CHAPTER 4

The Impact of Additive Manufacturing on the Supply Chain

High Tech

Research Support Service

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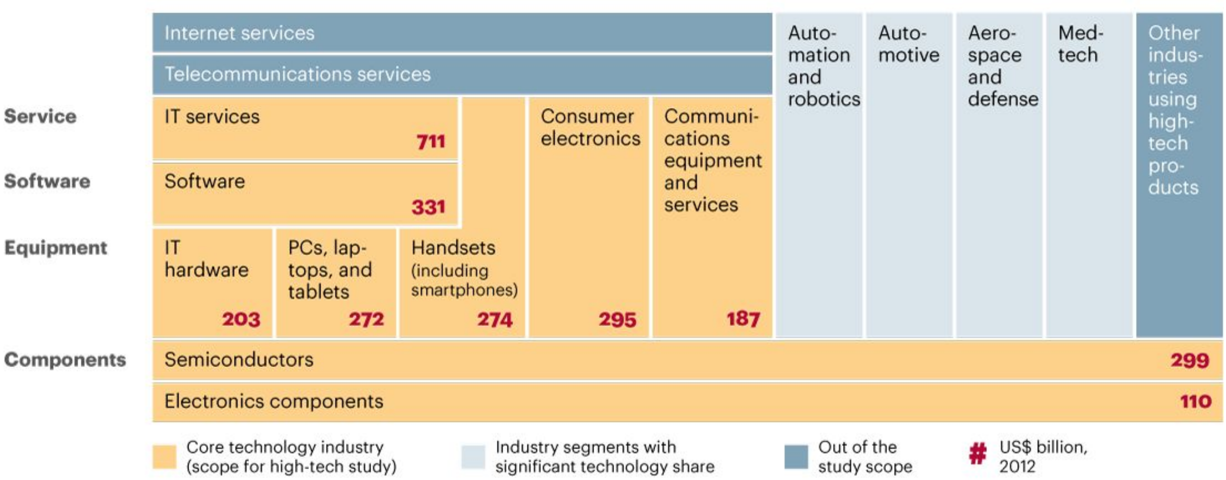
Executive Summary

This report is the fourth in our four-part series exploring how additive manufacturing and 3D printing are reshaping industries.

The High Tech industry focuses on a wide variety of products, services and components used in multiple industries (as seen in the figure below). This report focuses on hardware components and devices that can benefit from additive manufacturing - namely electronic circuits and components, as well as battery technology. Note that there are additional categories of products (e.g. optical components for telecommunications, packaging and casings for consumer electronics, etc.) coming out of the high tech sector that might benefit from AM, but these are not explored here.

Defining the global high-tech market



Notes: Telecom equipment and services includes OSS and BSS software solutions for telecommunications equipment.
Semiconductors excludes equipment and material.
Sources: Gartner, Reed Electronics Research, Marketline, Informa; A.T. Kearney analysis

Components of the global high-tech market. Source: Kearney.

References
https://www.africa.kearney.com/

Executive Summary

Additive manufacturing (AM) for high tech applications is beginning to emerge in the industry with the advent of higher resolution printing capabilities, the extension of AM to new materials and the need for better products coming from this highly competitive industry. Here, major advantages include the flexibility in manufacturing complex parts and the reduction in lead time caused by adoption of AM.

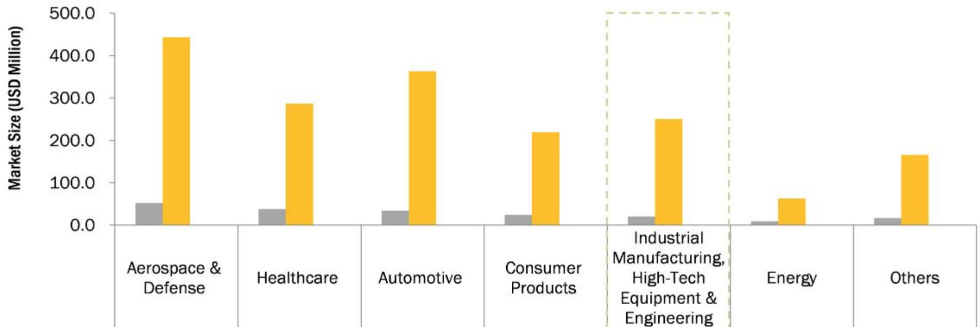
AM, or 3D printing, has found numerous uses in the high tech sector. Whether it is applied to electrical circuits, electronic components, batteries, or other high tech products - the benefits of AM in allowing for complex part formation, customization at scale and improved supply chain logistics paves the way for its increased use in the High Tech sector.

Many industries are undergoing digitalization, which requires novel electronic elements. 3D printing is now bringing possibilities never before imagined. 3D-printed electronics can contribute to all high-tech sectors and cause a revolution.

> Current disruptions to supply chains because of the COVID-19 pandemic will accelerate the adoption of Additive Manufacturing, as it will lessen the risk of disruption and is one of the few manufacturing methods that can be operated from a distance.
>
> *Dr. Sofiane Boukhalfa, Technical Director, PreScouter*

TECHNOLOGY-MARKET FIT

A 2018 report from Markets and Markets indicates that the high tech sector has one of the strongest growth rates in the automated AM market. Additional market data can be seen below for this sector. In this market, hardware manufacturing, multiprocessing and North America are respectively the product offering, process and region with the largest market share by 2024 according to this report. As such, the analysis that follows will focus on AM of hardware components used in the electronics sector, as well as on a complex electronic system (a battery) that can also be manufactured in this way.



	Aerospace & Defense	Healthcare	Automotive	Consumer Products	Industrial Manufacturing, High-Tech Equipment & Engineering	Energy	Others
2018	52.3	37.9	34.4	24.4	20.9	9.3	16.9
2023	443.8	286.9	363.1	219.6	251.0	62.8	165.9
CAGR (2018–2023)	53.40%	49.87%	60.19%	55.13%	64.35%	46.43%	57.85%

Automated 3D printing market for industrial manufacturing, high-tech equipment and engineering to grow at the highest CAGR during the forecast period. Source: ©2020 MarketsandMarkets Research Private Ltd. All rights reserved.

Offering	2015	2016	2017	2018	2019	2021	2023	CAGR (2018–2023)
Hardware	2.2	4.1	10.9	14.2	23.8	66.1	181.4	66.44%
Software	1.0	1.8	4.6	5.7	9.2	23.7	60.5	60.23%
Services	0.2	0.3	0.8	1.0	1.6	3.9	9.1	55.54%
Total	3.5	6.3	16.4	20.9	34.6	93.7	251.0	64.35%

Automated 3D printing market for industrial manufacturing, high-tech equipment and engineering, by offering, 2015-2023 (USD million). Source: ©2020 MarketsandMarkets Research Private Ltd. All rights reserved.

TECHNOLOGY-MARKET FIT

Process	2015	2016	2017	2018	2019	2021	2023	CAGR (2018–2023)
Material Handling	0.7	1.2	3.1	3.9	6.4	17.2	45.7	63.45%
Automated Production	0.2	0.4	1.0	1.3	2.2	6.3	17.6	67.68%
Part Handling	1.3	2.2	5.4	6.5	10.1	23.6	53.8	52.57%
Post-Processing	0.3	0.6	1.6	2.0	3.2	8.5	21.8	61.30%
Multiprocessing	0.9	1.9	5.2	7.2	12.6	38.2	112.2	73.24%
Total	3.5	6.3	16.4	20.9	34.6	93.7	251.0	64.35%

Automated 3d printing market for industrial manufacturing, high-tech equipment and engineering, by process, 2015-2023 (USD million). Source: ©2020 MarketsandMarkets Research Private Ltd. All rights reserved.

Region	2015	2016	2017	2018	2019	2021	2023	CAGR (2018–2023)
North America	1.7	3.1	7.8	9.7	15.7	40.5	102.9	60.32%
Europe	0.9	1.7	4.4	5.7	9.5	25.9	70.3	65.35%
APAC	0.7	1.3	3.4	4.6	7.8	22.8	65.3	70.19%
RoW	0.2	0.3	0.7	1.0	1.6	4.5	12.6	67.24%
Total	3.5	6.3	16.4	20.9	34.6	93.7	251.0	64.35%

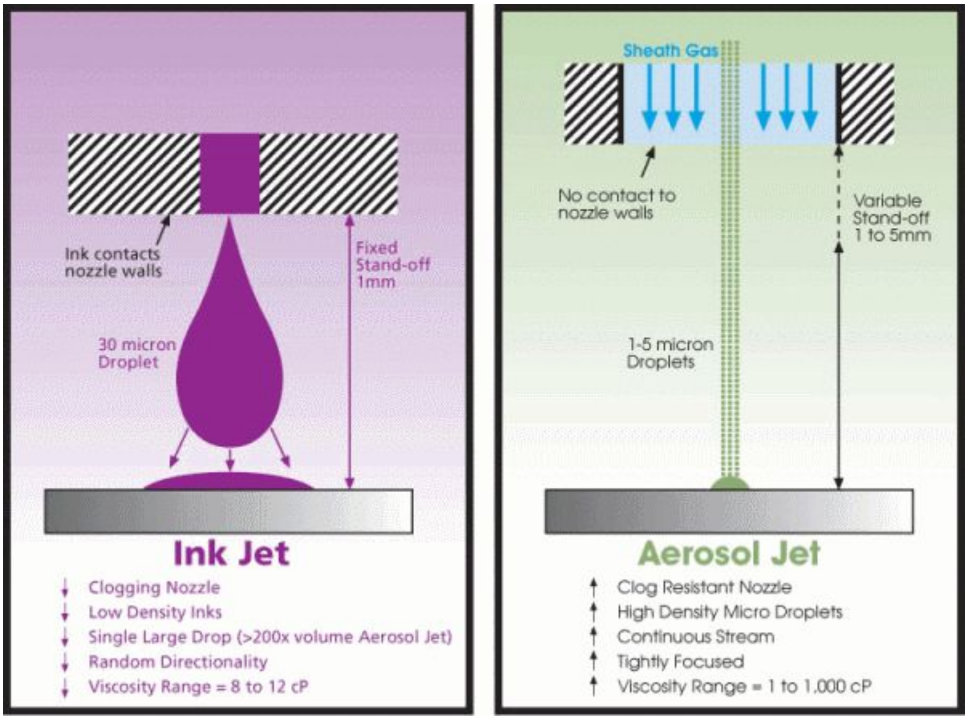
Automated 3d printing market for industrial manufacturing, high-tech equipment and engineering, by region, 2015-2023 (USD million). Source: ©2020 MarketsandMarkets Research Private Ltd. All rights reserved.

STATE OF THE ART TODAY

ELECTRONICS

ELECTRONICS
OVERVIEW

AM features solid object fabrication by depositing material onto their surfaces and many of its technologies can be used to print electronics. Electronics include many components, the most important of which are the circuits. Commercialized 3D-printing technologies for electronic circuits include aerosol jet and ink jet techniques (mechanisms shown below). The printers create conductive circuit patterns by spraying conductive ink onto a substrate. The printed circuit is not limited to a flat substrate, but to virtually all surfaces of any shape.



An illustration of the ink jet and aerosol jet working mechanisms. Source: Engineering.com.

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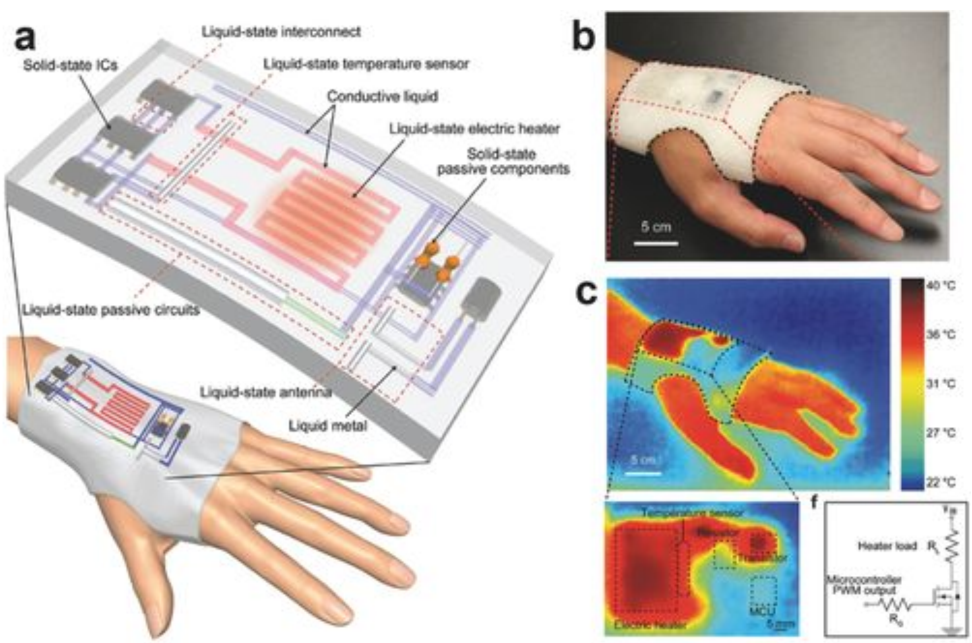
https://www.engineering.com/3DPrinting/3DPrintingArticles/ArticleID/7297/Optomec-Awarded-Patent-for-Electronics-Printing-Technique.aspx?e_src=relart

ELECTRONICS
OVERVIEW

Other than the circuits, electronics also consist of resistors, capacitors, structure support, frames, covers and other components. These components cover a wide variety of materials and properties. Common materials include plastics, metals and ceramics. These common materials can now be printed using 3D-printing technologies to manufacture the desired devices. Indeed, 3D-printing technologies for this purpose include fused deposition modeling (FDM) and selective laser melting. Different printing technologies for different materials are usually combined to print a complex electronic device. An example of a 3D printed glove is shown in the below figure. It consists of circuits, resistors, capacitors, etc.

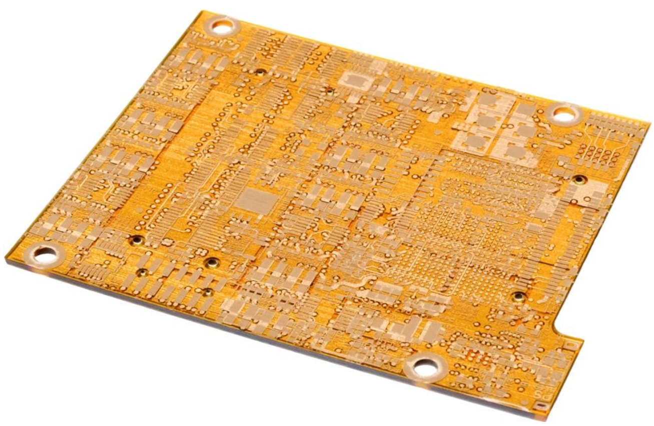


A 3D printing example: a flexible electronic glove with integrated circuits, sensors, and a plastic body. (a) structure illustration. (b) optical image. (c) thermal image during operation. Source: Ota et. al.

References
H. Ota, S. Emaminejad, Y. J. Gao, A. Zhao, E. Wu, S. Challa, K. Chen, H. M. Fahad, A. K. Jha, D. Kiriya, W. Gao, H. Shiraki, K. Morioka, A. R. Ferguson, K. E. Healy, R. W. Davis, A. Javey, Adv. Mater. Technol. 2016, 1, 1600013.

Examples of AM in multiplayer printed circuit boards (PCBs)

NanoDimension produces their DragonFly 3D-printing system for electronics. The system integrates the precise printing of various materials, allowing the printing of a complex design inside the system without any extra steps. The PCB is up to 200x200x3 mm. The trace limit is a maximum of 100μm in size and a minimum of 3μm in thickness. The system is used to produce commercial PCB prototypes. One representative product is a multilayer PCBs. 3D-printed PCBs have shown huge advantages in reducing lead time, delays and IP risks in the development phase of the electronics. Importantly, prototype PCBs can be printed in a small space and at a fast speed. Their system also enables high flexibility and an improved design process. Of note, these PCBs have been used on electromagnets, Arduino boards, molded interconnect devices, touch sensors, RF amplifiers, RFIDs, environmental sensors and embedded devices.

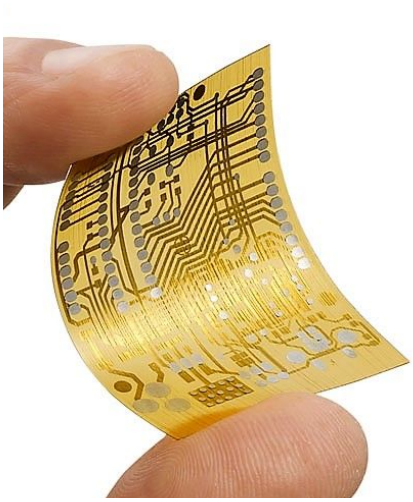


12-layer PCB printed by Nano Dimension. Source: Nano Dimensions.

References
https://www.nano-di.com/hubfs/Nano%20Dimension%2012%20Layered%20Printed%20PCB.jpg

Examples of AM in 3D flexible circuits

One major advantage of the 3D-printing system is that the printed object does not need to be planar. The circuit can thus be on a 3D structure on flexible, rigid or embedded substrates. One example, from Nano Dimension DragonFly Pro 3D-printing system, is shown below.



Flexible 3D printed PCB prototype produced by Nano Dimension's DragonFly Pro. Source: Nano Dimensions.

References
https://www.nano-di.com/image-gallery-of-3d-printing-on-the-dragonfly-pro

Examples of AM in antennas

Optomec has demonstrated their capability for mass production of 3D-printed antennas using their aerosol jet technology. The antennas are printed using conductive nanoparticle inks and polymer adhesives, whose formulation is also environmentally friendly. The antennas can be printed directly onto plastics, ceramics and metals. Moreover, the technology has shown increased flexibility, increased printing speed, simplified production, reduced cost, higher-volume capability and better reliability than traditional methods.

Photo of a 3D-printed antenna on a plastic frame. Source: Nano Dimensions.

References
https://www.optomec.com/wp-content/uploads/2014/04/AJ-Antenna-WEB0717.pdf
https://www.nano-di.com/hubfs/Nano%20Dimension%2012%20Layered%20Printed%20PCB.jpg

ELECTRONICS
KEY INSIGHTS

AM applications in the high-tech field is still at an early stage compared to other areas, but AM is widely researched and experimented with.

Research advances in 3D printed electronics

Antenna PCBs Sensors Activators Inductors Mechatronics integrated devices	Plastics Resins Metals Ceramics	Aerospace Automotive Consumer Electronics Healthcare Telecom Energy Education Research

Commercial products have appeared such as multilayer circuits, circuit-on-surface components and antennas. Conceptual products are promising, including flexible circuits, LEDs, solar cells, lamps and IoT devices.

Benefits include geometry flexibility, part customization, high material usage, less waste and a simpler production process.

Challenges include hardware capability, material specifications and multi-material processing.

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https://www.credenceresearch.com/report/3d-printed-electronics-market,
https://www.sculpteo.com/blog/2015/05/13/the-data-you-need-to-understand-the-3d-printing-world-and-build-a-3d-printing-strategy/
https://all3dp.com/2/3d-printed-electronics-5-most-advanced-companies/

LIMITATIONS AND FUTURE OUTLOOK

So far, 3D-printing technologies have shown great potential in printing electronics. Current commercial applications focus on printing prototypes, which has shown benefits that accelerate the research and development process.

Current limitations to 3D printing electronics include the material specifications and the printing size.

For example, 3D-printed electronic devices cannot currently be fully flexible, partially due to the materials. Also, current printed devices cannot be stretched and silicon-based hard chips cannot be bent, which limits the application of 3D printing in flexible devices.

The compatibility (e.g., adhesion) of multiple materials also creates challenges for embedded devices.

On the other hand, state-of-the-art electronic components have been developed at the nanometer scale, which is much smaller than current 3D-printing capabilities. To produce competitive electronic products, these aspects of 3D-printing technologies still need further development.

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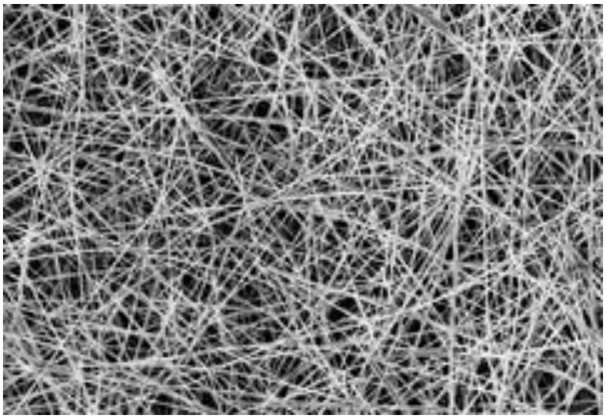
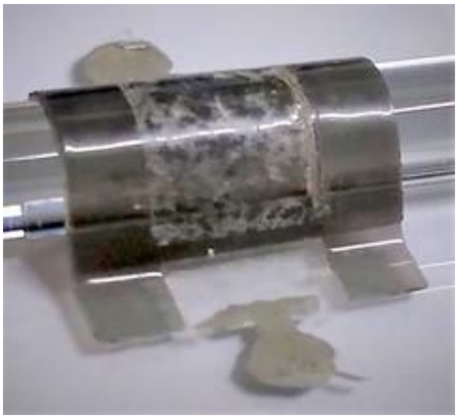
Yang, Hui, Wan Ru Leow, and Xiaodong Chen. "3D printing of flexible electronic devices." Small Methods 2.1 (2018): 1700259
Lu B H, Lan H B, Liu H Z. Additive manufacturing frontier: 3D printing electronics. Opto-Electronic Advances 1, 170004 (2018)

LIMITATIONS AND FUTURE OUTLOOK

Innovating more materials:

One solution to print more electronics is to innovate more materials. Researchers from the University of Hamburg and DESY have developed an AM process to produce transparent and mechanically flexible electronic circuits. They created silver nanowires of 10 to 20µm, which can be printed in suspension and embedded into plastics. The method can specifically increase the transparency and the conductivity of the material. As such, the process adds more possibilities to 3D printing. The figure below shows a flexible transparent capacitor as a demonstration.





Silver nanowires (left) and a flexible transparent capacitor made from them (right). Source: Desy.

References
https://www.desy.de/news/news_search/index_eng.html?openDirectAnchor=1623&two_columns=1&preview=preview

ELECTRONICS
LIMITATIONS AND FUTURE OUTLOOK

Increasing flexibility of printed electronics:

Increasing the flexibility of printed electronics is important for applications such as wearable devices and soft robots. Researchers from **Harvard University** reported a new 3D-printing method to produce flexible electronics. They demonstrated the method by printing a strain sensor within highly conformal and extensible elastomeric matrices. In the process, the elastomeric matrix is first placed at the bottom of the reservoir and a filler fluid is added at the top to fill the gap caused by nozzle movement. The conductive ink is then injected into the reservoir from the nozzle, forming the circuit structure with the nozzle movement. Finally, the reservoir and the ink are cured to form the product. This method enables printing soft sensors and thus opens possibilities for flexible devices.

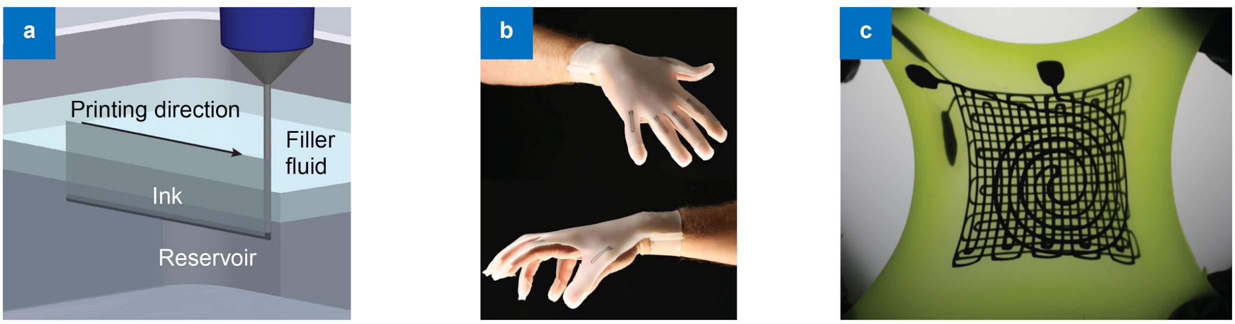


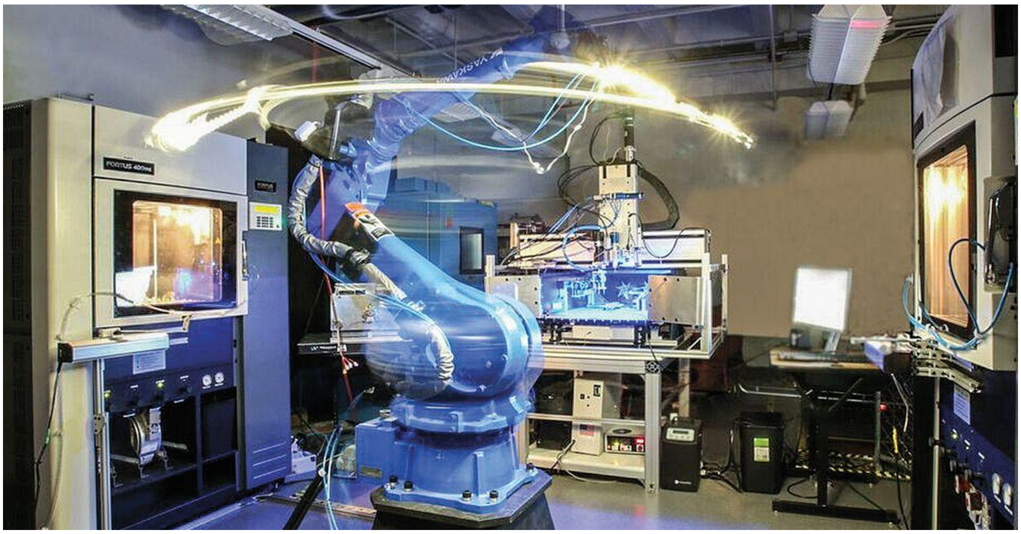
Illustration of the embedded 3D printing. (a) illustration of the printing process. (b) flexibility of the sensor on gloves. (c) sensor in a stretched state. Source: Muth et al.

References
Muth J T, Vogt D M, Truby R L, Mengüç Y, Kolesky D B et al. Embedded 3D printing of strain sensors within highly stretchable elastomers. Adv Mater 26, 6307-6312 (2014) DOI:10.1002/adma.201400334

LIMITATIONS AND FUTURE OUTLOOK

Printing embedded electronics:

Printing embedded electronic devices is an important avenue for many researchers. Indeed, researchers at the **University of Texas at El Paso** were able to embed a copper wire capacitive sensor into a 3D-printed polycarbonate structure. The sensor was made of copper wire meshes. Each wire was only 320μm. This work provides a proof of concept for advanced, fully encapsulated 3D-printable devices. It also verified the utility of fully embedded bulk conductors and interconnects.



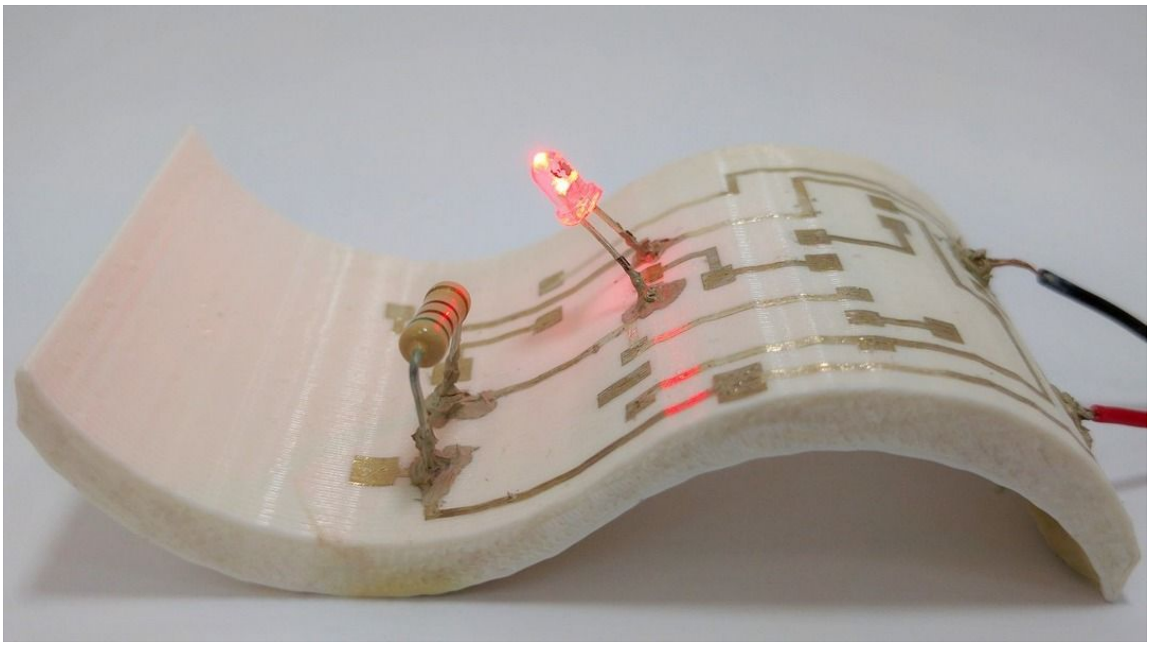
A long-exposure photo of the Multi3D Manufacturing system for multiprocess 3D printing. Source: Shemeyla et al.

References
Shemelya C, Cedillos F, Aguilera E, Espalin D, Muse D et al. Encapsulated copper wire and copper mesh capacitive sensing for 3D printing applications. IEEE Sens J 15, 1280-1286 (2015) DOI:10.1109/JSEN.2014.2356973

LIMITATIONS AND FUTURE OUTLOOK

Limitations when printing on non-flat surfaces:

3D printing using a nozzle has limitations when printing on non-flat surfaces, as the nozzle needs to face the surface. To address this challenge, researchers from the **Hebrew University of Jerusalem** in Israel and the **Nanyang Technological University** in Singapore have created a new process called hydroprinting to print a circuit pattern on a 3D surface during 3D printing. The circuit is printed first on water-soluble polyvinyl alcohol films and then sintered onto the 3D surface by exposing it to hydrochloric acid fumes. The process can be done multiple times to generate layer-by-layer patterns. The method is expected to benefit emerging 3D-printed electronics, including 3D-printed antennas for communications, biomedical devices and soft robotics.



A flexible circuit by hydroprinting method. Source: Advanced Science News.

References
https://www.advancedsciencenews.com/wp-content/uploads/2017/04/admt.201600289-Hydro-Printing-Conductive-Patterns-on-to-Three-Dimensional-Structures.jpg

Biological applications:

3D-printed electronics possess potential in many areas. A research group at the University of Minnesota is exploring the possibilities of 3D-printed electronics in biological applications. They have improved the 3D printers for use with more biological materials, such as cells and proteins, and interweaved them with electronics. Such combinations may bring novel biomedical devices, therapies, smart bioelectronics and human-machine interfaces.

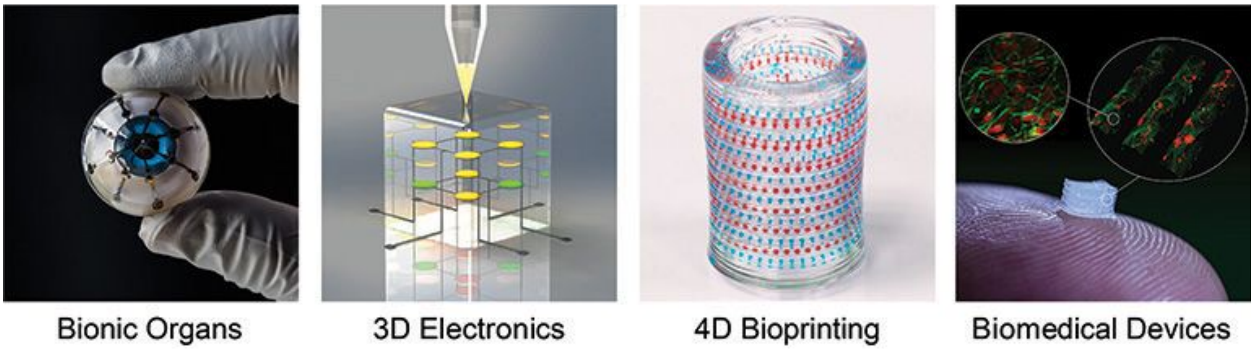


Illustration of embedded bioelectronics. Source: McAlpine Research Group.

References
https://sites.google.com/view/mcalpineresearchgroup

STATE OF THE ART TODAY

BATTERIES

BATTERIES OVERVIEW

Batteries differ in type and structure. Generally, a battery, whose output depends on a chemical reaction within, has three parts: an anode, a cathode and an electrolyte. To maximize the life as well as the safety of a battery, the internal structure is also optimized for each battery type.

Comparing to the traditional manufacturing methods, 3D printing can add benefits to a battery by enabling:

- highly customized configuration
- optimized micro and macro electrode and battery structures
- better integration with less assembly and packing and much better performance.

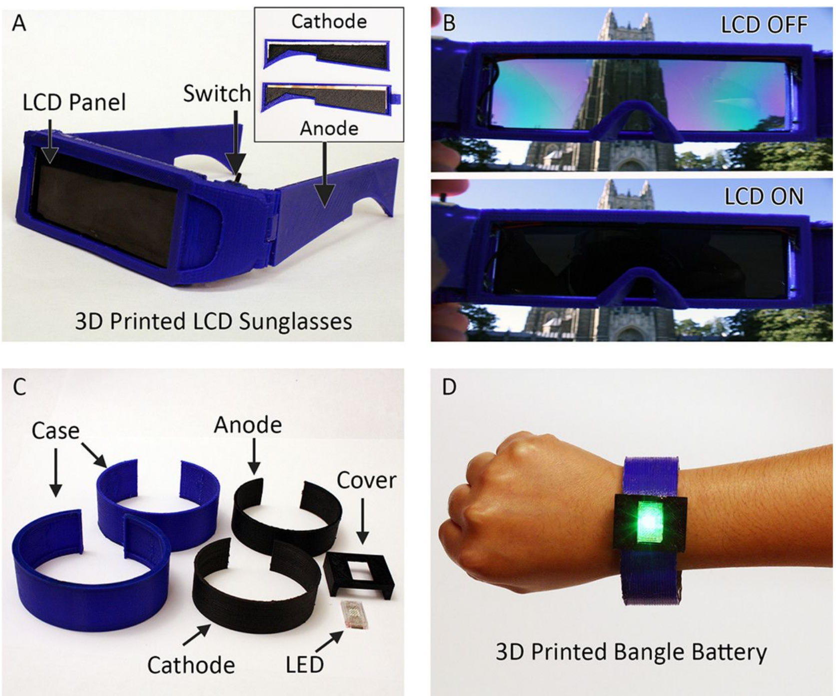
Due to the 3D-printing cost and application, most development efforts are focusing on printing **lithium-ion batteries, fuel cells and solar cells**. There have not been any commercial applications yet, but their development has shown great potential for printing these batteries.

3D printing has been shown to greatly improve the performance of one or more components.

Most current lithium-ion batteries on the market are rectangular or cylindrical. The shape limits the total volume and the application of the battery, and it is partially determined by the conventional manufacturing process. However, this is no longer a limitation if the battery is 3D-printed.

References
https://onlinelibrary.wiley.com/doi/full/10.1002/aenm.201700127

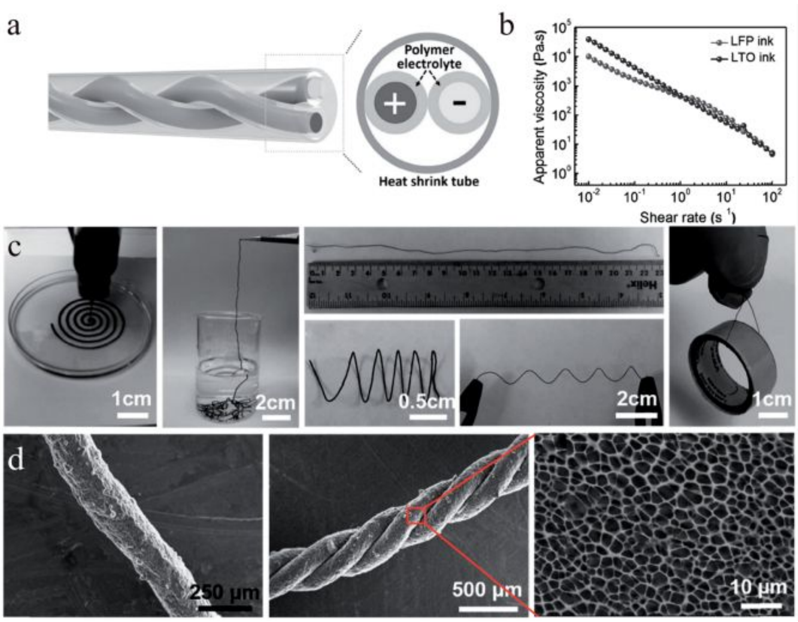
Researchers at Duke University printed a lithium battery completely using 3D printing. The electrolyte was made from poly(lactic acid), ethyl methyl carbonate, propylene carbonate and $LiClO_4$, and its performance was comparable to other polymer and hybrid electrolytes. The anode and the cathode performance were also optimized by adding lithium titanate, graphene nanoplatelets, lithium manganese oxide and carbon nanotubes. The researchers also demonstrated the potential of their irregularly shaped battery by integrating it into the frame of a pair of 3D-printed LCD sunglasses and a wearable bangle LED.



(a) Battery powered darkening LCD sunglasses (b) Illustration of the sunglasses (c) Components of the 3D-printed bangle LED (d) Illustration of the bangle LED. Source: Reyes et al.

References
Reyes, C.; Somogyi, R.; Niu, S.; Cruz, M.A.; Yang, F.; Catenacci, M.J.; Rhodes, C.P.; Wiley, B.J. Three-Dimensional Printing of a Complete Lithium Ion Battery with Fused Filament Fabrication. ACS Appl. Energy Mater. 2018, 1, 5268–5279.

As mentioned previously, 3D printing not only allows for the irregular shape of a battery, but also flexibility. Researchers from Beihang University reported a successful application of 3D printing to produce an all-fiber lithium-ion battery. The battery showed good mechanical strength, good flexibility and excellent electrochemical performance. The figure below shows that the spring-shaped fibers of 200μm in diameter was capable of lifting a heavy ring. The fibers were further twisted into a yarn to produce an all-fiber battery. The battery was shown to have a high energy density (111 mAh/g at 50 mA/g). This work shows great benefits for combining all-fiber flexible design and 3D-printing technology.

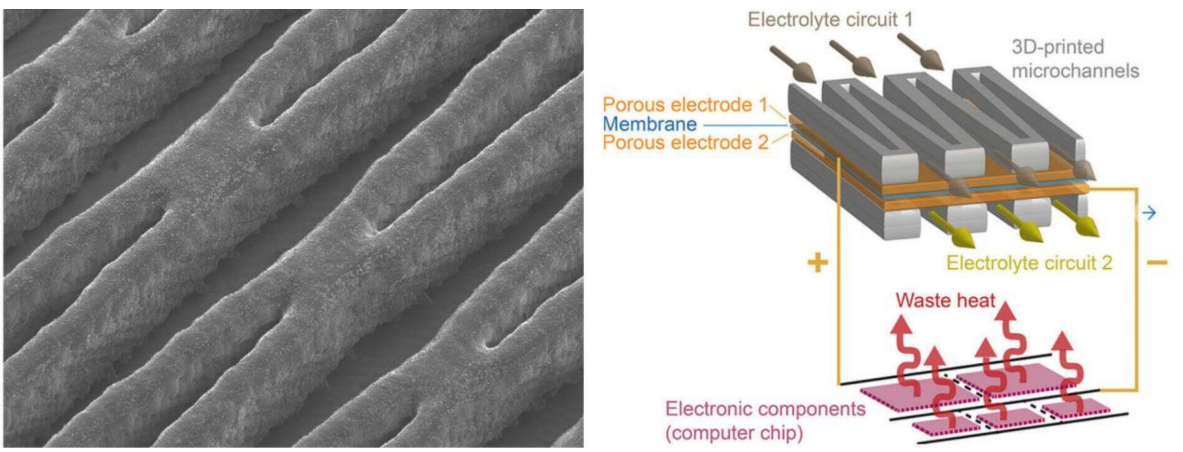


(a) Design of the 3D-printed all-fiber flexible lithium-ion battery. (b) Rheological properties of the ink. (c) Optical image of the fibers. (d) SEM image of the fibers. Source: Wang et al.

References
Y. Wang, C. Chen, H. Xie, T. Gao, Y. Yao, G. Pastel, X. Han, Y. Li, J. Zhao, K. K. Fu and L. Hu, Adv. Funct. Mater., 2017, 27, 1703140.

ETH zürich
IBM

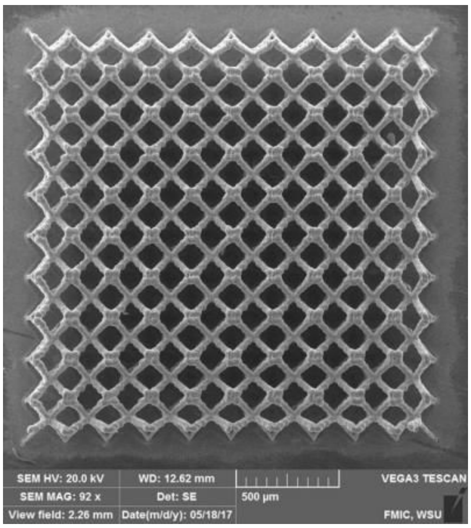
3D printing enables more battery structure designs and functionalities. Researchers at IBM and ETH Zurich printed redox flow batteries with micro channels to allow thermal management within the system. The micro channels guided the fluidic networks through the porous electrode at a high efficiency and helped to balance the flow pressure drop to maximize the battery power density. With the help of these channels, the electrolyte flow powers and cools the electronic components at the same time. This work showed a methodology for optimizing the mass transfer within the system by rational design and 3D printing.



SEM image of the micro channels and illustration of the printed battery concept. Source: All3DP.

References
https://all3dp.com/eth-zurich-ibm/

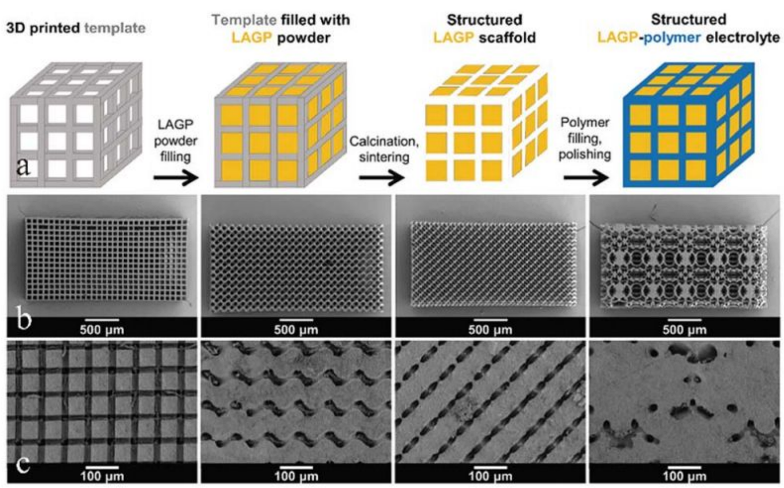
The electrode structure plays an important role in the battery performance, as it forms the basis of the battery reaction on a micro or nanometer scale. Researchers from Carnegie Mellon University and the Missouri University of Science and Technology have reported new 3D-printed battery electrodes that could represent a 4-fold increase in the battery charge capacities and enhance charge rates. The new, complex porous structure increased the usage of the electrode from 30%-50% to almost 100% and thus greatly increased the performance. Such improvement could not be possible without the help of 3D printing. This battery is also the first example of electrodes produced by depositing tiny droplets into a lattice structure.



SEM image of the printed electrode porous microstructure. Source: 3D Printing Media.

References
https://www.3dprintingmedia.network/3d-printed-lithium-ion-batteries/

One battery research frontier is the solid-state electrolyte battery, due to its safety, stability, energy density and charge rate. However, traditional manufacturing methods typically cannot optimize electrical performance and mechanical properties simultaneously. 3D printing, on the other hand, could address these issues. Researchers from the University of Oxford and the University of Edinburgh reported an example of 3D-structured hybrid electrolytes with the help of 3D printing. The first step was to print the template using stereolithography 3D-printing technology. Then LAGP (a type of ceramic electrolyte) powder was used to fill the template. LAGP was then calcined and sintered to create a negative replication. Epoxy polymer was added to fill the empty channels and produce the final product. The bicontinuous ceramic-polymer structure showed an improvement in mechanical strength due to the LAGP pellets, without any reduction of the ceramic ion conductivity.



(a) Printing procedure for hybrid electrolytes. (b) SEM image of the electrolyte templates. (c) SEM image of the LAGP scaffolds with different architectures. Source: Zekoll et al.

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https://pubs.rsc.org/en/content/articlelanding/2019/ta/c8ta11860d#!divAbstract
https://pubs.rsc.org/en/content/articlelanding/2018/ee/c7ee02723k#!divAbstract

AM IN HIGH TECH
IMPACT ON SUPPLY CHAIN

Traditional manufacturing relies on large-batch production, and so does the supply chain. The major drawbacks of the current supply chains include the **waste**, the **risks** and the relatively **slow response**.

Waste is generated during the traditional manufacturing process, where not all raw materials can be used.

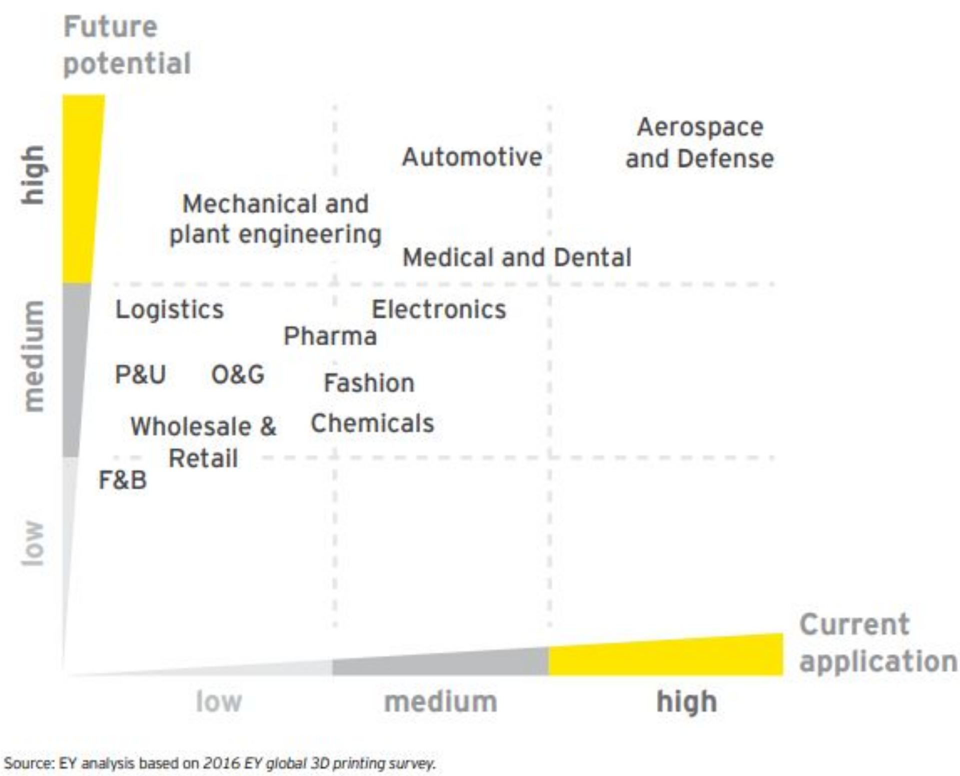
As most current electronics are manufactured in East Asia but sold in North America and Europe, associated **risks** include geopolitics, long lead times, quality control and rising labor costs.

The **slow response time** is associated with large-volume productions, where the tools and even the entire production lines were built for one specific product and it is very expensive to make adjustments.

3D printing can address many of the issues of the traditional manufacturing process. Ernst & Young in 2016 sent out a survey regarding the current application and the future potential of 3D printing in different industries. The electronics sector was found to have both many current applications as well as great potential for 3D printing.

IMPACT ON SUPPLY CHAIN

The electronics industry has adopted 3D printing for a long period of time. The latest developments have focused on the improvement of printing scales, materials and the integrity of printed objects and this has increased the potential for printing various electronic components including circuits, sensors, batteries and antennas. In the future, 3D printing can affect the electronics supply chain in many more aspects, including **product design, prototyping, materials, suppliers, manufacturing, inventory control, distribution and aftermarket services.**



Current application and future potential. Source: Ernst & Young.

References
"EY Global 3D Printing Survey," Ernst & Young, 2016

3D printing accelerates product design and prototyping:

The prototyping process will change significantly with 3D printing, as most of the process can be done in-house with higher efficiency. One good example explained earlier was the development of printed circuit boards.

Nano Dimension Ltd. has presented their latest 3D-printing system, which is capable of producing multilayer PCBs in hours, whereas the traditional process can take weeks. In the EY survey in 2016, on average, 3D printing was shown to reduce the prototyping time of electronics by 63%.

> 3D printing was shown to reduce the prototyping time of electronics by 63%.

3D printing changes the nature of the raw materials:

3D printing will change the nature of the raw materials for electronics to allow for printable materials. For example, current manufacturing of PCBs requires polymer plates, copper films and etching chemicals, whereas the 3D-printing process may need metal powder, polymer filament and conductive ink with metal nanoparticles.

Such a change will result in other changes such as new suppliers for new materials and new techniques for raw material processing.

> 3D printing will bring about new suppliers for new materials and new techniques for raw material processing.

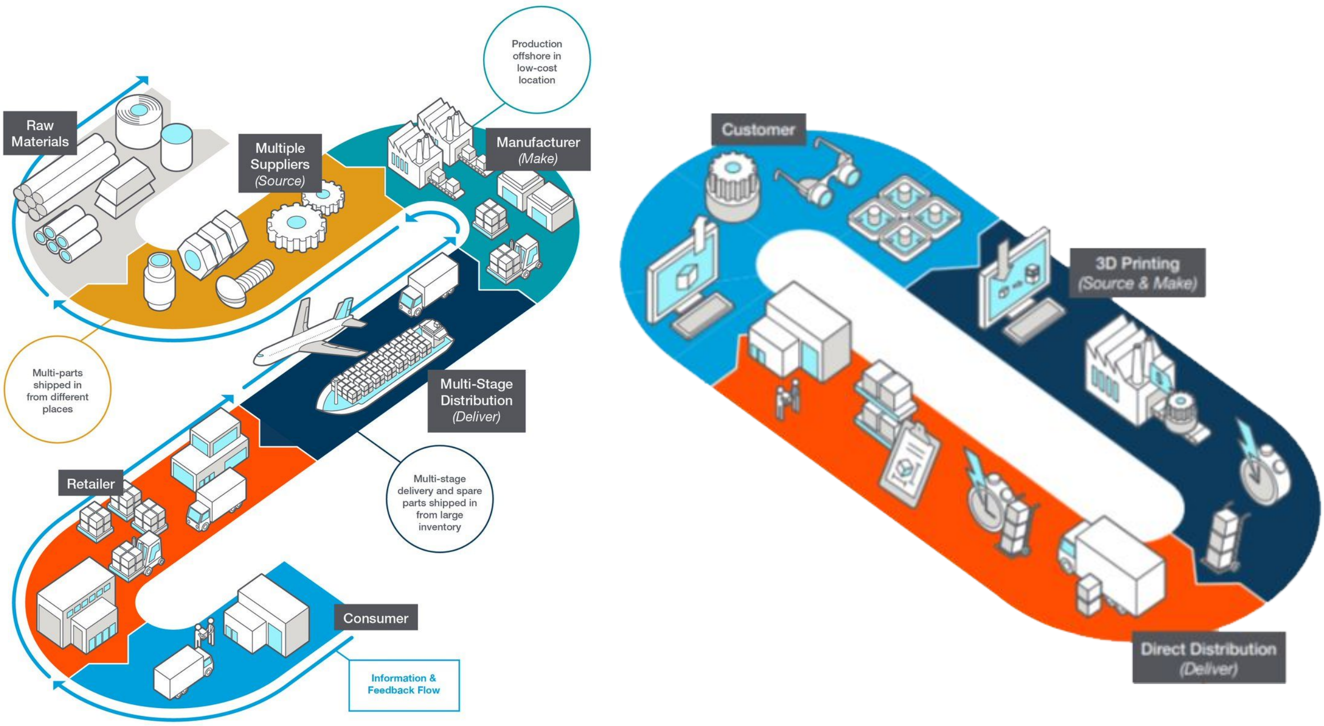
3D printing also changes the manufacturing process:

Current electronics manufacturing utilizes production lines to manufacture products in large quantity while also reducing costs. The major drawback of such a process is the difficulty in handling customized products. A product on a production line can only undergo minimal customization and needs to be manufactured in a large quantity, otherwise the cost of each item ramps up exponentially. However, such a challenge is not an issue for 3D printing, as each item in a 3D-printing process is printed individually.

3D printing can potentially **simplify the manufacturing process**, as many assembly and machining steps can be eliminated. This process simplification also will **save space, time and labor** needed for the manufacturing of the product.

IMPACT ON SUPPLY CHAIN

Of note, due to the change in the manufacturing process and the materials, supply chains will certainly change after the wide application of 3D printing. The hope is that 3D-printing application will shorten the supply chain and reduce the associated risks. As a result, companies can be more user-based and fewer suppliers will be needed. An illustration of the supply chain change is shown below.



A comparison of the traditional supply chain and the 3D prinitng supply chain. Source: Stratasysdirect.

References
https://www.stratasysdirect.com/resources/infographics/3d-printing-impact-supply-chain

ADVANTAGES

There are several additional advantages over traditional manufacturing that AM offers the high tech industry:

1 Reduction of inventory costs as products can be printed as needed, within a short period of time.

3D printing allows faster response to customer demand and less risk of storing inventory. It simplifies inventory management and eliminates the storage of spare or obsolete parts. This feature is most useful for highly customized products such as **implant electronics and wearable electronics.**

2 Reduction of distribution costs as products can be printed locally.

The logistics will change the focus onto printable materials, which is simpler than the final products. Here again, a good example is prototyping PCBs. With 3D printing, prototyping PCBs no longer needs the back-and-forth involvement of the manufacturing factory. It increases efficiency, reduces the need for communication and the shipment of the prototypes and increases the safety of IPs.

3 Eliminate the need to store parts.

3D printing may change aftermarket service, as the need to store spare parts is eliminated. As long as the design can be found, the part can be printed.

ADVANTAGES

4	Create new jobs	3D printing will also change the labor needs, as the new technology requires a different skill set from the current ones on the product lines.
5	Replace parts	Some printed parts, such as battery electrodes, may replace the current parts due to improved performance.
6	Complement existing manufacturing processes	The general components, which are needed in large quantities, may still be printed using the existing manufacturing process as a complementary method to 3D printing. The reason is that, at the current stage, the unit cost of the manufacturing process is still cheaper than 3D printing.

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Xianwei is currently a research fellow at the Colorado School of Mines. He earned his PhD in chemical engineering in 2017. His research focuses on the upstream sector of the energy industry. He collaborates globally with industrial and academic partners to study the fundamental challenges of energy production and seek novel solutions. As a researcher, Xianwei is passionate about the frontier of new technologies. With his scientific training, he follows and analyzes trends in new technologies, their application potential, and their impacts on different businesses.

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- DATA ANALYSIS & RECOMMENDATIONS

- REVIEW BEST PRACTICES
- SUPPLIER OUTREACH & ANALYSIS
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