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The rise of 3-D printing: The advantages of additive manufacturing over traditional manufacturing

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Abstract The use of additive manufacturing technologies in different industries has increased substantially during the past years. Henry Ford introduced the moving assembly line that enabled mass production of identical products in the 20th century. Currently, additive manufacturing enables and facilitates production of moderate to mass quantities of products that can be customized individually. Additive manufacturing technologies are opening new opportunities in terms of production paradigm and manufacturing possibilities. Manufacturing lead times will be reduced substantially, new designs will have shorter time to market, and customer demand will be met more quickly. This article identifies additive manufacturing implementation challenges, highlights its evolving technologies and trends and their impact on the world of tomorrow, discusses its advantages over traditional manufacturing, explores its impact on the supply chain, and investigates its transformative potential and impact on various industry segments.

1. An introduction to additive manufacturing

Three-dimensional printing (3-D printing), also known as additive manufacturing (AM) or rapid prototyping, has been around for decades. The first working 3-D printer was created in 1984 by Charles W. Hull of 3-D Systems Corp. He named the machine Sterolithgraphy Apparatus (Bogue, 2013). The technology was very expensive and not feasible for the general market in the early days. As we moved into the 21st century, however, costs drastically decreased, allowing 3-D printers to find their way into many industries.

The 3-D printer works in a very similar way to the standard inkjet printer, however, instead of printing layers of ink on paper, a 3-D printer uses materials to build a three-dimensional object (Berman, 2012). The term AM encompasses many technologies including subsets like 3-D printing, rapid prototyping

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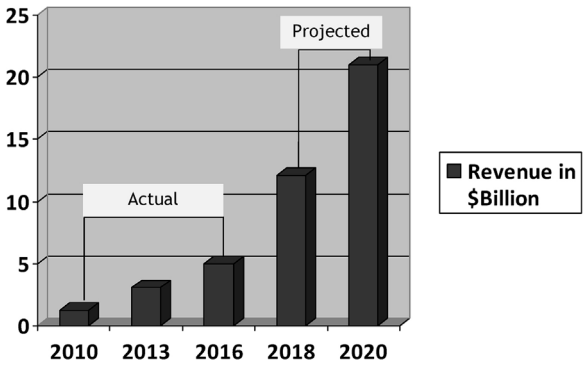
(RP), direct digital manufacturing (DDM), layered manufacturing, and additive fabrication.

Additive manufacturing—the industrial version of 3-D printing—is already used to make some niche items in many industries. The terms 3-D printing and additive manufacturing have become interchangeable. The term additive manufacturing refers to the technology—or additive process—of depositing successive thin layers of material upon each other, producing a final three-dimensional product. Each layer is approximately 0.001 to 0.1 inches in thickness (Wohlers Associates Inc., 2013). A wide variety of materials can be utilized, namely: plastics, resins, rubbers, ceramics, glass, concretes, and metals (Bogue, 2013). Rapid prototyping refers to the application of the technology. This was the first application for AM, which assisted in the increase of time-to-market and innovation. It can be referred to as the process of quickly creating a model/prototype of a part or finished good. This part or finished good will be further tested and scrutinized before mass production occurs. Most commercial 3-D printers have similar functionality. The printer uses a computer-aided design (CAD) to translate the design into a three-dimensional object. The design is then sliced into several two-dimensional plans, which instruct the 3-D printer where to deposit the layers of material.

In the past few years, many companies have embraced AM technologies and are beginning to enjoy real business benefits from the investment. The technology is maturing and has worked its way into a number of markets. It is now used in prototyping and distributed manufacturing, helping the next generation of users adopt AM. The technology is slowly reemerging as a valuable way to improve internal efficiencies. It is now one of the hottest and most interesting advancements in the design and marketing world today.

According to a 2014 report by Wohlers, the worldwide revenues from AM was $3.07 billion in 2013; the industry is expected to increase to $5 billion by 2016, $12.08 billion by 2018, and exceed $21 billion by 2020. These figures depict an AM market that is growing robustly. Drivers for the rapid growth are the reduction in cost to access the technology as well as an increase in applications (Wohlers Associates Inc., 2014) (See Figure 1).

Figure 1. Worldwide revenue from AM



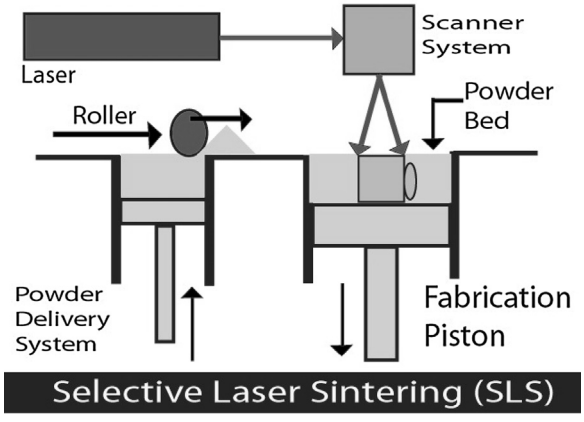
2. Evolving technologies and trends

2.1. Status of technologies

AM has existed for over 30 years, but only recently has this technology risen in popularity and captured the interest of both technology experts and the public. After 2009 when the last major patent for fused deposition modeling (FDM) expired, printers could be produced without infringing on intellectual property, which bred a newfound interest and investment in AM technologies (Van Lancker, 2015) (See Figure 2). The industry is still very young and technological advancements in AM, as well as the discovery of new applications of the technology, are still in development. It may be a number of years before AM truly revolutionizes manufacturing and other industries in a considerable way.

3-D printers all use additive manufacturing processes, but they use different technologies to build the layers that form the final object. Melting or softening material is used to produce the layers. The two most common 3-D printing technologies are selective laser sintering (SLS) and FDM. SLS utilizes a high-powered laser to fuse small particles of plastic, metal, ceramic, or glass powders into a mass that has the desired three-dimensional shape (see Figure 2). FDM employs thermoplastic materials injected through indexing nozzles onto a platform. Another method uses a UV laser or similar power source to cure a photo-reactive resin one

Figure 2. A diagram of the SLS build process



Source: Top Max Technology (2017)