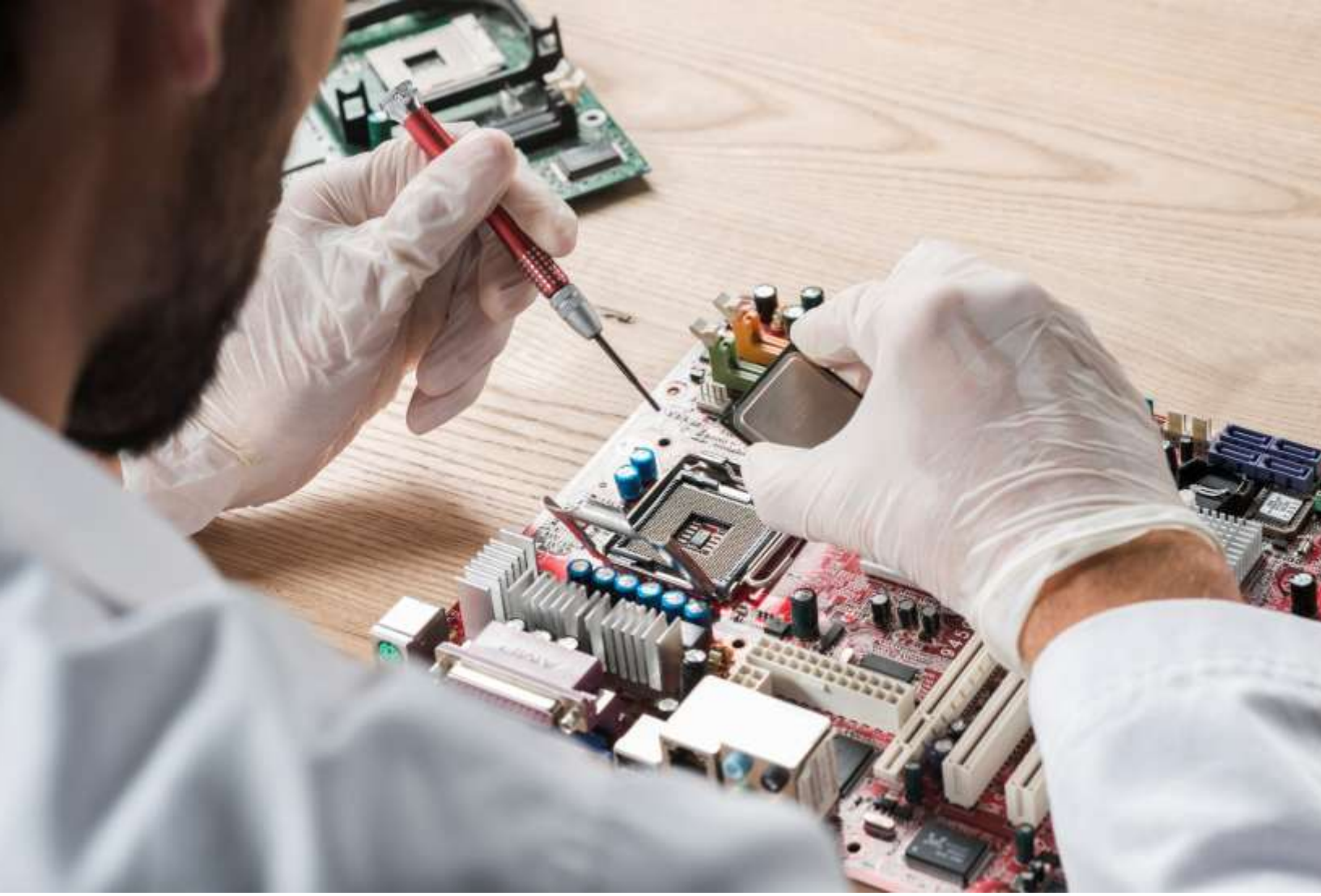


# Electronics Outlook in Allied Industries

www.industryarc.com sales@industryarc.com

# Preface

With great pleasure, IndustryARC presents the inaugural edition of the “Electronics Outlook in Allied Industries” journal. The journal is a collection of several thought pieces, from commercialization aspects to application-specific arguments along with the validation of emerging technologies. This journal envisions to highlight the surging need of market dynamics in emerging technologies that are widely recognized as integral parts of the electronics industry. Its objective is to provide independent opinion on the various technological developments, and address imminent issues within various industries, ranging from aerospace to electronics. The articles are well researched, and have standpoint opinion in terms of market uptake, key driving factors, as well as the challenges faces by them. The Journal is intended for stakeholders across the value chain to identify pertinent issues that need to be addressed and to shape the future course in terms of commercialization of respective technologies. The various blooming technologies explored in this journal include the Flexible AMOLED display technology, E-textiles, 4D printing, Solid State LiDAR, Kerfless Wafer Technology, Wifi 802.11ax, mmWave Sensors, GaN on Silicon Technology, Memristor, and Real-time Rail Integrity Monitoring. This edition captures a plethora of advanced technologies in the semiconductor and electronics industries as well as automotive, railway, consumer products, and communications. Various standpoints such as the use cases, investments, challenges, and key companies have been explored to provide a futuristic view of the technologies and their commercial aspects, and offer a glimpse of technologies the future markets would witness or even rely on.

## Features

1. Flexible AMOLED Displays and Their Future Path
2. Introduction to E-Textiles
3. 4D Printing: The Era of Self-Assembly, Renovation, & Modification
4. Solid State Lidar for Self -Driving/Autonomous Vehicles
5. Kerfless Wafering  A Game Changing Technology for Mass Production of Silicon Wafers
6. High Efficiency Wireless Wi-Fi 802.11ax, Paving its way into Commercial Space
7. mmWave Sensor: A Technological Breakthrough for the Automotive Industry
8. GaN-on-Silicon Technology: A Step Closer to Highly Efficient Semiconductor Devices
9. MEMRISTORS – For the Next Generation Computing Systems
10. Enhanced Safety and Reduced Transportation Challenges with Real-Time Rail Integrity Monitoring

# Flexible AMOLED Displays and

## Their Future Path

There are two types of organic light-emitting diode (OLED) technologies, namely Active Matrix OLED and Passive matrix OLED. The control scheme in the PMOLED is relatively simple and easy compared to AMOLED. Flexible AMOLED displays are used in various applications such as smartphones, TVs, laptops, and smart watches. They are significantly better than their predecessors such as LCDs and LEDs in their features such as flexibility, less power consumption, and manufacturability. The recent developments in various enabling technologies such as flexible substrates, backplanes, and thin film encapsulation have resulted in overcoming the numerous challenges faced during the manufacturing process of a flexible AMOLED display.

Flexible AMOLED displays have inherent ruggedness and offer conformability during usage as well as transportation and storage due to which they find unique applications in the consumer and residential industries. These products made using plastic and metal foil substrates are extremely thin and lightweight; and hence, greatly reduce the size of the overall product in which they are incorporated.

R&D activities in flexible AMOLED displays started in the late 2000s, primarily to implement this technology in mobile phones. Since then, its usage has spread to various industries such as automotive, consumer electronics, and residential. The significant rise in the disposable incomes of countries such as Brazil, India, and China has resulted in the increasing purchasing capabilities of the consumers who can afford these products, thereby resulting in the increase in demand for flexible AMOLED display TVs, which are made up of advanced technologies.

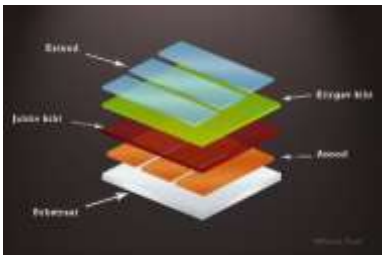
These flexible displays are of two types based on their flexibility such as foldable and curved display. Curved displays are already widespread in the industry, whereas foldable displays are expected to be launched in Q3 2019.

These AMOLEDs are also increasingly being integrated with wearables such as smart watches because they offer higher resolution and better performance.

- In 2016, Apple and Samsung entered into a $2.6 billion deal, wherein Samsung will provide Apple with 100 million OLED display panels. Apple is also rumoured to be in talks with LG Electronics regarding the supply of an initial 2 to 4 million OLED display panels in order to reduce their dependency on Samsung.
- In 2018, Royole Corporation of China launched the world's first flexible smartphone, called FlexiPai, beating the likes of Samsung and Huawei. This flexible smartphone runs on a snapdragon 8150 processor and can be operated in two different ways — foldable and flat.
- In 2017, LG Display Co LTD, a subsidiary of LG Electronics, announced its intention to invest around $13.5 billion in order to boost the output of the company's OLED display screens for the next three years.
- Due to the sluggish sales of Apple's IPhone X, Samsung Display's manufacturing facilities have faced underutilization, forcing the company to undertake significant cuts to the investment made into this cutting-edge technology.

Author
Akhil Emani
Strategic Consultant

There has been a significant interest in the development of flexible AMOLED displays for commercial and military applications. This is mainly due to the various advantages of the product such as low power usage, cost effectiveness, and superior aesthetics such as improved image quality and low UV output. The demand for these products has increased significantly due to the rising demand for energy efficient lighting technology as well as the increasing usage of electronic devices such as laptops, wearables, and smartphones.



Advanced composite polymers are being used for manufacturing these displays as they offer increased flexibility and durability compared to the displays made out of glass.

Due to the high cost of flexible AMOLED displays, smartphone manufacturers have been using this technology only for their higher end products. This has made the product qualification for the second tier flexible AMOLED suppliers even harder, resulting in low fabrication utilization for these companies.

Using the right kind of substrate is essential in the manufacturing process of these displays as the usage of metal foil substrates require additional features such as the top emission architectures due to their opaqueness. In order to achieve the acceptable yield of thin film transistor, these metal foil substrates have to be polished or additional surface layers have to be added for smoothness. In the case of plastic substrates, they are compatible with both bottom emission and top emission AMOLED display architectures.

Numerous companies have applied for patents, many of which have already been granted. The information has been listed below:

- LG Electronics Inc. recently received a patent regarding a flexible smartphone. The company is also rumoured to launch TVs that can be rolled up into a box.
- Samsung Electronics revealed its foldable smartphone at the 2018 Samsung Developer Conference. The smartphone is anticipated to have features such as infinity flex display along with a bendable display panel that offers a large viewing area.
- Huawei is also planning to launch its foldable smartphones along with Lenovo and Xiaomi, which have launched their respective prototypes for foldable smartphones.
- BOE Technology, a leading display manufacturer in China, has recently unveiled its flexible and foldable AMOLED displays in May, 2018.

These new technologies require a close coupling of the hardware and software for stream less user interface with minimal interruptions and diversions. The display manufacturers have to invest significantly for the next few years to realize this dream. This also requires extensive partnerships between the flexible AMOLED display manufacturers and software providers, such as Google. The extent to which these deals can materialize and yield actual results will determine the future of flexible AMOLED displays.

# INTRODUCTION TO E-TEXTILES

### Introduction to E-Textiles

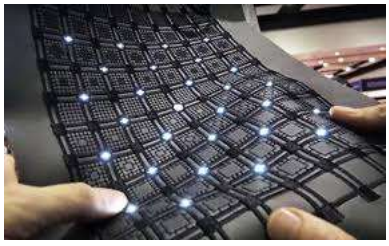
Textiles have been evolving over the years. From naturally available silk and cotton to today's broad range of textiles such as nylon, polyester, and Kevlar, they have enhanced **our** lives greatly. There has been a large amount of research undertaken to develop electronic textiles that are also often referred to as smart textiles, smart garments, smart clothing, or smart fabric. However, they have achieved commercial success only in the past two decades. Although the e-textile industry is in its nascent stage, many players in the industry are lining up their varied product lines of e-textiles ranging from bandages to clothing, and industrial fabric to bed linen.

E-textile, besides conducting electricity, should provide warmth and comfort.

Author
Eashwar
Associate Research Analyst

An electronic textile is broadly referred to as a textile substrate that can sense, transmit, communicate, and interconnect with sensors or other processing devices within a fabric. E-textiles are of two types.

One type includes e-textiles that embed electronic components such as Integrated circuits, LEDs, conductors, and so on into the garments and the other type includes those in which electronic components are integrated into textile substrates. These electronic components include passive components such as resistors or active components such as transistors, and diodes.



### E-Textile Development Techniques

Various techniques and materials such as such as conductive fibers, conductive coatings, inks, and so on, are employed in the manufacture of e-textiles.

- E-Textiles are woven with conductive fibers that contain metallic elements such as nickel, copper, silver, and other alloys. These textiles offer low surface resistance and excellent electrical properties. E-textiles produced using this technique are ideal for soft and printed electronic circuits.
- E-textiles are also prepared using conductive yarns or threads that have similar purpose like wires. However, these conductive yarns are flexible enough to be woven or sewn. This technique offers

the advantage of being processed on textile machinery by using embroidery techniques.

- Another technique involves the usage of conductive coatings that are applied to the traditional fibers and yarn such as cotton and nylon to convert them into electrically conductive materials. Conductive coatings also make sure that flexibility and the density of the fabric is not changed. These conductive coatings find applications in industrial and home furnishing. They have also started to find applications in interactive textiles lately.
- Conductive inks are used as alternatives to conductive coatings that have powdered conductive metals such as copper, and silver mixed with traditional inks. These special inks are applied to the fabric for drawing circuits on the fabric. Digital printing is an area that is drawing much attention in the application of conductive inks.

### Applications of E-Textiles

E-textiles find a wide range of applications in military, healthcare, transport, and fashion.

- **Military**: E-textiles can be of great help in the safety of the soldiers by detecting hazards and monitoring the health. They also facilitate in operational tasks such as navigation.
- **Healthcare**: Healthcare is one of the prominent areas of application for e-textiles. They can assist in health monitoring and empower individuals to manage their own health care needs.
- **Transport**: The transport industry is also exploring the application of e-textiles or smart fabrics to improve the safety and comfort of travelers.
- **Fashion**: Major fashion brands around the world are teaming up with the major technological companies to revolutionize the fashion world with smart textiles.

Increased applications across various industry verticals coupled with growth and technical advancements in the associated technologies such as smart materials, IoT, and integrated micro electronic promises a bright future for the e-textile industry.

### Research and Development


Majority of the current e-textiles cannot withstand high temperatures. However, researchers from South Korea have endeavoured to overcome this challenge.

The researchers have picked natural silk from the silkworm *Bombyx mori,* which contains chains of bi polymer protein that can help the fabric to withstand high temperatures (up to 2,800°C). The researchers have used this attribute of the fabric to produce e-textiles from heat treated, stretched silk proteins. The e-textiles produced from pyro proteins offer excellent conductivity and thermal durability while retaining the properties of natural silk.

Researchers from China have developed screen printed washable e- textiles that allow a person to control computers and other appliances from distance, offering great help to people with less mobility. The researchers used nylon fiber onto which they deposited an electrode array of conductive carbon nano tubes.

For the e-textile to be washable, polyurethane has been incorporated into carbon nanotube ink, which enables the nanotubes to adhere to the fabric of nylon firmly. This textile has been fashioned into a wrist band. When swiped in different patterns, the band generates different signals that coupled with computers and other home appliances. The researchers proclaimed that large scale production of the textile would be inexpensive and that the textile would be breathable for the human skin.

The Engineering and Physical Sciences Research Council (EPSRC) has funded Smart Electronics Materials and Systems (SEMS) research group of University of Southampton with £600,000 in an attempt to boost the e textile technology development to mitigate the pain of osteoarthritis patients.

The research group is focusing on developing e-textiles that contain dry electrodes printed on them. This would help in delivering a small current to interfere with the pain signals and stimulate the release of endorphin hormones; thus, easing the pain of patients.

Bally Ribbon Mills, a U.S. based company, markets its e-textiles under the trademark E-WEBBINGS. By combining non-conductive base fibers with specialized conductive elements, the company offers e-textiles that find applications in sensing environmental hazards, speed and distance logging, temperature collection and so on. The company adopts techniques in the manufacture of e-textiles.

- Metal Stranding: This involves combining non-conductive textile fibers such as nylon, cotton with the stands of conductive fibers such as carbon, titanium, nickel and other conductive metals or alloys.
- Metal Injection: This technique involves combining fabric with metal base powder, which results in the ability of the fabric to conduct electricity.

A few of the major players of the e-textile industry include: Bally Ribbon Mills, OTEX, Adetexs, Sensoria, Schoeller Textiles AG, and Interactive Wear.

### Challenges

The e-textiles of today have the following challenges to overcome to achieve large scale commercialization.


- **Durability**: The durability of the e-textiles is a major concern, considering the mechanical stress the fabrics are exposed to like any other clothing. It is extremely important for the e-textiles to be durable to serve in demanding applications, especially in the defense industry.
- **Eco Design**: Sustainability is an important driver in today's world of limited resources. Designing the product with options to re-use and re-cycle holds the key for a sustainable industry.
- Cost: While the increasing amount of research and development can catalyze the large-scale commercialization of e-textiles, the real challenge lies in arriving at optimized manufacturing techniques and cost-effective processes. Any technology can offer commercial viability only with large-scale adoption, which is always driven by affordability.
- **Security, Privacy and Safety**: These are crucial to any smart product or system around the world considering the amount of critical data these smart products collect.

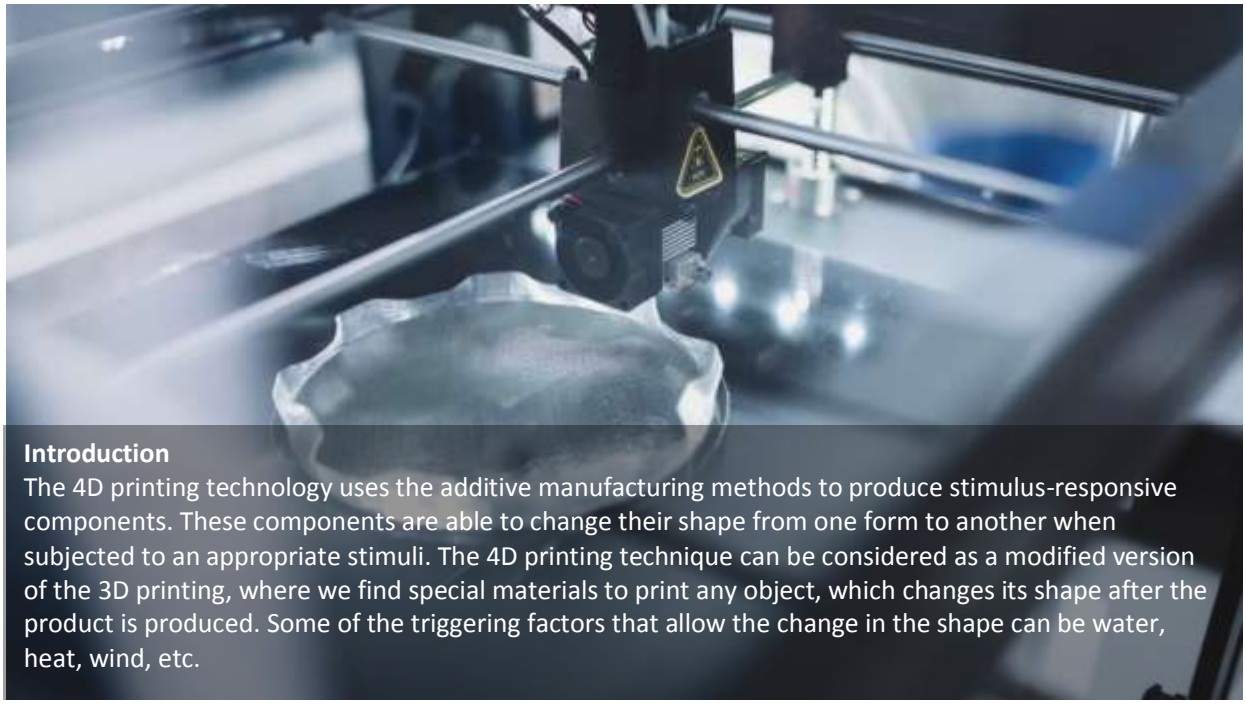
### Conclusion

Like any new product or technology at its infancy, e-textiles have to overcome various challenges to attain large scale commercialization. The quick commercialization of e-textiles is forecast to occur in late 2019 mainly due to the high number of on-going research activities. R&D activities in e-textile technology are drawing huge fundings from various industrial verticals due to the multi-disciplinary applications that e-textiles can offer.

Going forward, what are the alternatives of batteries in e-textiles?
Considering the limitations of batteries, there is a need for developing new energy harvesting technology using special fabrics that can convert kinetic energy and heat energy into electronic energy.

# 4D Printing:

## The Era of Self-Assembly, Renovation, & Modification



**Introduction**

The 4D printing technology uses the additive manufacturing methods to produce stimulus-responsive components. These components are able to change their shape from one form to another when subjected to an appropriate stimuli. The 4D printing technique can be considered as a modified version of the 3D printing, where we find special materials to print any object, which changes its shape after the product is produced. Some of the triggering factors that allow the change in the shape can be water, heat, wind, etc.

### How Was 4D Printing Developed?

There are three main companies /research labs, namely, MIT's" Self-Assembly Lab", the 3D printing manufacturer "Stratasys", and the 3D software company "Autodesk" having major contributions towards the development of the 4D printing technique. The 4D printing technique started in 2013, through the efforts made by the above-mentioned companies.

Although the technique is still in its nascent stage, it is popularly used in prototyping facilities, art installations, and architectural exhibitions.

### Real-World Application of the Technology

One of the real-world applications of the 4D printing can be the pipes used for plumbing. These pipes change their diameter dynamically with the change in the rate of flow as well as the demand of water. These pipes can be healed automatically in case of any cracks as they are able to change with respect to the changes in the surroundings.

Author
Neha
Associate Research Analyst

4D printing is popularly incorporated in the medical field by the doctors in the neonatal intensive care unit also known as NICU. In the University of Michigan's CS Mott Children's Hospital, the doctors have developed a 4D printed airway splint that prevents the collapsing of the infant's windpipe. This splint automatically expands the windpipe as the child grows, and the process is continued until the child is strong enough to support itself.

### Technological Development and its Applications in Various Sectors

The 4D printing technology shows a steady growth in the U.S. The technological advancement as well as the increasing R&D investment has propelled the growth of this technology across various end user industries, such as healthcare and others. The government as well as the researchers are focused on the development of the 4D printed materials that can adjust to diverse climatic conditions. Following are some of the applications of 4D printing:

The 4D printing technology finds its application in the healthcare sector. The technology can be used for self-assembling biometrics and creating nano-robots used for chemotherapy. The technology also finds its application in the automotive industry, wherein, 4D printing technique is used for coatings, which can easily adapt to the sun, wind, and rain. The technique can be potentially used in construction, leveraging the self-repairing capabilities of materials used for bridges and roads. Another application of the technique is in space exploration, where the parts are assembled at a predetermined environment, without applying any external force.


### Some of the Key Players

Autodesk, Inc., one of the key players in the field is working on the bio-molecular self-assembly human scale 4D printing, and also on a technology called 4D printing: Multi-material shape change over time. Autodesk, Inc., is also working on the bio/nano/programmable matter, which is responsible for various shape transformations.

The major collaboration between MIT's Self-Assembly Lab and Stratasys is basically working on the 4D technology, where each particle of the material can activate the self-assembling feature when responsive substrate is stimulated by water.

Another key player involved in the development of 4D printing technology is Materialise NV. Their newly launched product "A self-transforming lampshade" defines the era of 4D printing in the best possible way. It provides a push to the 4D printing technology and allows a healthy growth of the technology.

### Conclusion

Despite all the challenges faced by the 4D printing technology, it is expected that the technology will demonstrate a healthy and steady growth in future. Major companies as well as the collaborations are working to enhance the technology in order to produce standard products and to overcome the challenges. The R&D department seems to be taking a major interest in the development of the technology, which might further propel the growth of this technology.

# SOLID STATE LIDAR FOR SELF - DRIVING/AUTONOMOUS VEHICLES


Light Detection and Ranging (LiDAR) is a technique that uses light waves to measure the distance of nearby objects. It transmits a light wave and receives it when hit by any obstacle and calculates the distance based on the round trip time. In short it is a RADAR that uses light instead of radio waves. A single LiDAR could easily cost approximately $75,000 more than the car, thereby proving a hindrance for the adoption of single LiDAR in cars. Solid state LiDAR, on the contrary, provides sharper and better vision at an affordable cost for self-driving vehicles. Solid state LiDAR improves the performance of self-driving vehicles by providing increased precision through long range detection; better classification of objects and tracking of movement that is necessary for high speed driving; and accurate 3D imaging in any weather. Moreover, as it is in solid state, it is immune to shock and vibration; and thus, less prone to motion blur.

**The working of LiDAR in self-driving cars can be seen in the picture below.**

Solid state LiDARs are used in automotive, aerial mapping, 3D mapping, and many other industrial applications.

Author
Pragnya
Intern

Capital investments that are internally funded for research and development of LiDAR are limited due to the small size of the sector. Furthermore, growth and development of the technology in the commercial sector depends completely on the ability to work cooperatively with the academic and research sector to find out common research priorities and objectives, especially those that are related to specific applications.

In 2014, Quanergy sated that their LiDAR can detect a range of 300m and later in 2016, it released a solid state LiDAR-M8 which the company said would detect 50m but when tested it could detect only 11m indoors and even worse outdoors. In 2017, it revealed the range of the M8 as simply 'long' to the press. Hence the self-driving cars lacked performance needed for general use autonomous driving when launched.

Velodyne has come up with the solid state Velarray, the smallest LiDAR that can be placed behind the windshields and bumpers.

BMW has announced its plan to launch a self-driving car based on the solid state LiDAR technology, which will be put into production by 2021. The technology will be supplied by Innoviz and Magna.

The challenges facing solid state LiDARs include reduced signal power from power emission and reception inefficiencies, and limited range and performance.

Companies that develop products based on the solid state LiDAR technology include

**Key Business Takeaways**

- Velodyne – It manufactures advanced LiDAR sensors with 360-degree environmental view and 3D mapping features.
- LeddarTech – It is globally recognized for its cost-effective LiDAR technology solutions.
- Innoviz Technologies – It is collaborating with Magna to utilize its high definition solid-state LiDAR (HD-SSL) sensors to provide a complete sensor-solution package for self-driving vehicles to the automotive manufacturers.
- Oryx Vision – It has announced a new LiDAR sensor that utilizes long wave infrared lasers to track objects that are on the roadway.
- Luminar technologies – The company has launched a LiDAR system that has a farther range than those of its competitors' LiDAR based sensors.
- Quanergy - Quanergy's sensors are much smaller than other sensors and feature no moving parts.

The initiation of BMW to opt for the solid state LiDAR in the self-driving car is one of the first in the automotive industry that is going to increase the advancement of the technology and also autonomous vehicles at affordable cost.

As Mercedes Benz's self-driving car based on solid state LiDAR was failed to succeed due to small sensors which were low in cost but exhibited poor performance, there are certain questions that can be raised:

Can the self- driving car that is to be released by BMW in collaboration with Magna and Innoviz can overcome the inefficiencies encountered by Benz and still remain cost effective?

Will the competitors such as Audi, Volkswagen, Volvo and others opt for autonomous vehicles using solid-state LiDAR technology?

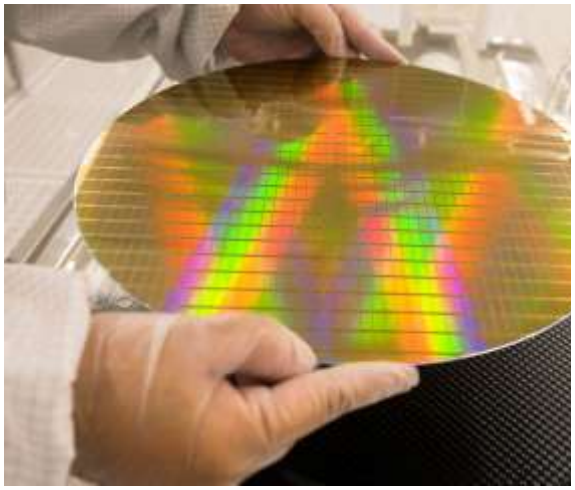
# Kerfless Wafering :

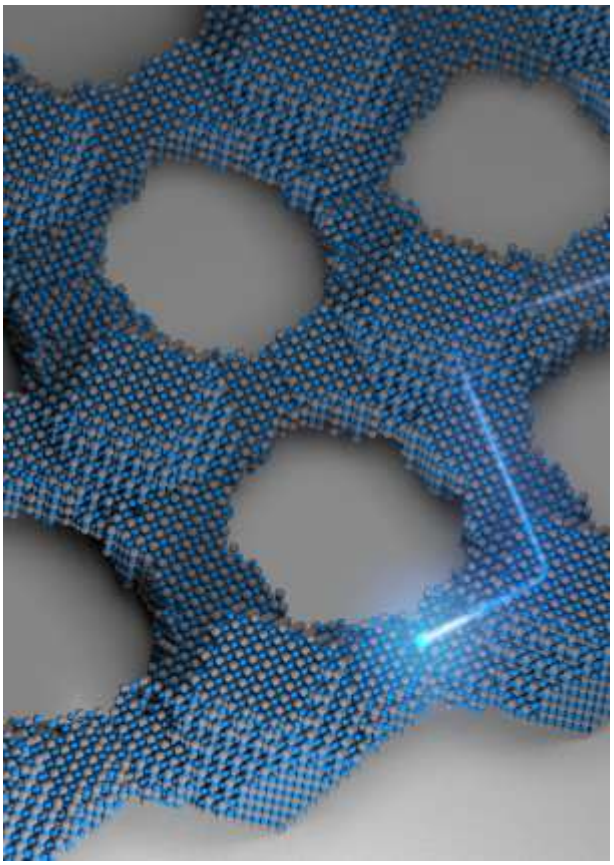
## A Game Changing Technology for Mass Production of Silicon Wafers

### Introduction

Kerfless wafering is the process of manufacturing thin wafers of silicon from a slab of silicon crystal. The use of this process ensures minimum waste of material with high efficiency and guarantees cost reduction. The minimum wastage of the material in kerfless wafering helps increasing the manufacturing of the wafers from the raw material.

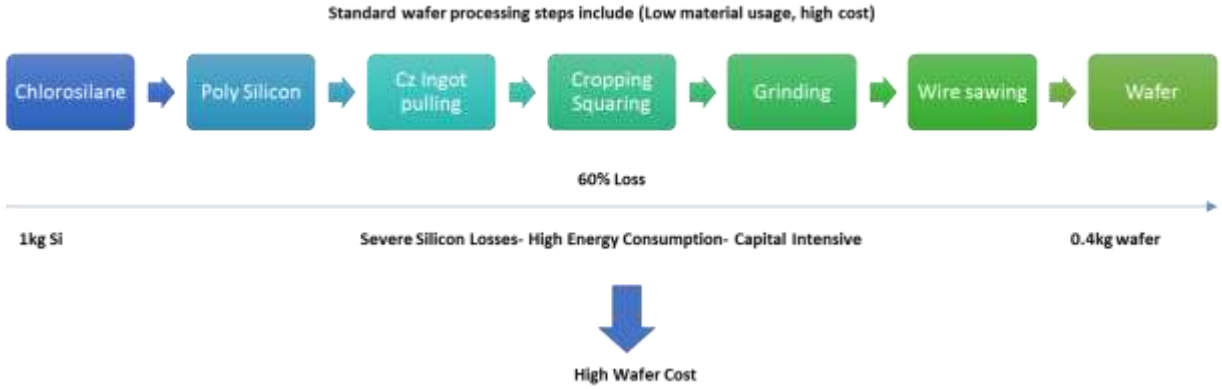
There are two different methods for manufacturing the wafers: implant and cleave process, and the stress-induced lift-off method. Implant and cleave is a two-step process, wherein a cleavage of silicon is removed from the ingot by first introducing or implanting ions in the silicon. The stress-induced lift-off process lifts the silicon off by applying stress on the thin film and silicon interface, and then cutting the wafers by means of a thin wire.





The burgeoning use of the kerfless wafer technology is expected to reduce the waste of raw material. Along with the increasing use of this technology, several techniques have been proposed for the manufacture of wafers. The proposed techniques, such as proton-induced exfoliation, which uses the process of implant and cleave, are expected to reduce the Si material loss, and consequently the cost of manufacturing.

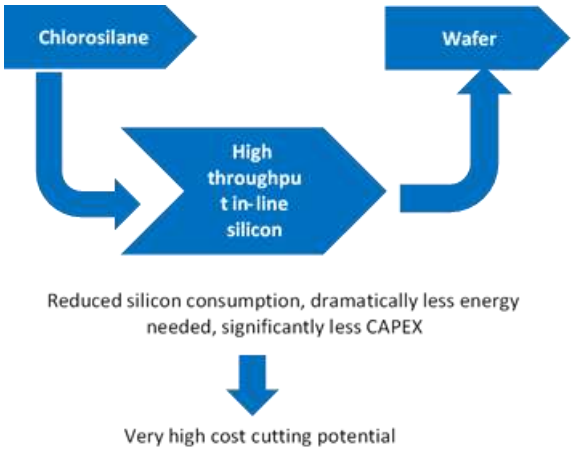
Author
Ramya
Associate Research Analyst




In the standard wafer process. If 1kg of Si is taken at the beginning of the process, that is, at the chlorosilane stage, at the end of the process only 0.4kg of wafer is manufactured, which means that 60% of the Si is wasted in the process of manufacturing. The cost of the manufactured wafers is also high in the standard wafer process.

NexWafe Company is focusing on reducing the steps involved in the process. This is also expected to reduce the material usage and reduce the cost of the wafer.

**NexWafe smart and efficient value chain of manufacturing the wafers**




NexWafe Company is planning to implement the thermal treatment and isotropic etching processes which are expected to allow nearly complete removal of implantation damages in the cleaved-thin wafers. Furthermore, the company is also focusing on developing the laser interference lithography and a reactive ion etch process, a facile nanoscale texturing process for the kerfless thin wafers. The increased use of this process will help in cutting down the cost of the wafers.

The company is also focusing on implementing several techniques such as epitaxial Si lift off, stress-induced spalling, and smart-cut. Using an epitaxial Si lift-off technique, a thin wafer is epitaxially grown on a porous seed Si wafer by atmospheric chemical deposition (APCVD) and exfoliated from the parent seed wafer. The use of the epitaxial technique will help in producing high Si wafers with improved efficiency of up to 21%.

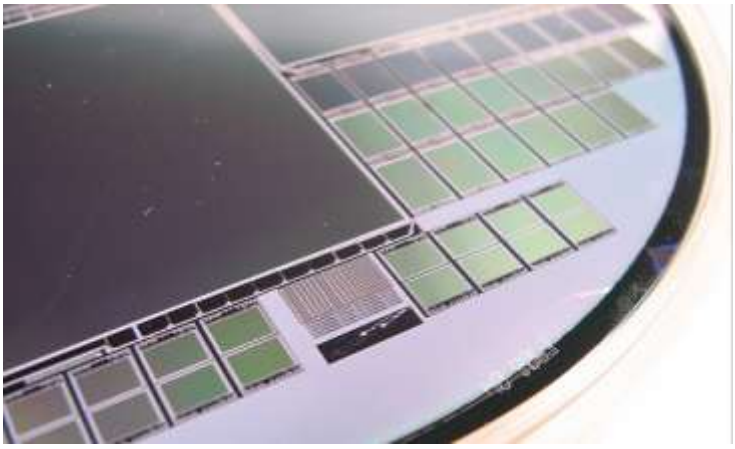
The stress-induced technique or SLIM-cut employs a stress induced layer on the Si wafer, and the stress is activated by thermal expansion mismatch between the stress layer and the Si wafer for spalling of thin wafers. Recently, a novel method of electrodeposit-assisted stripping (EAS) has been developed to minimize the formation of micro-structural defects during the SLIM-cut process. In the EAS process, a thin stress layer is electro-deposited at room temperature, and the lattice mismatch between the stress layer and the wafer induces a large stress field, which causes the lift-off of a thin Si wafer without high temperature annealing.

**R&D investments, initiatives and funding by NexWafe**

NexWafe has invested $9.4m for the next stage of its kerfless wafer manufacturing plants. The company sees big market potential for the product, with cost reductions of 50%. Along with the investment, the company is also planning to invest $8m in financing for the commercialization of its kerfless wafers production line in Freiburg, Germany.

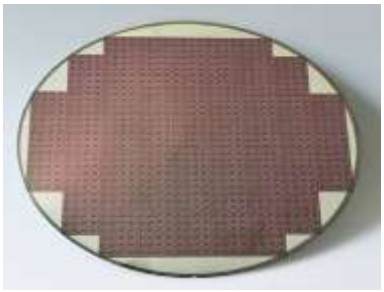
**Challenges**

- The major challenge faced by silicon solar technology companies is to increase the efficiency and reduce the cost of the wafers. The companies are targeting to reduce the cost by 50% without compromising on the quality of the wafers. Many R&D investments and fundings are being observed in manufacturing of the wafers. 1,366 Technologies of Bedford, Massachusetts, the U.S., has announced it capability to create wafers directly from molten silicone. Another start up named Solexel has introduced a new approach that uses silicon more efficiently, and results in a more uniform wafer quality than industry standard processes.
- The manufacturing of thin wafers, at times, may necessitate a change in the whole production line. To address this issue NexWafe Company is planning to keep its wafers adhered to a substrate during the initial phases of cell processing. This step will help the company with potential breakage issues and increase the production line of manufacturing of the wafers. It is also planning to shift towards the use of the direct wafer formation that is based on silane gas deposition on a substrate. The increasing use of this technology will offer fewer steps, and eventually reduce the cost of replacement of the equipment. This process is estimated to reduce the cost of the wafers by 54%.
- The production of thin wafers is a major challenge for the companies. Along with the production of thin wafers, companies are also focusing on reducing the cost of the wafers. To achieve this cost reduction, NexWafe Company is investing $30m in R&D. This R&D investment will not only focus on reducing the cost of the wafers but also on increasing the efficiency of the wafers by reducing the use of silver.



**NexWafe Company**

NexWafe Company is being supported by a seed funding from Fraunhofer Venture. NexWafe's groundbreaking kerfless wafer technology is expected to serve the multibillion dollar high-end wafer market. Based on epitaxy, the kerfless wafer, which has been developed throughout the last fifteen years, is a drop-in replacement for conventional wafers produced by a single-crystal ingot and wire sawing process. NexWafe´s kerfless wafers enable significant cost reduction in solar cell production.



NexWafe has developed a reliable epitaxial deposition process for crystalline silicon layers, which is transferable to the photovoltaic industry. The focus is on atmospheric pressure chemical vapor deposition (APCVD) at temperatures up to 1300°C. This process is well-known from microelectronics, but had to be radically adapted for photovoltaic applications in terms of throughput of the equipment. The company has launched a new product named ProConCVD, which has been designed for high throughput as required in industrial production, demonstrating low-cost high-quality silicon epitaxy for PV.

**Can the use of wire-saw technology take the industry as far as it needs to go?**

*Not likely, although certain improvements are made to the technology, the saws generate a considerable amount of subsurface damage when you get down to the thickness, with 10--20 micron microcracks propagating in the substrate that cancels out the perceived benefits of thinness. Along with this issue of reduced thickness, there is the continuing problem of what is to be done with that annoying leftover kerf.*

# High Efficiency Wireless Wi-Fi 802.11ax,

## Paving its way into Commercial Space

### Introduction

802.11ax, also called High-Efficiency Wireless (HEW), is the new Wi-Fi standard that mainly focuses on implementing mechanisms to serve more users. This is a dual-band 2.4- and 5-GHz technology, in which the clients can take advantage of its benefits right away. It is the latest step taken in building on the strengths of 802.11ac, by adding flexibility and scalability, thereby enabling new and existing networks to power next generation applications. This emerging Wi-Fi standard is expected to displace the current 802.11ac standard, offering higher throughput and overcoming poor performance in crowded environments.

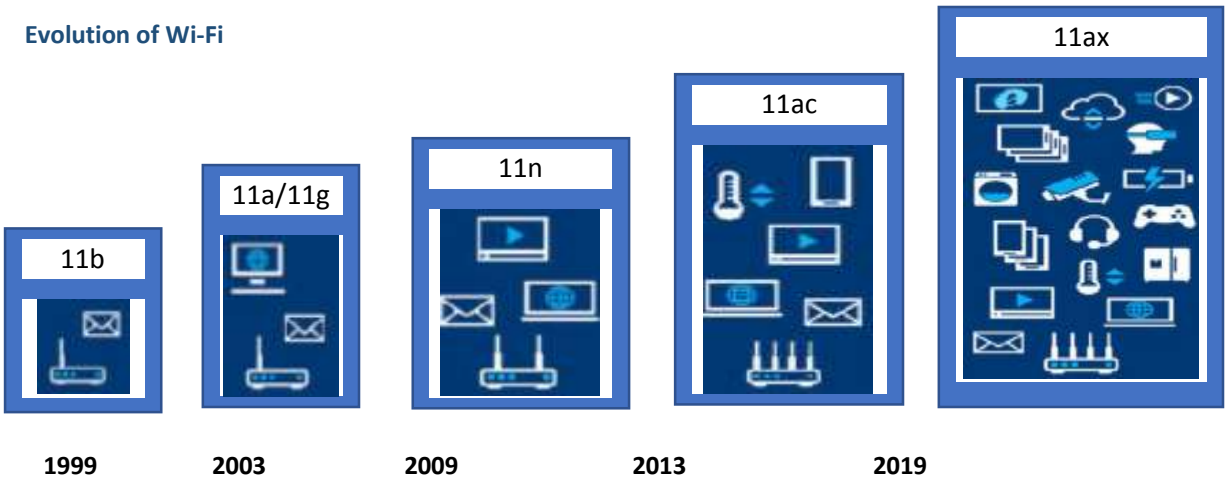
802.11ax has the challenging goal of improving the average throughput per user by a factor of at least 4X in dense user environments.

The developments in 802.11ax will allow enterprises and service providers to support new and emerging applications on the same Wireless LAN (WLAN) infrastructure, while delivering a higher grade of service to the present applications. This scenario is expected to set the stage for new business models and increase Wi-Fi adoption in different applications.

In addition to the improvements from parallel transmission, 802.11ax offers other advantages for users, such as an improved target wake-up time (TWT), which increases the battery life for mobile clients.


Author
Ramya
Associate Research Analyst

**Evolution of Wi-Fi**




### Use Cases for 802.11ax Technology

The advancements in 802.11ax technology is expected to benefit a wide range of use cases which are particularly important for dense environments in which large numbers of users and devices are connecting to the network. Some of the use cases are mentioned below:

1. Large public venues (LPVs)
2. Transportation hubs
3. IoT and Smart city deployments
4. Educational institutions
5. Residential areas
6. Enterprises

### R&D Investment & Initiative, funding

In early 2019, Qualcomm Technologies announced that its Wi-Fi 6 Networking Platform has now been featured in products. Qualcomm Wi-Fi 6 Networking platforms offer robust 11ax configurations and a differentiated feature profile, allowing manufacturers to deliver premium networking products which helps in maximizing capacity, coverage and performance. The key features included in the products are:

- Highly integrated SoC which significantly offers flexibility built on a 14nm FinFET process, optimized for superior power.
- Up to 12 streams of dual-band Wi-Fi with up to eight spatial streams in the 5 GHz band and four in the 2.4 GHz band
- Peak aggregate speeds of up to 6 Gbps that can support more than 1000 simultaneously connected Wi-Fi clients
- Virtually simultaneous multi-user radio access enabling up to 8 simultaneous transmissions using upstream/ downstream MIMO or more than 32 simultaneous transmissions using OFDMA

### Standards and Certificates

The launch of a new Wi-Fi equipment requires the Wi-Fi CERTIFIED Agile Multiband certificate, a group of features allowing clients broader visibility into network loading and the ability to move the optimum band and access point. All the Wi-Fi equipment has to meet the security standards for authentication, authorization and encryption

### Outlook

In the old versions of Wi-Fi, the channels were held open until the data transmission had finished. To address this issue, the upcoming Wi-Fi is provided with orthogonal frequency division multiple access (OFDMA) in which each channel is chopped up into hundreds of smaller sub-channels, with each sub channel provided with a different frequency. The signals in the sub channels are turned orthogonally so that they can be stacked on top of each other and de-multiplexed. The main aim of OFDMA is to reach up to 30 clients by sharing each channel instead of having to take turns broadcasting and listening on each.

### Challenges of Wi-Fi 802.11ax HEW (High-Efficiency Wireless)

- The present WLAN standards are provided with carrier-sense multiple access, in which STA (Station) has to check if the channel is clear before transmitting its data, and if the channel is occupied, STA has to wait for a certain amount of time before transmitting the data. This process becomes inefficient when larger numbers of users are sharing a network, or when an STA unnecessarily waits to transmit because it senses transmissions from an adjacent network. 802.11ax addresses this inefficiency by allowing multiple STAs to transmit at the same time using orthogonal frequency division multiplexing (OFMD).
- The other major challenge for 802.11ax is meeting the standards set by the governments of different regions or countries. Europe has come up with special norms and standards, such as EN 301 893. The introduction of this norm is causing stakeholders some concern. However, it is planning to revise the norms to meet the performance.

### Companies

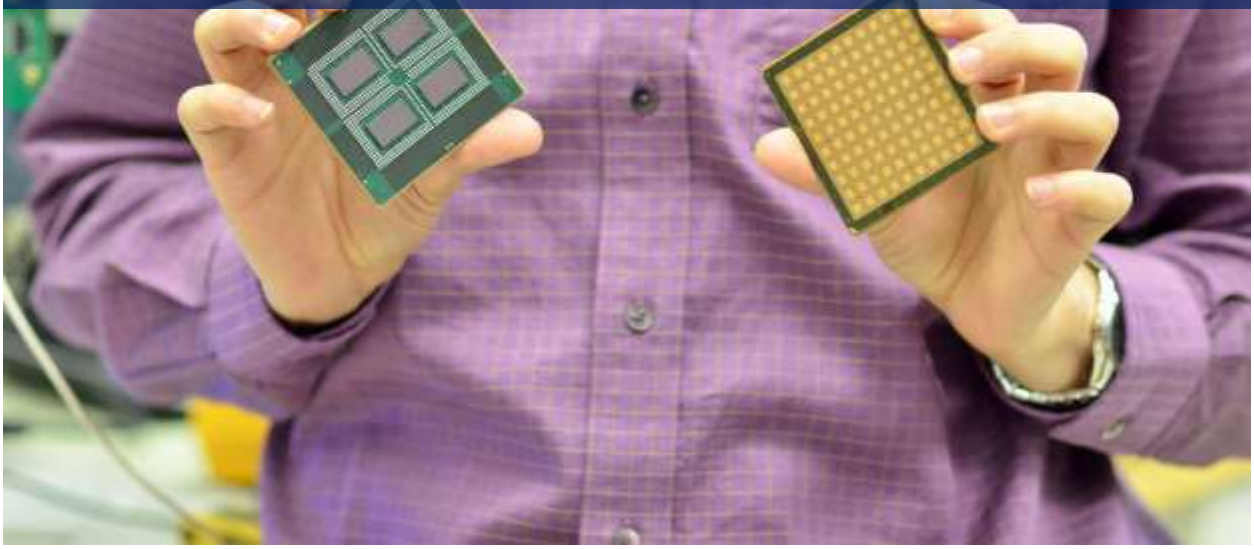
The different companies that provide Wi-Fi 802.11ax include Aerohive Company, and Aruba. Aerohive Company is planning to launch new products that are designed by combining the latest Wi-Fi standards. These products are provided with latest Ethernet standards which helps in enhancing the location driven services. Aruba, on the other hand, has launched a series of products with advanced technologies, which have the capacity to support unique features such as radio management and some other additional services which are mainly used in IoT applications. Along with the implementation of 802.11ax, companies are also planning to implement the next generation Wi-Fi which is 802.11ay. The main goal of this standard is to support a maximum throughput of at least 20Gbps within the 60GHz frequency, as well as increase the range and reliability.

We will have to wait and see how the commercialization of 802.11ay, which is likely to happen in late 2020, impacts the penetration of the 802.11ax.

### Will 802.11ax devices in Europe operate to their full performance?

Europe is planning to implement EN 301 893 norm which includes a number of exemptions for 802.11ax. These exemptions will permit devices accessing Wi-Fi channels to use four-way handshake mechanisms and improve performance.

# mmWave Sensor:
## A Technological Breakthrough for the Automotive Industry



Intelligent Transport Systems (ITS) incorporate ultrasonic sensors, infrared LiDAR sensors, image-processing sensors, millimeter wave radar (mmWave) sensors and various other sensors for monitoring a vehicle's surrounding environment. The data captured is further processed by the on-board computing unit to provide further assistance to the driver. Infrared LiDAR sensors are preferred over other object detector technologies due to their longer range and higher accuracy. However, due to their exorbitant price and requirement for hefty on-board offers the advantage of providing stable recognition of targets under moderate climatic conditions and at low-cost. computing power, the adoption of these sensors is limited to a few brands. Compared to other types of sensing technology, a millimeter wave radar sensor offers the advantage of providing stable recognition of targets under moderate climatic conditions and at low-cost.

Author
Samvrant
Associate Research Analyst

### Preface

Millimeter-wave (mmWave) radar sensors were recently launched for enabling Advanced Driver Assistance Systems (ADAS) applications such as Adaptive Cruise Control (ACC), and enhancing safety functions such as emergency braking, pedestrian detection and 360-degree sensing. The mmWave radar sensors focus on sensing the conditions around trafficked areas and collecting data that can help the rider react to changes.

- The following are the types of radar sensing mmWave sensors with respect to the detection range: Long-Range Radar (LRR)
- Medium Range Radar (MRR)
- Short-Range Radar (SRR)

Out of all these, the short-range radar is highly used for its good functionality of detecting objects. It is generally mounted around the chassis of the vehicle to detect objects at close range — approximately 0–40m. With the help of short-range radar, the vehicle's safety systems are activated automatically when any object that can cause potential danger is detected.

Long range radars, on the other hand, are capable of detecting objects at long range — up to 150m — and are primarily used for Adaptive Cruise Control (ACC). The sensors enable advanced driver-assistance and security functions including collision avoidance, airbag activation, parking assistance, better road handling, lane change support, and stop and go capability.

Automotive Cruise-Control (ACC) Systems are playing a crucial role in the industry. ACC can be realized by three different technologies, namely millimetre wave radar, stereo metric, and light radar. ACC systems help maintain the speed set by the driver while automatically adjusting the speed to maintain a pre-set distance. They are also capable of analyzing the outdoor conditions and performing their defined tasks without the intervention of the driver.

Automated Highway Systems (AHS) provide drivers with details of obstacles and vehicles that are out of sight. This communication technology significantly improves safety. The information provided is on a real-time basis to support secured driving. The AHS system enables automated driving with information processing equipment for velocity and steering controls. Millimeter wave sensor, a cost effective alternative to LIDAR system, is set to witness higher adoption, especially with the growing emphasis on autonomous vehicles and adaptive cruise systems in conventional vehicles. This could also promote the penetration of AHS into economy class vehicles in the future..

### Application of mmWave Sensors in the Automotive sector

The core application areas where mmWave sensors are designed to function are adaptive cruise control, automatic emergency braking, lane change assistance, blind spot detection, and so on. Automotive-grade mmWave sensors can be used to detect obstacles, which include open spaces near doors, rear bumpers, side skirts, bonnets, front, rear side guards, and facilitate occupancy detection inside the cabin, intruder alert, and smarter automated parking.

### Funding and Developments

- In September 2018, Lunewave, an Arizona based start-up, raised $5m of seed funding, with the backing of Fraser McCombs Capital, BMW I Ventures, Baidu Ventures, and other investors. The investment will help Lunewave improve its radar and antenna technology for smart vehicles as well as other applications.
- In July 2018, Israel-based Arbe Robotics, raised $10m in a funding round led by 360 Capital Partners, taking its total private funding to $23m. Arbe Robotics, the world's first company to demonstrate 4D high-resolution imaging radar, will be utilizing these newly raised funds to expand its reach in China.
- Metawave, a company focussed on building intelligent beamsteering radars for autonomous driving, received a $10m additional funding from Toyota AI Investors, Hyundai Motor, DENSO Corp and other strategic investors in May 2018.

### Leading Companies in Mmwave Radar Sensors

Texas Instruments is the leading player in the existing market. Texas Instruments is known for its single-chip millimeter wave sensor used in an autonomous vehicle. Apart from vehicle automation, TI's mmWave sensors are creating smarter and more effective cities and machines.

SAGE Millimeter, Inc. is the next leading player in the mmWave sensors in automotive market. Aviat Networks, Inc., E-Band Communications, LLC., and Bridgewave Communications, Inc., are some of the other prominent players in the industry.

### Upcoming Developments for Current Challenges:

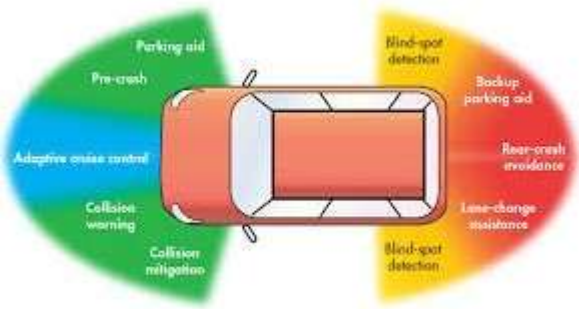
Here are a few challenges faced by mm Wave sensors:

**Sensing Condition:** Under low visibility or bad weather conditions, millimeter wave sensors at times fail to detect the range, velocity, and angle of objects. To overcome these, the manufacturers are in the process of developing higher radar signal sensors.

**Size and Accuracy:** Single-chip millimeter wave sensors are currently facing accuracy and size challenges. The replacement of Silicon Germanium (SiGe) technology with Complementary Metal-Oxide-Semiconductor (CMOS) technology will help overcome this challenge. The developments in CMOS will include higher transistor density, lower power, and take less mounting space on board. The improved technology will offer 79GHz bandwidth which is essential for higher range resolution in ADAS.

### Conclusion

In this exciting era of technological innovation, the automotive radar industry have been seen always active in the process of development. The industry is approaching new opportunities behind the technical development in sensor functionality with chassis to ground monitoring. There's no doubt this technology will be key in spanning autonomous and robotic cars as people look for more safety driven vehicles.




Earlier the mmWave radar sensors were not accurate enough to detect objects under bad weather conditions. Considering this issue as a challenge, and to reduce the possibility of potential hazards, technical changes is a must in the upcoming radar sensors. As the growing adjacent markets continue to deliver important off-the-shelf technology developments, the components are quickly becoming expensive. Companies should look to efficiently minimize the costs associated with validation and production. Comparing and coming up with new strategies will help the manufacturers grow in the industry.

# GaN-on-Silicon Technology: A Step Closer to Highly Efficient Semiconductor Devices

### Introduction to GaN (Gallium Nitride) Based Devices

Power MOFSETs started appearing in 1976 as an alternative to bipolar transistors. Thus, switching power became way easier. GaN-on-Silicon technology emerged as a cost-effective alternative to the old traditional ways of power generation through MOSFETs and bipolar transistors. The demand for GaN-on-Silicon technology is constantly increasing due to the surge in demand for cost-effective power supply.

### R&D Activities in GaN Technology

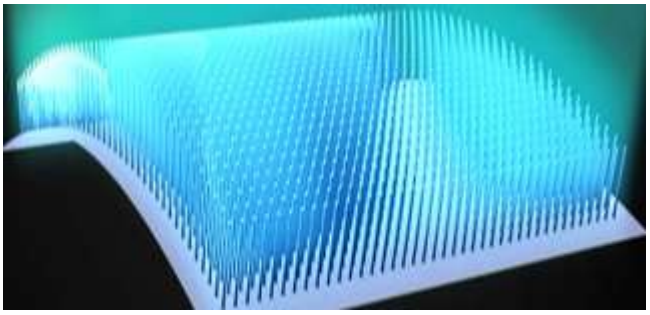
Recently, STMicroelectronics and Leti have jointly agreed to industrialize the GaN-on-Silicon technology for power switching devices.

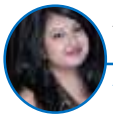
This will enable ST to address high efficiency and high power applications, including automotive on-board chargers for hybrid and electric vehicles, wireless charging, as well as servers.

**Transphorm targets to** manufacture high voltage GaN-on-Silicon power devices with better power efficiency, which can be used in power supplies, inverters for solar panels, electric vehicles, and other such applications.

### Applications of GaN-on-Silicon Technology

GaN-on-Silicon technology has a wide range of applications in defense, telecommunication, electronics, IT, and many other fields.



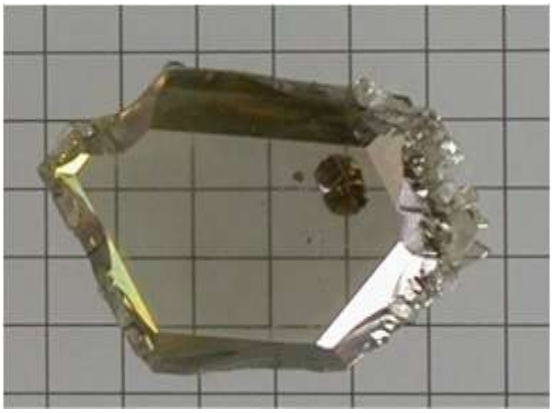


Author
Srishti
Associate Research Analyst

- Telecommunication: Large TV screens or smaller full color panels in trains and buses can be potentially made of GaN.
- Electronics: LEDs consume less power and are cost effective. Nitride based semiconductors can be mixed with phosphor convertors to produce white light. Gallium nitride-based lasers, which work at room temperature have quite long-lasting lifetimes.
- IT industry: CD, DVD, and opto-magnetic memories have a potential scope for GaN.
- Aerospace: GaN materials, when used as microwave amplifiers in wireless communication systems show greater transmitting power supply and efficiency. This indicates that few geostationary satellites can yield power equal to many low-earth satellites together.

### Challenges for GaN-on-Silicon Technology

GaN is in headlines due to its outstanding features. It has surpassed other technologies such as GaAs and Si in terms of reliability and performance. Despite being such a promising future for semiconductor devices, it still has to face certain challenges, as mentioned below, to be accepted on a larger scale.



- It cannot replace the current devices completely, instead it can complement them and achieve excellence in applications by providing high frequency, high power, switched-mode power supply.
- Since, this is a newly invented technology, not all power designers are familiar with the usage of GaN.
- GaN devices for sure have extravagant features, however, the major challenge is that the technology is still in the development stage.

### Some Key Players

Companies such as Efficient Power Conversion Corporation, Wolfspeed, GaN Systems, Inc., Toshiba Corporation, N X P Semiconductors N.V., Transphorm Inc., Infineon Technologies AG, Qorvo Corporation, and others are making significant contributions in the field of GaN-based devices.

One of the most important key players in the technology is Cree Inc., which has currently declared that it has signed a multi-year silicon carbide wafer supply agreement with STMicroelectronics. Another important player in the field, NexGen, plans to produce GaN FETs using AIXTRON MOCVD technology.

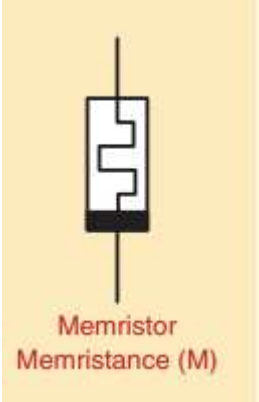
### Conclusion

With such promising features, GaN-on-Silicon technology has a larger scope for use in a wide range of applications. Presently, the technology is still in its infancy and lots of R&D is being carried out towards the advancement of this technology.

# MEMRISTORS – For the Next Generation Computing Systems

## Introduction

Memristor is an electric component which is used to regulate the flow of current in a circuit. It remembers the amount of charge flows through it and retain the data when the power supply cuts off. The resistance of this memristor is variable and can be sensed and controlled using the control and sensing terminals. It is also referred as a memory resistor and as matrix switch. It is a semiconductor that joins a capacitor, resistor, and inductor to make a fourth new kind of element whose resistance is called as memristance that varies as a function of current and flux.



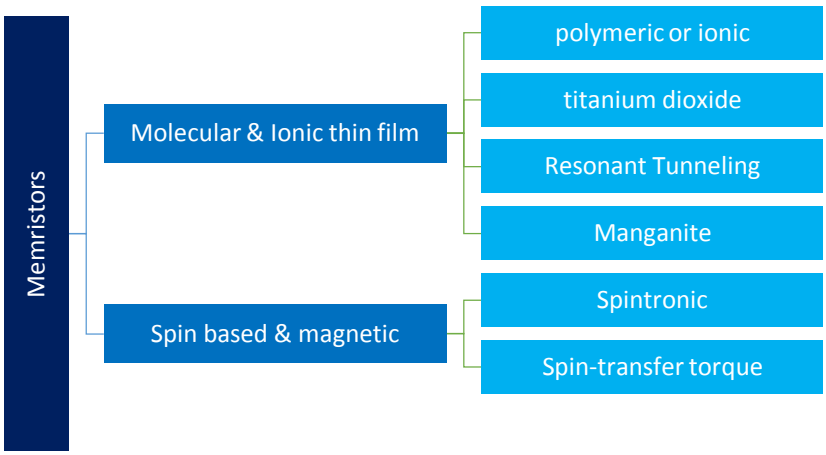

Memristors offer many advantages, which include a source of randomness at the hardware level. This could be used as a barrier to cloning-based hacking, in which whole data networks can be forged, in fine detail, by hackers, and then exploited to gain access to information or a system.

Digitizing the resistance of the memristors such that they mapped to 16-bit precision numbers. Once that was done, an operation that could multiply and sum the rows and columns of the grid can be performed simply by measuring the current at the end of each column.

With the evolution of transistor technology, memristor based products were developed, in an effort to contribute to the world's migration from purely digital to analog computing and to handle super-binary forms of data and it's processing.

Author
Kalyan Maridi
Sr. Strategic Consultant

**Types of memristors:**




**Use case:**

New type of neural network made with memristors can dramatically improve the efficiency of teaching machines to think like humans. The network, called a reservoir computing system, could predict words before they are said during conversation, and help predict future outcomes based on the present.

Next-generation computer components use pattern recognition to shortcut the energy-intensive process conventional systems use to dissect images. It relies on a technique called "sparse coding" to coax their 32-by-32 array of memristors to efficiently analyze and recreate several photos. Memristors make computers smaller, faster and more efficient.

A new memristor computer circuit prototype has the potential to process complex data, such as images and video orders of magnitude, faster and with much less power than today's most advanced systems.

**Outlook:**

Memristors is an emerging technology for next-generation chips, which is highly reconfigurable, scalable, affordable and energy-efficient. Moreover, this technology is absolute for developing novel hardware that can learn and adapt autonomously, much like the human brain.

Memristors can be used for many applications, including digital memory, neuromorphic systems, and logic circuits. These are evolving as it uses less energy and generates less heat. It eliminates the need to write computer programs. As a non-volatile memory these do not consume power when idle. Thus, creating an analog computer that works much faster compared to digital ones.

Increase in the number of industrial robots as there is a huge demand for automation process across industries. These robots required flash memories with zero boot time, more durability, and smaller space consumption, which is possible by memristors. Increase in demand for industrial robots that require memory element, increase in a number of data centers, and growth in a number of portable electronic products where memristor has emerged as a replacement of non-volatile memories.

### R&D Investment & Funding

Research in the field of memristors is still in its early stages; new applications will soon be developed. There is still a significant need for relevant design methodologies and architectures.

Southampton University is leading a project focused on enhancing modern electronics through the development of memristor technology. Southampton University has previously demonstrated a new memristor technology that can store up to 128 discernible memory states per switch, which is nearly four times more than previously reported.

While more than 50 leading technology companies and organizations such as IBM, Amazon, Google, Facebook etc. have recently signed a billion-dollar deal to develop artificial intelligence, memristors could provide the hardware to enable it.

Korea advanced institute of science and technology research team has developed a nonvolatile logic in memory circuit using memristor. These can be used in battery powered flexible electronic devices such as wearable devices and mobile phones. Increase adoption of wearable devices. Wearable devices, such as smart fabrics, smart watches, heart rate monitors, fitness bands, and smart glasses, monitor fitness levels by tracking daily activities of the user. With the help of mobile communication technology, these devices provide communication services.

Researchers are developing a chip that deploys ionic memristor technology to solve the digital problem of security with an analog memory hardware solution.

Intel Labs is developing Spintronic and Memristor based Neuromorphic chip architecture. This proposes a design-scheme for ultra-low power neuromorphic hardware using emerging spin devices and also proposes device models for neuron, based on lateral spin valves that constitute of nano-magnets connected through metal channels.

According to the researchers, memristors could hold the key to a new era in electronics, being both smaller and simpler in form.

### Challenges

As memristor technology is rather new technology which is likely to pave its way in to the commercial sphere, though it is not yet advanced enough to get integrated into next-generation systems. Memristor technology requires significant investment for refining the design and manufacturing process. Lack of proper investment and government funding is hampering its evolution into the market space.

Technology scaling had a great impact on memory in the areas of power and cost, but challenges due to small geometry are hindering this trend. Current 'memristor technology' suffers from a wide variation in terms of how signals are stored and read across devices, both for different types of memristors as well as different runs of the same memristor. Several performance and manufacturability challenges are inhibiting its industry adoption.

Moreover, in terms of material stack, that leads to the perfect device properties has not been discovered yet. Thus, significant R&D investment have been made to sort out the key attributes of Memistors.

### Companies

**HP-** Hewlett Packard headquartered in U.S is multinational information Technology Company produces molecular and ionic thin film titanium dioxide memristors.

**Rambus** – Rambus Incorporated headquartered in U.S designs and develops chip interface technology and architectures. It produces memristors, which change resistance when different voltages are applied and are ideal for Internet of Things applications.

**SK Hynix** – is a South Korean semiconductor company offers ReRAM Memristor which is a non-volatile memory that is used in mobile phones and MP3 players.

smart watches, heart rate monitors, fitness bands, and smart glasses, monitor fitness levels by tracking daily activities of the user. With the help of mobile

### How Internet of things help the memristor technology grow?

The number of internet connected devices within internet of things framework is expected to be more than 200 billion by 2020 which further generates an incredible amount of data that needs processing. As these memristors can retain data for a long period of more than 10 years without power, work with low voltages.


Evolution of IoT and rise in demand of artificial intelligence across several industry verticals, lucrative opportunities are awaiting for memristors.

### Does Machine Learning, artificial intelligence, and neural networks open opportunities for Memristors?

Scientists has created a neural network based on polymeric memristors devices, which can potentially be used to build fundamentally new computers. These developments will primarily help in creating technologies for machine vision, hearing, and other machine sensory systems, and also for intelligent control systems in various fields of applications, including autonomous robots.

# Enhanced Safety and Reduced Transportation Challenges with Real-Time Rail Integrity Monitoring


With rapid development of the railway industries and the demands of Next Generation of Train Control, System, much attention is being paid to the safety of train operations. Rail integrity monitoring is an ongoing trend to help provide safety by tracking the trains along complete railway sections in real time. This is done by gathering reliable information on different parameters, such as the train speed to prevent any collision. Trains operating outside the expected parameters or anomalous activities along the track is also tracked.

Author
Gaurav Samanta
Sr. Strategic Consultant

Pinpoint flat wheels and rail defects, along with the status of generators and trackside machines are monitored. Real-time rail integrity monitoring also helps to detect intruding personnel as well as identify

landslides and rockfall alerts along train routes to prevent harmful incidents.

Major rail track accidents can be prevented with real-time digital visibility for the driver and onboard computer system with rail integrity monitoring. Rail Integrity Monitor employs innovative sensor-mounted technology called SenTrack Monitoring System, provided by Metrom Rail. These systems are placed under the locomotive, which helps in continuously tracking rail integrity in real-time.

### How It Works?

Integrity monitoring system provides a solution by placing the devices along the rail track or on the wagons, which provide 24-hour reporting of the exact condition of the track in terms of gauge distortion, support structure, erosion, and other damages. All exceptions that may cause a train accident are reported in real-time to the monitoring control center as well as broadcasted to the oncoming trains to avoid any potential hazard.

### Type of Rail Integrity Monitoring

There are basically two types of rail integrity monitoring.

**Wireless Sensor Network (WSN) Based Approach:** WSN node is been placed on each wagon starting from the locomotive engine to the last wagon, which measures the acceleration and GPS data and sends it to the coordinator located in the locomotive. This coordinator holds the reference measurements and compares it with the measurements sent from each node. This helps in detecting the train integrity in real time.

**GNSS Approach:** Based on the Global Navigation Satellite System, the train Location Determination Systems (LDS) are located at the rear and the front-side of the train wagons, which are connected to each other by a radio link to track in real time.

**Major Companies Offering Rail Integrity Monitoring Solutions**

**GE:** General Electric, the U.S.-based company provides rail integrity monitoring solutions combining both sensors and cutting-edge analytics to prevent rail incidents before they happen.

**Avante International Technology, Inc.:** AVANTE Rail Gauge & Integrity Monitoring System provides devices to be located along the rail track that provide 24-hour reporting of the exact condition of the track in terms of gauge distortion, support structure, erosion, and other damages.

**Metrom Rail:** Metrom Rail headquartered in the U.S. provides innovative solutions for the rail industry. The company's SenTrack monitoring system provides a complete detection package to monitor the most prevalent hazardous railway conditions.

**Alta Rail Technology:** Alta Rail Technology based out of Brazil is a leading provider of rail technology solutions. It offers a device called End of Train (EOT) to certify the integrity of trains and addresses the fundamental information required for smooth functioning of the rail system. It also offers Locomotive Cabin Unit (LCU), a device that informs the driver of the full length of the train.

**Ansys Rail:** Ansys Rail, a part of Ansys Limited, designs and develops trackside and onboard systems. It also specializes in the design and integration of monitoring, communication, and control in the rail domain.

**Meteorcomm LLC:** Meteorcomm LLC headquartered in Washington offers wireless communication technology for the rail industry that provides reliable mission-critical information.

**Siemens:** Siemens offers onboard communication systems to include various networking components and solutions for onboard and onboard-to-wayside connectivity.

### R&D Investment Activities

GE has been researching on new ideas of the Rail Integrity Monitoring technology that can be implemented on a wide range on the rolling-stock platforms including locomotives, passenger and freight cars. GE transportation division is working on digital offerings for the Indian railways. It is planning to offer a digital path across the platforms for fleet management by providing real-time data connectivity.

In 2017, the Government of Australia established $10 Billion National Rail Program. The program aimed at improving the passenger rail networks in and around the cities as well as the nearby regional centers and setting up reliable transport networks.

Key challenging techniques such as composite transportation, train-to-train communication, security for high speed railway and the fifth generation wireless communication related techniques are being developed by the U.S. railway for safer and more secure operation.

Development activities by companies such as Tata Power Solar, Suzlon, and others related to green energy technology has been increasing in the recent years. This is due to the high preference for the usage of solar and wind power to power wireless networks and also because of their relative high performance-cost ratio.

### Challenges

- Uncertainty of wireless communication channels, may lead to failure of communication and positioning would be a major challenge.
- It is difficult to provide reliable, practical, and vital train integrity monitoring systems in trains having no electrical infrastructure.
- Introduction of train integrity monitoring is limited to only few dedicated passenger corridors or lines that operate with the state-of-the-art freight trains and are equipped with a train bus system.

### Conclusion

By deploying the Rail Integrity Monitoring solutions, trains can be tracked to ensure safety with a very high degree of dependability. The efficient communication offered by this solution between the front and rear of the train reduces the accidents. Some of the instances such as uncertainty in the wireless communication is posing a challenge to the rail integrity monitoring system. However, rapid technological advancements in the wireless connectivity industry will more likely eliminate the uncertainty in the wireless communication, thereby providing prospects to the rail integrity monitoring solutions in the future.

## Related Reports

1. **Head Mounted Display Market**
   https://industryarc.com/Report/15023/head-mounted-display-market.html
2. **Interactive Display Market**
   https://industryarc.com/Report/16315/interactive-display-market.html
3. **High K-Dielectric Material Market**
   https://industryarc.com/Research/High-k-Dielectric-Material-Market-Research-501560
4. **Printed Electronics Devices and Material Market**
   https://industryarc.com/Report/18051/printed-electronics-devices-material-market.html
5. **Disposable Medical Textiles**
   https://industryarc.com/Research/Disposable-Medical-Textiles-Market-Research-501648
6. **Ceramic Textile Market**
   https://industryarc.com/Report/16458/ceramic-textile-market.html
7. **3D printing**
   https://industryarc.com/Report/18389/3d-printing-market-research-report-analysis.html
8. **Silicon EPI Wafer Market**
   https://industryarc.com/Report/18467/silicon-epi-wafer-market-research-report-analysis.html
9. **Silicon Wafers Market**
   https://industryarc.com/Report/15369/silicon-wafers-market.html
10. **Wireless Infrastructure Market**
    https://industryarc.com/Report/16386/wireless-infrastructure-market.html
11. **Wireless Sensor Network Market**
    https://industryarc.com/Report/211/Wireless-Sensor-Network-Market-Research-Report.html
12. **Safety Sensors and Switches Market**
    https://industryarc.com/Report/121/Safety-Sensors-Market.html
13. **ADAS Camera Market**
    https://industryarc.com/Report/17953/adas-camera-market.html
14. **LiDAR Market**
    https://industryarc.com/Report/15765/lidar-market.html
15. **Automotive LiDAR Market**
    https://industryarc.com/Report/18128/automotive-lidar-market.html#menu1
16. **Gallium Nitride (GaN) Substrates Market**
    https://industryarc.com/Report/1264/GaN-substrates-market-research-report.html
17. **Nanotechnology Market**
    https://industryarc.com/Report/15022/nanotechnology-market.html
18. **Railway Management System Market**
    https://industryarc.com/Research/Railway-Management-System-Market-Research-500759
19. **Intelligent Railway System Market**
    https://industryarc.com/Research/Intelligent-Railway-System-Market-Research-502729
20. **Memristor Market**
    https://industryarc.com/Report/15092/memristor-market.html#menu1

## Contact Us

**Address**

Plot No. 56, Huda Techno Enclave, 4th Floor,
LP Towers, Madhapur,
Hyderabad,
Telangana - 500081


**Phone**

INDIA Sales Support
(+91) 040-64621234
U.S Sales Support
+1 614-588-8538 (Ext-101)

**Social Media**

Facebook.com/industryarc
Twitter.com/industryarc
Youtube.com/industryarc