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Metal Printing Process
Development of a New Rapid Manufacturing Process for Metal Parts

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Abstract
The Metal Printing Process is a rapid manufacturing concept aimed at developing the equivalent of a high-speed photocopier that produces three-dimensional objects from powder material. In the Metal Printing Process each layer is deposited in a die where it is sintered by means of uniaxial hot pressing. The potentials of the process are the possibility 1) to produce components with extraordinary material combinations, 2) to produce complex shaped components, 3) to produce components with a controlled porosity, and 4) to produce full density prototypes in metal that can be tested in their actual application environment. The process is under development at SINTEF, Norway.

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].

Data capture

The digital part, a 3D CAD drawing, is represented by a series of individual layers, or slices, which are typically 0.1 millimetre 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[3].

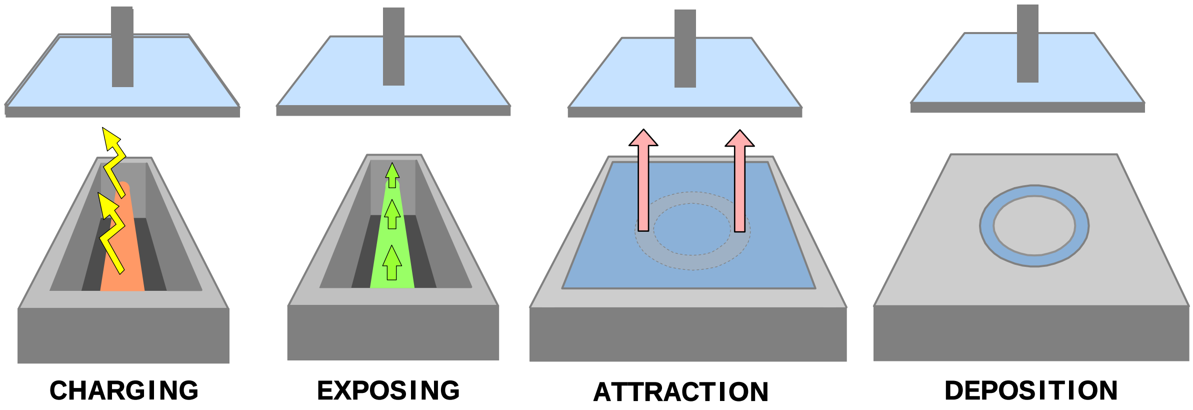

Figure 1. A schematic illustration of the process steps during layer fabrication.

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 colour photocopiers.

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 looses 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[4,5].

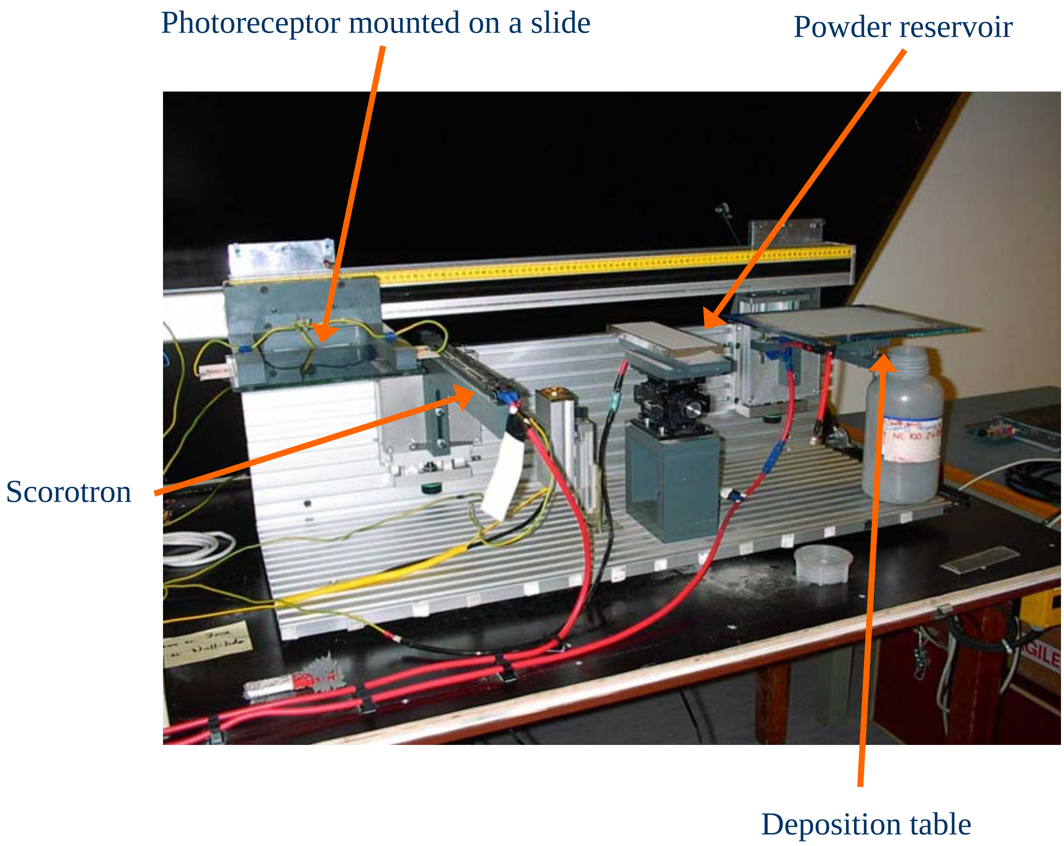

Figure 2. Laboratory set-up of the layer fabrication process sketched in Fig. 1 apart from the LED exposing station.

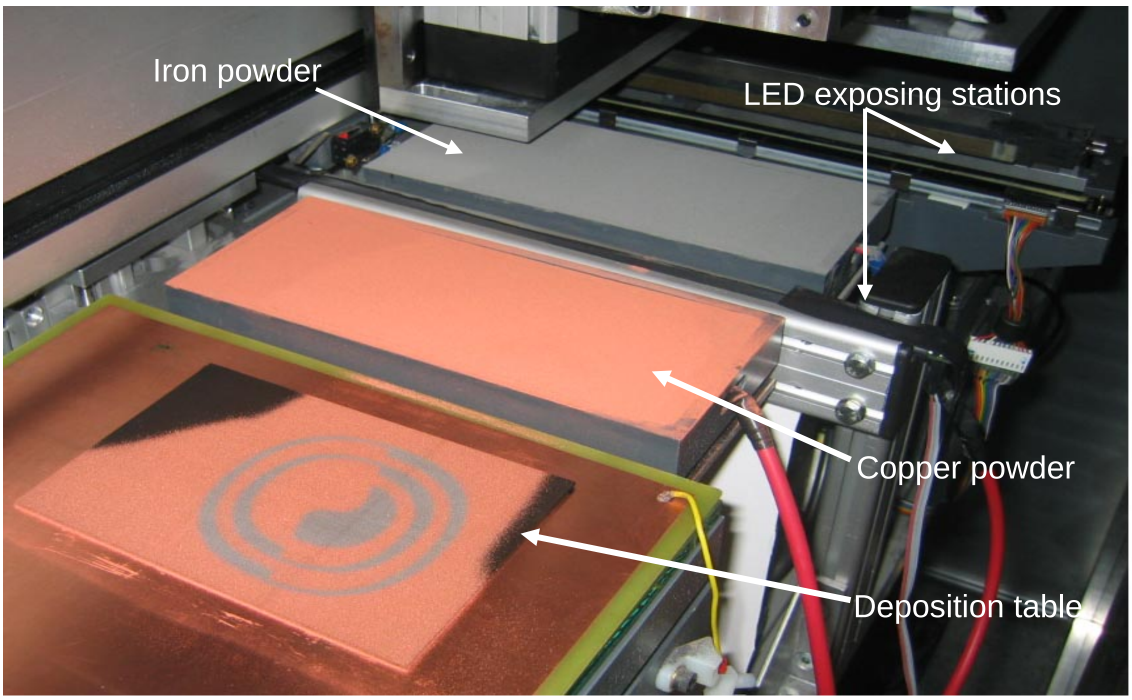

Figure 3. Layer fabrication of two different powders in the same layer.

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

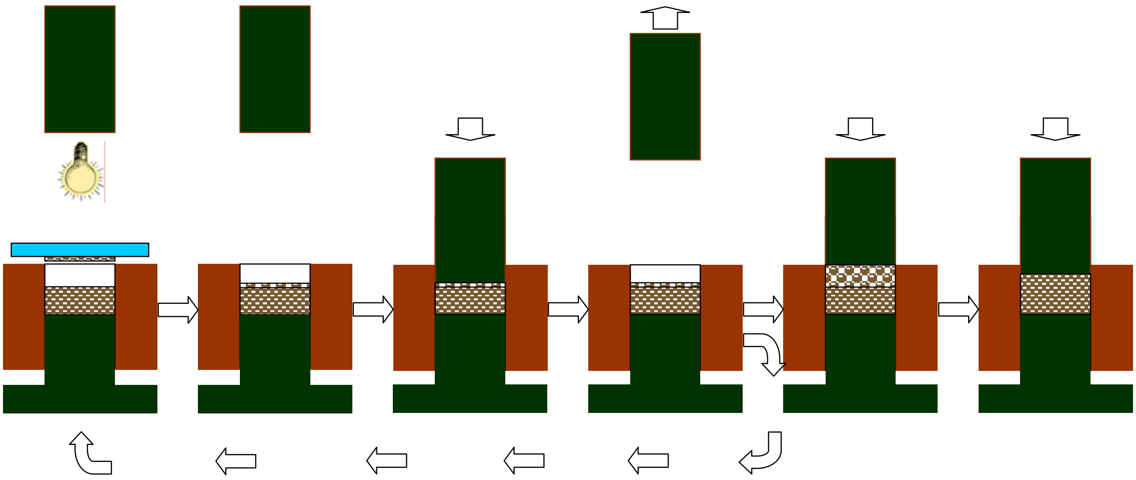

Figure 5. Schematic representation of the compaction cycle and subsequent sintering.

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 then 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.

Acknowledgements

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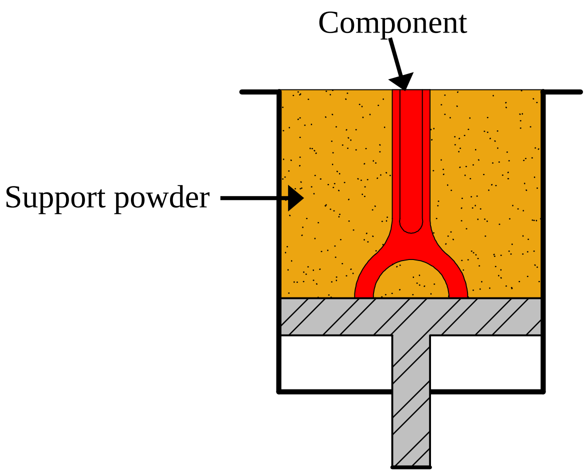

Figure 6. Method with which shaped components can be build using two different powders.

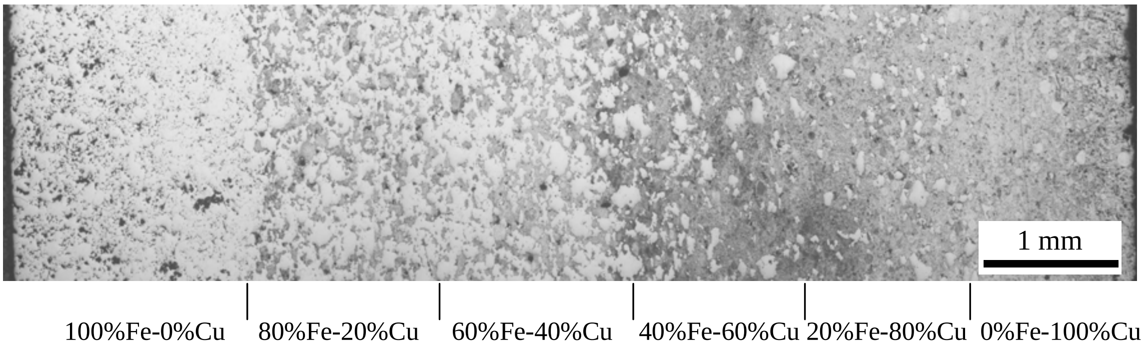

Figure 7. Sintered structure with a progressive change from iron to copper.

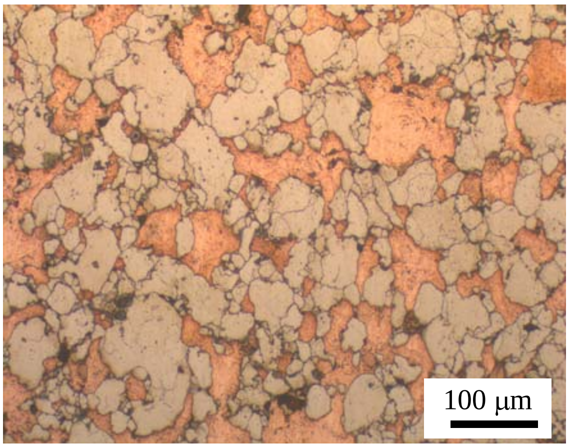

Figure 8. Distribution of Fe particles in Cu matrix.

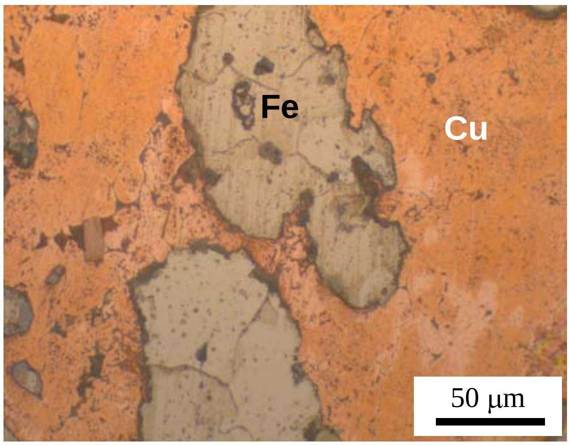

Figure 9. Iron powder particles in copper matrix.

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