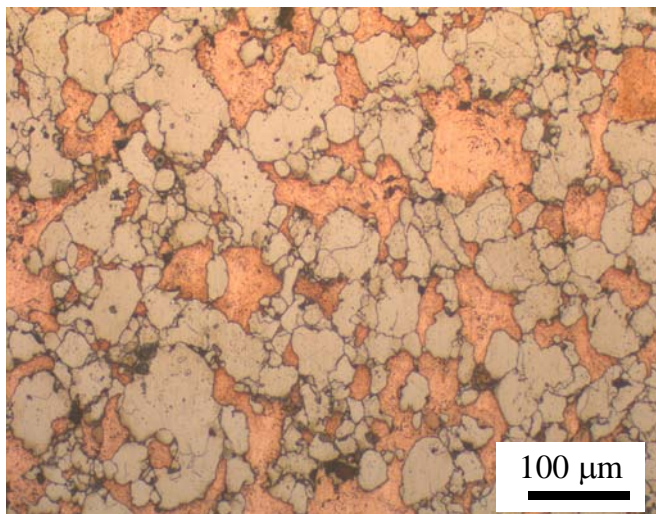


Figure 8. Distribution of Fe particles in Cu matrix.

Figure 9. Iron powder particles in copper matrix.

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