e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:01/January-2024 Impact Factor- 7.868 www.irjmets.com

DEVELOPMENT OF CONDUCTIVE INK PRINTER FOR PCB PRINTING

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DOI : https://www.doi.org/10.56726/IRJMETS48797

ABSTRACT

Innovative approaches are required for the efficient and economical manufacture of printed circuit boards (PCBs) due to the quick evolution of electronic devices. The creation of a specialized conductive ink printer for PCB manufacture is the main goal of this project. The goal is to develop a flexible and accurate printing system that can replace conventional etching techniques by depositing electrical traces on a range of materials. For excellent conductivity, resolution, and dependability, much care has been taken in the formulation of the conductive ink, printer design, and deposition procedure. This project attempts to expedite the PCB prototyping process, saving money and time by utilizing sophisticated printing technologies. Additionally, the suggested printer allows for design freedom, which speeds up PCB layout modification and iteration. The incorporation of intuitive software enabling smooth design-to-print workflows is one of the technology's key characteristics, opening up use for both enthusiasts and professionals. When evaluating the environmental impact, eco-friendly ink formulations and waste reduction in comparison to traditional PCB manufacturing procedures are highlighted. The initiative is important because it has the potential to completely change the PCB fabrication industry by providing a productive, economical, and ecologically friendly substitute.

Keywords: Printed Circuit Boards, Conductivity, Fabrication.

I. INTRODUCTION

Background: Virtually all electronic devices are built around printed circuit boards (PCBs), which act as a platform for connecting various electronic components. Chemical etching is one of the complex and frequently resource-intensive processes used in traditional PCB fabrication methods. Innovative manufacturing techniques that can meet the challenges of miniaturization, flexibility, and rapid prototyping are becoming more and more necessary as the electronics industry develops. Technology for printing conductive ink appears to be a promising way to transform the manufacturing process of printed circuit boards. In contrast to traditional techniques, which frequently entail subtractive steps and produce chemical waste, conductive ink printing presents a more accurate and sustainable solution. With the use of this technique, conductive traces can be directly deposited onto substrates, increasing design flexibility, and minimizing material waste. One promising way to transform the PCB manufacturing process is using conductive ink printing. An environmentally friendly and more efficient substitute for traditional etching is the ability to print conductive traces directly onto substrates. A dedicated printer designed for PCB applications is required because the compatibility of current commercial inkjet printers with conductive inks is frequently restricted. By developing a specialized printing system, the "Development of Conductive Ink Printer for PCB" project seeks to close this technological divide. This system will enable complex PCB designs by offering high-resolution printing in addition to supporting a range of conductive ink formulations. This project has the potential to be revolutionary because it can democratize PCB prototyping, enabling engineers and designers to test and iterate ideas quickly on the spot and cut down on the time and expense involved in outsourcing PCB production. Additionally, this project is in line with the larger industry trend towards eco-friendly and sustainable practices. The suggested conductive ink printer is positioned as a forward-thinking solution in electronic fabrication due to its formulation of environmentally conscious conductive inks and decreased material waste when compared to traditional manufacturing methods

Relevance: A fundamental change is required in the field of electronics manufacturing, specifically in the fabrication of printed circuit boards (PCBs), due to the rapid advancement of technology. Traditional techniques, like chemical etching, have several drawbacks, from restrictions on precision and customization to environmental issues. The need for a revolutionary solution grows as we navigate an era dominated by wearable, personalized electronics, and the Internet of Things. The "Development of Conductive Ink Printer for PCB" project is driven by the desire to address the drawbacks of conventional PCB manufacturing techniques. In addition to being resource intensive, chemical etching processes impede the quick iterations needed for research and development prototyping. With a tool that combines accessibility and precision, the proposed conductive ink printer seeks to enable designers, engineers, and innovators to convert concepts more easily into working prototypes. Furthermore, the project is in line with the expanding need for environmentally friendly and sustainable manufacturing methods. Our goal is to lessen the environmental damage caused by chemical waste and energy usage in conventional PCB manufacturing by introducing a conductive ink printer. Creating environmentally friendly ink formulations and incorporating an intuitive user interface are two aspects of a comprehensive strategy that guarantee the technology not only satisfies technical specifications but also adheres to the values of conscientious and progressive electronics design. Essentially, the goal of this project is to transform PCB fabrication into something more accessible, effective, and eco-friendly. The conductive ink printer aims to be a catalyst for innovation, opening a new era of electronics development that is sustainable and adaptable to the changing demands of the tech landscape by bridging the gap between current manufacturing capabilities and the needs for rapid prototyping

Scope and Limitations:

Scope:

- Conductive Ink Formulation: The goal of the project is to investigate and create a specific conductive ink formulation that can be used in printed circuit boards (PCBs). To achieve this, the conductivity, adhesion, and substrate compatibility of the ink must be optimized.
- Printing Design and Development: The scope of work encompasses the design and construction of a conductive ink printer that is capable of precisely depositing traces onto PCB substrates. This includes making sure the formulated ink is compatible, designing precise nozzles, and choosing the right printing technologies.
- Software Integration: To enable smooth design-to-print workflows, user-friendly software will be created as part of the development. For effective and personalized PCB prototyping, users will be able to import PCB designs and operate the printer with the software.
- Environmental Considerations: In comparison to conventional PCB manufacturing techniques, the project will investigate environmentally friendly features like the use of eco friendly ink formulations and waste minimization. 5. Versatility: To allow for a wide range of electronic applications, the conductive ink printer should be adaptable enough to handle PCBs with varying sizes, shapes, and designs.

Limitations:

- Material Compatibility: Depending on whether conductive ink is compatible with a particular material or substrate, the project may be limited. Comprehensive testing will be necessary to guarantee wide applicability.
- Print Speed: The printer's speed may be constrained based on the printing technology selected. Requiring accuracy while maintaining speed is a crucial factor
- Cost Constraints: The development may run into issues with the cost of materials, printer parts, and the manufacturing process. This might affect how widely available the technology is to users.
- The durability of Printed Traces: One important consideration is the printed conductive traces' longevity. The project might not be able to achieve long-term stability and dependability, particularly in harsh environmental circumstances.
- The complexity of Design: It can be difficult to strike a compromise between a small, user-friendly design and the complexity needed for extreme precision. Achieving the ideal balance is essential for broad adoption.
- Regulatory Compliance: Complying with PCB regulations and industry standards may present challenges. A crucial factor is making sure that the applicable standards are followed

II. METHODOLOGY

To develop a conductive ink printer for PCB (Printed Circuit Board) printing, following structured methodology has been utilized:

Research and Planning:

1. Conducted thorough research on existing PCB printing technologies and conductive inks Explored and analysed the current state-of-the-art PCB printing technologies, including inkjet, screen printing, and other emerging methods. Studied the strengths, limitations, and applications of each technology. Investigated the properties, compositions, and characteristics of various conductive inks available in the market or reported in the research literature.
2. Defined project objectives, scope, and constraints Identified the main goals of developing a conductive ink printer for PCB printing. For instance, objectives included enhancing efficiency, reducing costs, or enabling rapid prototyping. Defined the scope of the project, including the intended applications, targeted user base, and potential scalability. Identified and outlined the constraints such as budget limitations, timeframes, available resources, and technological limitations that could influence the project's execution.
3. Set specific goals for the printer's capabilities and performance. Established specific, measurable, achievable, relevant, and time-bound (SMART) goals for the conductive ink printer. Determined the printer's desired capabilities, such as resolution, printing speed, accuracy, substrate compatibility (e.g., flexible, or rigid substrates), and the ability to print various conductive patterns or circuits. Defined performance metrics that will be used to evaluate the printer's effectiveness, such as conductivity levels, adhesion strength, reliability, and repeatability of prints.
4. Risk Assessment and Mitigation. Identified potential risks and challenges associated with the project, such as technical complexities, material availability, or regulatory hurdles. Developed mitigation strategies or contingency plans to address these risks proactively.

Requirement Analysis:

1. Identified the required functionalities and specifications of the conductive ink printer. Printing Capabilities- Defined the specific printing capabilities required, such as resolution (in DPI), printing speed, accuracy, and the ability to print different sizes and complexities of PCBs. Ink Deposition Mechanism- Determined the most suitable ink deposition method (e.g., inkjet, screen printing) for achieving precision, reliability, and the desired conductivity. Control Systems- Specified the necessary control systems and software required to manage ink deposition, movement, and alignment of the printer components. Substrate Compatibility Identified the range of substrates the printer should be compatible with, such as various types of flexible or rigid substrates commonly used in PCB manufacturing. Printhead Design- Defined the print head specifications, including nozzle size, number of nozzles, printhead technology (thermal, piezoelectric), and printing modes (single-pass or multi-pass) to ensure accurate and consistent ink deposition. Precision and Alignment- Determined the required precision and alignment mechanisms to ensure the accurate placement of conductive ink for intricate PCB designs
2. Determined the materials needed, such as compatible substrates and conductive inks. Substrates- Identified and specified compatible substrates suitable for the intended application. Considered factors like flexibility, thermal stability, and compatibility with the conductive ink. Conductive Inks- Determined the type of conductive inks required based on the printing technology, substrate, conductivity levels needed, adhesion properties, curing methods, and compatibility with printer components. Additional Materials- Apart from substrates and conductive inks, auxiliary materials such as adhesion promoters, surface treatment chemicals, or protective coatings are essential for the printing process and PCB functionality. Quality Standards- Ensured that the selected materials meet quality standards and are readily available for consistent and reliable printing. Environmental Considerations- Assessed environmental factors such as the ink's eco-friendliness, toxicity, and disposal requirements to align with sustainability goals and regulatory compliance.

Assembly of the Printer:

As the Ender-3 is a 3D Printer kit and not a pre-built machine, the assembly is carried out into several different stages:

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1. Frame Assembly

The base of the Ender-3 comes pre-assembled; there is only a need to attach the vertical beams at this stage. These consist of (2) 20×40 aluminum extrusions secured to the frame using two screws on each side (inserted from the bottom). The base needs to be shifted to the side for

Fig 1: Frame Assembly.

Right Side- The right side of the frame was the one to be started first, where one 20×40 beam with vertical pre-drilled holes is required. The hole closer to the end, which is approximately 80mm away, is placed at the bottom, indicating that this is the side into which the base will be screwed. The beam was secured into place by inserting two M5x45 screws through the bottom and into the beam, ensuring they were tightened properly.

Left Side- The second 20×40 beam had pre-drilled holes positioned side by side on one end of the beam. This end is to be screwed into the base of the frame, just as it was done with the right side before.

It was ensured that the holes in the vertical beams were correctly aligned on both sides, according to the provided image for reference.

Fig 2: LCD and Power supply Assembly.

When facing the machine from the front, two electrical components needed to be installed on the right side, namely the LCD screen and the power supply. The LCD screen, accompanied by a bracket, was mounted on the front right side, while the power supply unit was mounted onto the right vertical beam from behind. Concerning the LCD screen, two M5x8 screws were used to attach it to the base of the frame. The diagonal holes on the screen bracket were aligned with the corresponding holes in the extrusion behind it, and then the screws were inserted and tightened as depicted in the first image. As for the power supply, two M4x20 screws were utilized to attach it to the right vertical beam. The holes in the power supply were aligned with the holes in the extrusion, and afterward, the screws were inserted and tightened as shown in the second image of figure 2.

Fig 3: Z limit switch and Z motor Assembly

On the left side of the frame, two more components needed to be installed, namely the Z-Limit Switch and the Z Motor. The Z-Limit Switch was mounted to the side of the left vertical beam, while the Z Motor was attached using a bracket on the back of the vertical frame. Regarding the Z-Limit Switch, the L-shaped bracket with two screws and T-nuts, found in one of the plastic zip-lock bags, was used. This bracket was installed upside down, with the switch facing the top of the frame. The T-nuts were adjusted as required to ensure free movement, rotated to face vertically, and then the bracket was inserted into the side channel as demonstrated. The precise location was to be adjusted later, with the exact position being unimportant at that particular stage. Concerning the Z motor, it was attached to the rear side of the left vertical beam using two M4x18 screws. The motor had a pre-installed bracket, which was utilized to mount the assembly to the frame. The screws were inserted and tightened to securely fasten the motor in place.

Fig 4: Inserting Lead screw.

At that instant, the lead screw was to be inserted into the Z motor coupler, with instructions to leave the set screws loose temporarily. It was emphasized to handle it using the rubber sheath provided. The lead screw had already been lubricated, and the protective cover was to prevent the grease from being removed by hands.

2. X-Axis Assembly

The X-axis, identified as the thin 20×20 extrusion running horizontally across the frame, had been mounted to the vertical beams on both sides. It has the capability to move in various directions—up, down, left, and right—during the printing process. Mounting assemblies were present on both sides of the X-axis, with the extruder carriage positioned in the middle. The motion of the carriage is controlled using a belt. Please take note that the package included two beams with the same dimensions but different pre-drilled hole patterns. There were three holes on either.

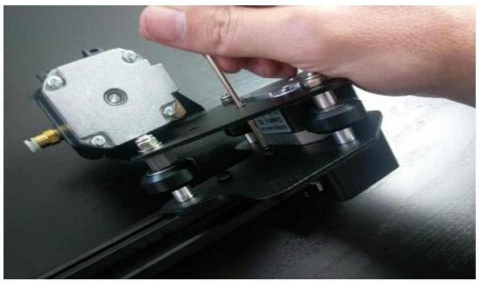

Fig 5: Assembly of left mount.

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The left mount, containing two motors—the X-axis motor and the Extruder motor—was also identifiable by the Facebook QR code. This assembly was attached to the X-axis beam using two M4x16 screws, which were inserted from within the metal plate, as illustrated in figure 5. It was instructed to align this with the smaller holes at the end of the beam and hand-tighten the screws to secure the unit in place. After the mount had been fastened to the beam, the hex wrench was inserted through the holes in the second metal plate, and the screws were tightened down. It's important to note that the innermost hole of the X-axis beam was larger than the others, specifically drilled to accommodate the large bolt head on the motor assembly. This allowed the unit to sit flush against the beam. To aid in alignment of the other two holes, positioning the bolt head first was suggested due to limited visibility at that stage.

Fig 6: Positioning of gantry

The gantry was slid into place from the open end of the X-axis beam by positioning the wheels at the top and bottom. It was ensured that the wheels could now roll smoothly back and forth. In cases where all three wheels did not sit flush against the beam, the eccentric nut behind the bottom wheel was turned until it clamped in place. Please note that the side with the fan was to face the front of the machine, similar to the positioning of the QR code on the left side of the beam, as depicted in second image of figure 6.

Fig 7: Mounting bracket and belt tensioner.

The finalization of the X-axis assembly involved the installation of the mounting bracket and belt tensioner on the right side of the beam. The mounting bracket was affixed to the rear of the X-axis beam using two M4x16 screws to secure it in place. The bracket was aligned with the corresponding holes, and the screws were inserted and tightened to fix it into position, as demonstrated in first image of figure 7. On the opposite side of the extrusion, the belt tensioner was then installed using the pre-threaded bolts and T-nuts. The T-nuts were rotated to fit inside the channel, and the bracket was positioned at the end of the beam. This positioning was to be adjusted after the belt installation, with the exact position being unimportant at that particular stage.

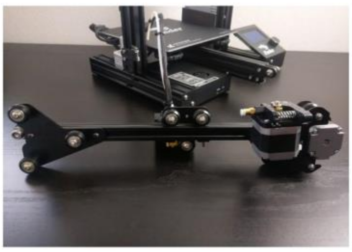

Fig 8: Assembled X-axis.

3. X-axis Belt Installation

The completion of the X-axis assembly left only the installation of the GT2 belt pending. Even though this task might have been more convenient to undertake at an earlier stage, the official instructions postponed this step until the final stages With the teeth facing into the beam, the GT2 belt was inserted inside the channel and laid over the edge. the extruder carriage was rolled over the belt with minimal force, enabling it to slide under the wheel and feed into the empty space below. The same process was repeated for the second wheel, positioning the belt beneath the carriage At each end of the X-axis, there was a pulley around which the belt needed to be wrapped. These pulleys served as guides to maintain the belt's position and facilitate smooth motion during operation. With the belt's teeth facing inward toward the pulleys, it was wrapped around both ends and directed back towards the extruder carriage, passing underneath the beam. notches were present on either side of the lower wheel, designed to secure the ends of the belt. The brass ends of the belt were inserted just below these notches, generating moderate tension. To complete the procedure, the bolts on the previously installed X-axis belt tensioner were loosened. The tensioner was pulled outwards as far as possible to eliminate any unwanted slack and create tension on the GT2 belt. Following this, the bolts were tightened back down to secure the tensioner in its new position, ensuring it was taut.

4. Machine Assembly

With the frame and X-axis both assembled, all that remains now is to put these pieces together. With the front of the X-axis positioned forward, the entire unit was positioned above the vertical beams on either side of the machine. The X-axis was then lowered onto the frame, allowing the outer wheels to slide into the side channels of the extrusion. There had been a need to slightly press the Z beams inwards to facilitate the fitting of the X-axis. The lead screw was threaded up into the gold bracket behind the bowden motor. If additional room for movement was necessary, the bracket was loosened. The X-axis was lowered to the bottom by manually rotating the Z coupler, and then the lead screw was locked and secured into position by tightening the set screws. It's crucial to remember that the Z coupler was used to raise and lower the X-axis in order to ensure smooth movement. Adjustments were probably needed to make sure the lead screw wasn't restricted if it locked up .The remaining 20×20 beam had four M5x25 screws threaded into the available holes. It was noted that one side had larger openings designed for the washers to fit into. To ensure proper fitment, the screws were inserted through these larger openings, as they wouldn't sit flush otherwise. Subsequently, the beam was positioned across the top of the frame, aligning the screws with the holes in the vertical beams. These screws were then tightened down to finalize the machine assembly

5. Wiring Guide

1) Power Cable: Uses two XT-60 connectors to connect the main board and electronics to the power supply unit. Securely plug these ends into each other, making sure that the red and black wires match on both sides.
2) Z-Axis Motor Cable: Powers the Z-axis motor, which raises and lowers the gantry.
3) X-Axis Motor Cable: Powers the X-axis motor, which moves the gantry left and right.
4) Extruder Motor Cable: Powers the extruder motor, which feeds filament into the extruder’s hot end.
5) Z-Axis Limit Switch: Triggers when the Z-axis has reached this switch. Stops the printer from trying to move outside of the defined bounding box.
6) X-Axis Limit Switch: Triggers when the X-axis has reached this switch. Stops the printer from trying to move outside of the defined bounding box

6. Final Adjustments

The Ender-3 was almost operational once it had been put together. However, there were still a few minor adjustments that needed to be done before turning on the machine. Some elements had temporary placements or default settings during the early stages, to be calibrated later

1. Power Supply Voltage

The Ender-3 comes equipped with a 24V switching power supply, allowing it to operate on either 110 volts or 220 volts. It was emphasized that configuring this correctly was crucial, as an incorrect setting would bring the 3D printer to a halt. Before powering on the machine, it was strongly advised to double-check this setting. The switch was clearly visible, with a yellow sticker indicating which side to use for each voltage. It had a notch designed to accommodate a tool for adjusting the setting, and a small flat-head screwdriver or an equivalent tool worked well in this scenario

2. Z-Limit Switch

The Z-Limit Switch, recognized as the upside-down L bracket situated on the left side of the frame, was responsible for signaling the Ender-3 to halt the lowering of the X-axis towards the bed. This was installed during the frame assembly, initially placed in an estimated position that was intended to be adjusted later. Initially, the four thumb wheels beneath the bed were rotated in a counter-clockwise direction. This action contracted the springs and lowered the build plate. Care was taken not to overtighten these wheels but to continue turning them until the springs were completely compressed. This adjustment provided adequate distance between the bed and the extruder, ensuring ample space to level the bed once the process was completed. Subsequently, the Z-Limit Switch on the left side of the frame was loosened, allowing the bracket to be slid up or down. The switch was positioned several millimeters above the bed itself to prevent the extruder from colliding with the build plate during homing. Thus, setting it higher at the beginning was preferred to prevent any potential impact The Ender-3 was turned on using the power switch located underneath the power supply. From the LCD screen, the knob was pushed once to access the menu. Then, the menu was navigated to Prepare -> Auto Home, and the knob was pushed once more to select it. This action homed the extruder by moving it to the far left and subsequently lowering it until the Z-Limit Switch was triggered. Upon completion of the homing process, the distance between the nozzle and the bed was observed. As the build plate was currently in its lowest position, a small gap of approximately 3-5mm of space between the nozzle and the bed was desired. The Z-Limit Switch was lowered as needed to make modifications if the nozzle was noticeably farther away from the construction plate than this designated distance. The Auto Home process was repeated until the distance between the nozzle and the bed was minimized accordingly.

III. MODELING AND ANALYSIS

Printer Development for Ink Printing:

Design the printer considering aspects like ink deposition mechanisms, precision, resolution, and substrate compatibility.

1. Ink Deposition Mechanisms

Determined and designed the ink deposition mechanism based on the chosen printing technology (e.g., inkjet, screen printing). Ensure the mechanism is capable of accurately depositing conductive ink onto the substrate with the desired precision and resolution.

2. Precision and Resolution

Focused on achieving high precision and resolution in the printer's design to ensure accurate placement of conductive ink for intricate PCB designs. This involved the selection of high quality components, precise mechanical movements, and optimized print head characteristics.

3. Substrate Compatibility

Designed the printer to accommodate various substrates commonly used in PCB manufacturing, considering their sizes, thicknesses, and flexibility.

4. Printer Architecture

Determined the printer's overall architecture, including the frame, movement systems (linear stages or XYZ stages), and any additional components necessary for ink loading, substrate handling, and print bed stability. Selected and designed print head attachment suitable for depositing conductive ink accurately.

5. Printer Prototyping and Testing

Built a prototype of the printer based on the designed specifications for conductive ink printing. Conducted iterative testing to ensure accuracy, reliability, and consistency of PCB printing.

6. Optimization and Refinement

Analyzed test results and refined the printer design, and ink formulation as needed. Optimized printing parameters for better efficiency and quality.

7. Performance Evaluation

Evaluated the printer's performance against predefined metrics like accuracy, speed, and print quality. Conducted tests on different types of PCB designs to validate its versatility. Throughout this methodology, it was crucial to maintain documentation, conduct regular tests, seek feedback, and be prepared for iterations and refinements to achieve the desired outcomes in developing the conductive ink printer for PCB printing.

Modification Of Printer Head

1. Need for development of attachment for printer head

The nozzle of Ender 3D printer has diameter of 0.4 mm and very fine size it is not suitable for ink dispensing. After experimentation with the conductive ink, it is observed that the ink had not come through the nozzle. So, it was decided that the nozzle attached to the printer is to be changed. Further it is decided that the ink is to be filled in a cartridge. The printer head is not designed to print the pattern with an attach pen. The development process consists of different steps.

2. Different Steps of Development

2.1. Offsetting The Extruder Position

The offsetting of extruder is done by the changing the START and END G-code in the machine settings. The result of this is by performing above instruction printer knows where the actual pen is attached.

Start G-Code

Ender 3 S1 Start G-code

G92 E0 ; Reset Extruder

G28; Home all axes

M420 S1 Z2; CR/BL Touch Auto Level. Remove line

G92 Eo ; Reset Extruder

End G-code

Ender 3 S1 End G-code

G91; Relative Positioning

G1 Z10; Raise Z more

G90; Absolute Positioning

G1 X0 Y{Machine_depth} ; Present print

M84 X Y E; Disable all steppers but Z

Table.1 Nozzle Setting

Nozzle Settings	Units
Compatible Material Diameter	1.75 mm
Nozzle Offset X	20.0 mm
Nozzle Offset Y	-60.0 mm
Cooling Fan Number	0

4. 3D Printing of Attachment

For rapid prototyping of attachment, the 3D printing of designed part is followed. The fused deposition method is used to print the part. The material used is PLA of red color with infill density of 60 percent. The design is converted to STL file at the time of saving the file. Further by using the Creality slicing software the STL file is converted to g-code and then the printing is continued.

5. Post Processing and Assembly

The printed part is not ready for assembly the supports generated for overhanging structure are need to remove. For assembly, first the material already inside the extruder of printer is heated by changing the

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settings of extruder with the help of knob and display. After waiting few minutes at heating condition, the PLA wire is pulled backward this leads in removal of material from extruder then the entire coil of PLA wire is detached. The next step is removing the nozzle head and attach the printed part by help of two spare M4 bolt.

Conductive Ink Preparation:

1. Synthesis Of Graphene Oxide by Hummer's Method

With the Hummers' method, potassium permanganate is added to a solution of graphite, sodium nitrate, and sulfuric acid to produce graphite oxide. It's a dependable way to produce large amounts of graphite oxide, and scientists and lab technicians use it frequently. In order to create a version of the material known as graphene oxide that is only one atom thick, it is also customisable. In 1958, Hummers' method was created as a quicker, safer, and more effective way to produce graphite oxide. Prior to the development of the technique, the use of powerful sulfuric and nitric acid made the manufacture of graphite oxide slow and dangerous. The addition of potassium chlorate was made possible by the Staudenmeier–Hoffman–Hamdi method. One gramme of graphite oxide was created for every ten grammes of potassium chlorate using this process, but it also included additional risks. As a substitute for the methods mentioned previously, William S. Hummers and Richard E. Offeman developed their own approach after observing the risks that the National Lead Company's employees faced. They took a similar strategy in that they mixed graphite into a strong acid solution. But they reduced it to a simple mixture of potassium permanganate, sodium nitrate, concentrated sulfuric acid, and graphite. They also avoided the majority of the explosive risk associated with the Staudenmeier-Hoffman-Hamdi approach and did not need to use temperatures higher than 98 °C. The fundamental chemical process of Hummers' approach is the oxidation of graphite, which introduces oxygen molecules to the pure carbon graphene. Sodium nitrate and potassium permanganate serve as catalysts in the reaction between concentrated sulfuric acid and graphene. For every 100 grammes of graphite consumed, the technique can produce about 188 grammes of graphite oxide. Graphite oxide is characterized by a carbon to oxygen ratio that falls between 1 and 2.1–2.9. Ash and water are found to be the main pollutants. The process results in the evolution of toxic gasses such nitrogen dioxide and dinitrogen tetra oxide. The end product's carbon-to-oxygen ratio is usually 47.06% carbon, 27.97% oxygen, 22.99% water, and 1.98% ash. Since the procedure is the fastest typical way of making graphite oxide with a relatively high C/O ratio, it has been adopted by a large number of researchers and scientists who are interested in using graphite oxide for different uses. Hummers' approach is typically mentioned in some capacity when scientists and researchers are adding a significant amount of graphite oxide within time constraints.

2. Reduction Of Graphene Oxide

The most popular method for producing graphene in large quantities is oxidizing graphite to generate graphene oxide (GO), which is then chemically reduced to form reduced graphene oxide (rGO) or graphene. Different methods have been used to decrease GO with different atomic ratios of carbon to oxygen (C/O). In order to get the necessary functionalized graphene materials, the researchers have chosen to employ a controlled reduction process for the chemical reduction of graphene oxide (GO). This requires taking into account the GO's structure, the reducing source's chemical reactivity and efficiency, factors influencing the degree of reduction, and the mechanism of action. This review places a special emphasis on each of these factors in a methodical manner, which may inspire scholars everywhere to develop new techniques for the industrial manufacturing of materials based on graphene.

3. Washing And Filtering

To extract the reduced graphene oxide from the reaction by-products, strain the mixture through a filter. Wash the recovered rGO multiple times with water or an appropriate solvent to get rid of any remaining reaction by-products and hydrazine hydrate

4. Drying And Collection

Reduced graphene oxide should be dried. Techniques like hoover drying and freeze-drying can be used for this. Gather the film or powdered reduced graphene oxide.

5. Preparation Of Nano Particles (sol-gel method)

A more chemical (wet chemical method) for creating different nanostructures, particularly metal oxide nanoparticles, is the sol-gel procedure. This process involves dissolving the molecular precursor (often metal

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alkoxide) in alcohol or water, heating it, and stirring it to cause hydrolysis or alcohol hydrolysis to turn it into gel. Depending on the required qualities and intended use of the gel, the wet or damp gel formed from the hydrolysis/alcoholysis process should be dried using the suitable techniques. For instance, burning alcohol completes the drying process in the case of an alcoholic solution. The generated gels are pulverized and then calcined following the drying phase. The sol-gel process is an economical technique that allows for excellent control over the products' chemical makeup because of the low reaction temperature. In many applications, the sol-gel technique can act as a bridge between thin films of metal oxides and can be employed as a molding material in the ceramics manufacturing process. The sol-gel process yields materials that find use in surface engineering, optical, electrical, energy, medicinal, and separation technologies (like chromatography). The production of nanoparticles with varying chemical compositions can be achieved by the conventional and industrial sol-gel process. The homogenous solidification of the precursors and subsequent gelation form the foundation of the sol-gel process. The drying technique has a big impact on the dried gel's characteristics. Put differently, the "removing solvent method" is chosen based on the intended usage of the gel. Dried gels are employed in a variety of industries, including surface coating, insulation for buildings, and the creation of speciality apparel. It is noteworthy to emphasize that the gel can be ground using specialized mills to produce nanoparticles. The sol-gel process is carried out in a liquid state and at low temperatures—typically less than 100°C. Naturally, the end product is a solid, and these solids are produced by the polymerization process, which entails the formation of M-OH-M or M-O-M bonds between the metal atoms in the raw materials (where M is the metal atom). The sol-gel method of aero gel synthesis involves two processes, which are as follows:

(i) Separate colloidal solid particles of nanometre-sized diameters form during the first stage.

(ii) Colloidal particles in the solvent combine to form a gel during the second stage.

6. Addition Of Binder to Synthesized Graphene and Metal Nanoparticles

During this step synthesized graphene and the metal nano particles are mixed with binder so that these all ingredients get synchronized well. For binding purpose, a binder called as PVDF (Polyvinylidene fluoride) is used which has best binding properties. PVDF – Synthetic resin polymerized vinylidene fluoride ($CH_2=CF_2$) yields polyvinylidene fluoride (PVDF). PVDF is a hard plastic that can withstand flames, electricity, and most chemicals. It is extruded as an electrical insulating sheet and injection-molded into bottles for the chemical industry. Because of its flame resistance, insulating wire in buildings and airplanes is particularly advantageous uses for it. Piezoelectricity also exists in PVDF, which responds to pressure by altering its electrical charge and, in turn, applies pressure in reaction to an applied electric field. Because of this special quality, it works well as a material for transducers in headphones, microphones, and sound detectors.

IV. RESULTS AND DISCUSSION

The significance of the adopted process of using the 3D printer for printing the circuit or to check the conductivity of the PCB results in the flow of electricity through the PCB. The results explain that the conductivity flowing through the printed line is acceptable. For the PCB conductivity, different thickness was used to determine the relation between thickness and the electrical conductivity. The relation between electrical conductivity and thickness is given below.

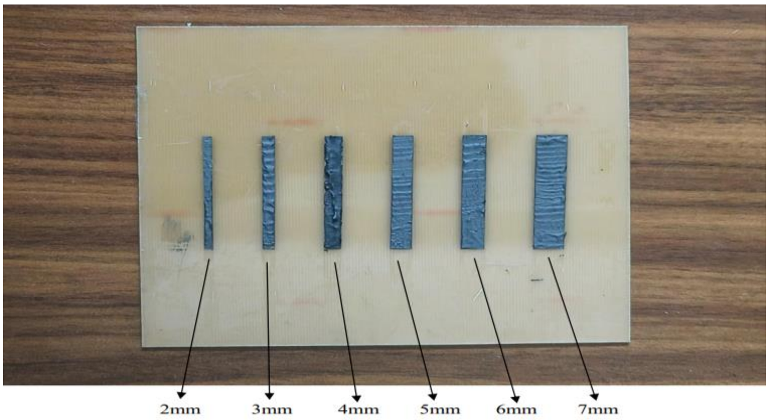
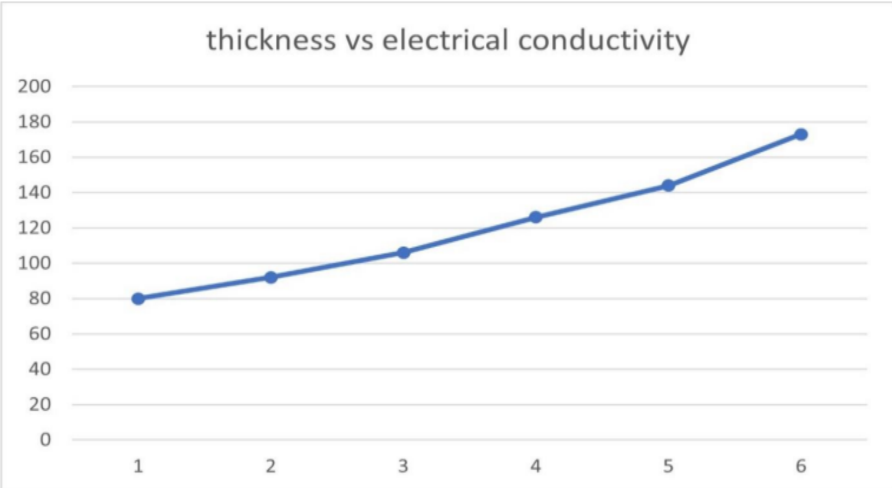


Figure 9: The image shows the thickness of the Ink for checking the electrical conductivity.

Table 2: An increase in thickness increases conductivity.

Thickness(mm)	Conductivity (siemens per meter)
1	80
2	92
3	106
4	126
5	144
6	173



Graph 1: Relation between Thickness of ink and electrical conductivity

V. CONCLUSION

Future Scope

The below graph shows the increase in the electrical conductivity with the increase in the thickness of the ink. Where the conductivity is given in Siemens per meter using the multimeter device. On the other hand, thickness is given in mm, From the given relation it shows that the electrical conductivity is directly proportional to the thickness of a given material.

Future advances in PCB 3D printing have the potential to completely transform the electronics manufacturing industry. The capacity of the technology to quickly prototype and alter circuit boards is expected to simplify the development process, allowing for quicker iterations and a shorter time to market for electronic products. As materials continue to progress, 3D printing may make it possible to incorporate electronic parts straight into the architecture of devices, opening the door to smaller, lighter designs. Another predictable trend is on-demand manufacturing, which is made possible by 3D printing's ability to produce customized products in small, affordable batches. With time, 3D printing materials and technology will likely grow more affordable, making it a more realistic choice for a variety of sectors. To drive innovation and integrate new technologies, cooperation between 3D printing companies and well established electronics manufacturers will be essential. It's crucial to remember that different sectors and applications may use 3D printing for PCBs differently. Although there is a lot of interesting potential, widespread adoption requires addressing issues including material characteristics, quality control, and scalability. To stay informed about the future of 3D printing in the electronics business, keep a watch on research, industry changes, and technology improvements. On-demand manufacturing might be facilitated by 3D printing, which would eliminate the need for large-scale production runs and save inventory expenses. Small production batches and niche markets may benefit most from this. The range of potential uses for 3D-printed PCBs may increase because of ongoing advancements in 3D printing materials, which could result in the development of conductive and insulating materials appropriate for electronic applications. The cost of 3D printing supplies and equipment may go down as the technology develops and is used more extensively, opening new possibilities for its use.

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