CHARACTERISTICS OF NANOSTRUCTURES, THEIR APPLICATION

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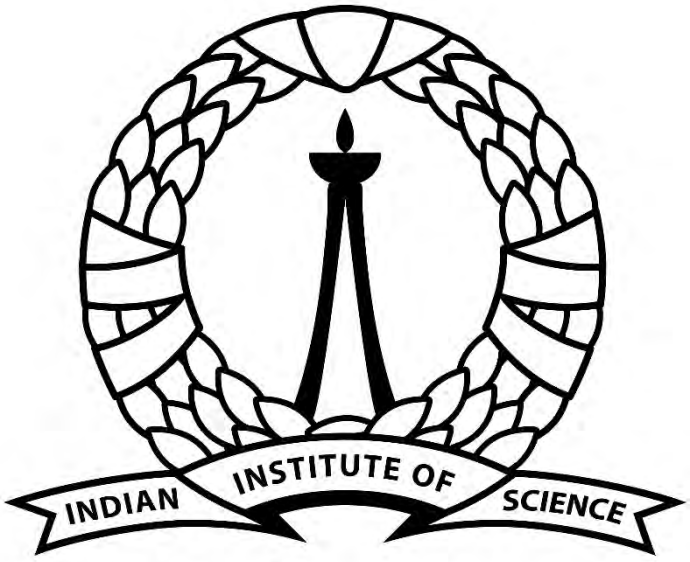

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3.7 Reference

Introduction

The concept of nanotechnology was introduced by physics Nobel laureate Richard P Feynman in his famous lecture entitled 'There's plenty of room at the bottom' at the December 1959 meeting of the American Physical Society [6]. Nanotechnology is the science that deals with matter at the scale of 1 billionth of a meter (i.e., 10^{-9} m to 1 nm), and is also the study of manipulating matter at the atomic and molecular scale. A nanoparticle is the most fundamental component in the fabrication of a nanostructure and is far smaller than the world of everyday objects that are described by Newton's laws of motion

In general, the size of a nanoparticle spans the range between 1 and 100 nm. Metallic nanoparticles have different physical and chemical properties from bulk metals (e.g., lower melting points, higher specific surface areas, specific optical properties, mechanical strengths, and specific magnetizations), properties that might prove attractive in various industrial applications.

Nanotechnologies are now widely considered to have the potential to bring benefits in areas as diverse as drug development, water decontamination, information and communication technologies, and the production of stronger and lighter materials. Nanotechnologies involve the creation and manipulation of materials at the nanometre scale, either by scaling up from single groups of atoms or by refining or reducing bulk material [7].

Our lab, has developed a simple way of synthesizing silver nanostructures called the Print-Expose-Develop technique. This process makes use of a simple desktop inkjet printer and silver halide photochemistry, enabling us to print different nano metallic structures of silver on various substrates like paper, chromatographic paper, flexible substrates etc. It has been observed that the cost and the complexity associated with synthesizing nanoparticles of silver through this method is far less compared to the various other methods which are present out there in the scientific community.

This technique is inspired by the photographic development of images. Here we use the help of latent image centers present in the lattice, after exposure to a halogen lamp, to further develop the silver ions into nanostructures. Our group has successfully created silver nanowires and nanowires which will be discussed later in this review.

Moreover, in this study, I'm focussing on optimising parameters of the 3D printer available at the lab to extend the Print-Expose Develop method to it from inkjet printing. The study is expressed in detail later in this review focussing on the advantages that 3D printer has over the inkjet printing technique.

All these studies are used to develop the nanostructure-based catalyst that can be used to increase the effectiveness of the combustion on Microthrusters. Electrical and chemical propulsion are possible for micro propulsion. Chemical propulsion has the advantage of high energy density, and it consumes little electrical power. From these choices, many microthruster studies are motivated towards chemical propulsion by monopropellants. The catalyst required will be in the form of nano structures over the supports (adsorbents).

Another project that has been undertaken here is the application of nanowires to replicate the Nadi Vidhya. It is one of the oldest forms of medicine practiced by the tribal community in rural India. An effort is made to exploit the sensitive nature of resistance of nanowires against any external disturbances to precisely detect the diseases.

During my time here, all the works undertaken by me was to aid the projects of Microthrusters and Nadi Vidhya. Detailed analysis of using 3D printer to develop nanostructures is extensively done which will be seen later in this review.

Materials and Methods

2.1 Silver Nanostructures on Chromatographic Paper by Inkjet Printers

Inkjet printing is one of the cheapest methods to develop nanostructured thin film because of its cost-effectiveness, variable loading capabilities, ability to be developed into various forms of nanostructures (like fryums, particles, or wires), adaptability to various substrates (like Chromatographic paper, Nafion membrane, etc.), high precision, and small footprint. This process of using inkjet printing used to print metal salts, here, provides the synthesis of durable conductive metal substrates on flexible surfaces. The photographic development process used to generate images from films was the inspiration for the employment of the *Print-Expose-Develop* method for the generation of silver nanostructures. HP Deskjet 1212 inkjet printer which houses HP 805 black cartridge was used to print the precursor salts.

(a) (b)

Fig 1 shows (a) HP Deskjet 1212 inkjet printer loaded with a cartridge and (b) HP 805 black cartridges

The aim was to prepare silver nanowires for which a 1:2 molar ratio of silver nitrate ($AgNO_3$) and potassium halide (KX) were printed layer-by-layer on chromatographic paper. Nanowires were developed on a 2x2 inch area (designed in Microsoft Presentation) of different loadings. All the solutions were prepared on DI water. 2M $AgNO_3$ and 4M solution of 95:5

weight percent of KBr: KI each of 5 mL was prepared. Despite the fact, that the equimolar mixture would be sufficient for reaction to produce silver halide (AgX), clear from the stoichiometric equation, exceeded the concentration of KX was used to ensure the complete utilization of Ag in $AgNO_3$. The developer solution (electron-rich) ID78 was prepared according to the standard.

Two separate HP 805 black cartridges were used to print the $AgNO_3$ and KX solutions. Prior to their usage for printing, the cartridges were break-opened (lids) and thoroughly cleaned under running water, with DI water and sonication. Test patterns were printed to assure that no black ink remained in its reservoir. Loading calculations were done beforehand so that the volume of solution dispensed for each print was precisely calculated. Following the printing of the desired amount of $AgNO_3$ and KX, the substrate was exposed under a halogen lamp for 15 minutes. Then it was dipped in the developer solution for 20 minutes, followed by rinsing the

sample in a tray filled with DI water. It was allowed to dry under ambient conditions overnight.

The reaction scheme for the development of silver nanowires are as follows:

Photolysis: $AgX + h\upsilon \longrightarrow e^- + h^+$

Nucleation: $kink + ne^- + nAg^+ \longrightarrow kinkAg_n$

Growth: $mAg^+ + Developer \xrightarrow{kink\ Ag_n} mAg + Developer_{oxidised} + qH^+$ [8]

Photoelectrons generated within the silver halide crystal react with silver ions at the crystal defect sites on the surface (kink sites) to form nuclei. The nuclei (latent images) that can be developed have at least four silver atoms. Electron transfer between reducing agent and silver ions occurs during the development of nanostructures, catalyzed by nuclei acting as an electron reservoir.

2.2 Synthesis of Silver Nanostructures by 3D Printers

In inkjet printers, some salt like gold, platinum, etc will wear down the aluminum strip in the nozzle of the cartridge and the solution will drip. Also, it can't be used to print on rigid surfaces. So, to print these types of salt we bring up 3D printers. The main privilege of 3D printers is that they can print on any surface, in any direction (x, y, z), with high accuracy, and can adjust the feed rate, variable loading capabilities, and ability to be developed into various forms of nanostructures like frames, particles, or wires. Here, we used the same photographic development process *Print-Expose-Develop* method for the generation of silver nanostructures.

(a) (b) (c)

Fig 2: (a) 3D printer and (b),(c) Different pen holders printed in 3D printer

G-codes (a gcode is a programming language that tells the printer what to do) is used to print structures in the 3D printer. So, we should develop the G-code for the structure to be printed. Here we use Vectary software[9] to build an STL file, and after using Creality Slicer software[10] convert it into G-code.

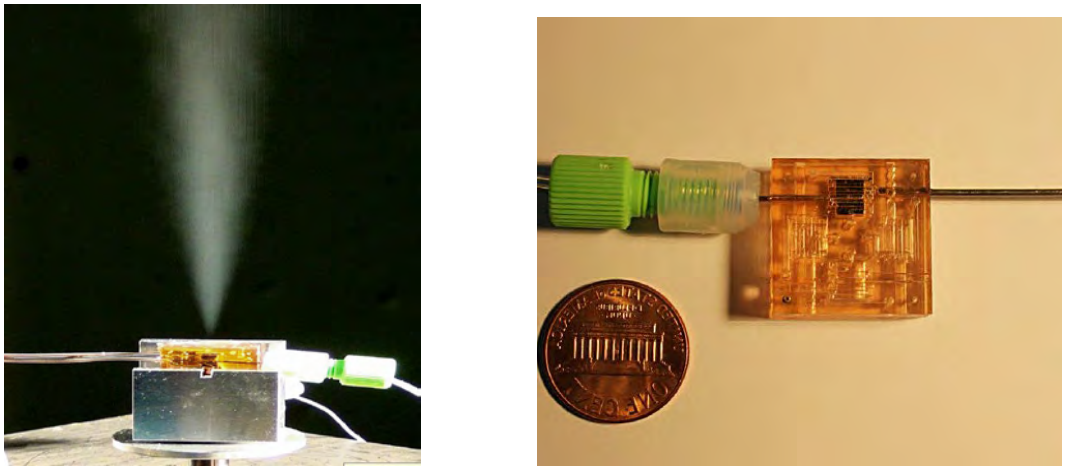
Different pens like marker pens, chrome-plated pens, and brush pens are used to dispense salt solutions to the structures. It was required to make appropriate pen holders for each of the pens. The holders were designed and fabricated using the same 3D printer prior to their use for printing the precursor salts.

Prior to the printing, the pens are cleaned with DI water and IPA (Isopropyl Alcohol) to completely remove the ink present in the pen. After that, the nib and the refill are sonicated with IPA and dried. Test patterns were printed to assure that no ink remained in its nib and refill. Loading calculations were done beforehand so that the volume of solution dispensed for each print was precisely calculated. The molarity of the solution and the method of developing nanostructures are the same as in the inkjet printers. The precision of the printer is 100 microns, so we can print the salt solution with a precision of 100 microns, or the distance between the two that can be printed using this printer is 100 microns.

2.3 MICRO THRUSTERS

In space, there is no friction, meaning that only a very small amount of force is required for the movement of microsatellites. This can be solved using micro thrusters. Microthruster is a rocket motor with a thrust of several dozen newtons to several hundredths of a newton that can be fired repeatedly and operated a large number of times. Microthrusters are mainly for stabilization and altitude control in microsatellites, and also an engine to move astronauts through space outside their spacecraft.

Satellites with weights in the 10–100 kg range are typically called microsatellites and those with weights in the 1–10 kg range are known as nanosatellites. Exceedingly small satellites with a basic unit (1U) of 1 L volume and 1.33 kg mass are referred to as CubeSats. Microthrusters are composed of small mechanical parts and generally produce thrust in the range of μN-mN. Microthrusters are challenging to manufacture therefore, the MEMS (Micro-Electro-Mechanical) System used in the fabrication of semiconductors has to be applied.



(a) (b)

Fig 3: (a) Firing of the regeneratively cooled monopropellant micro thruster and (b) Integrated micro thrusters.[2]

Both electrical and chemical propulsion can be possible in microsatellites, but electrical propulsion required high electric power, which is a burden for the small satellite. So, chemical propulsion is used, there are monopropellants, bipropellants, solid propellants, and cold gases. This monopropellant has a higher specific impulse.

Monopropellants release energy through an exothermic decomposition reaction with the help of a catalyst and produce high-temperature gas which is converted to kinetic energy for the satellite. Hydrazine (N_2H_4), Hydrogen peroxide(H_2O_2), HAN (NH_3OHNO_3), and

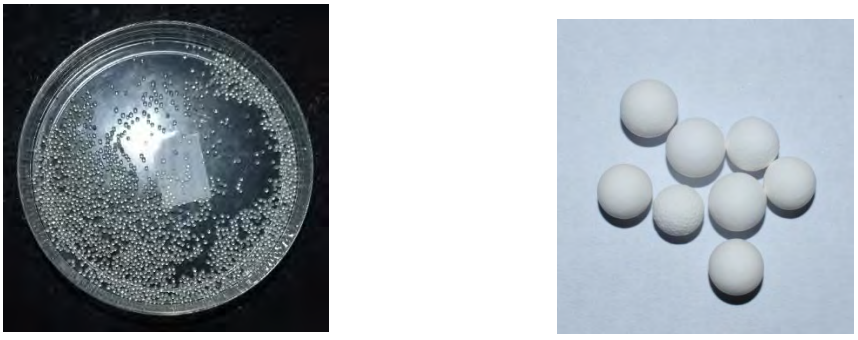
ADN ($NH4N(NO_2)_2$), are generally used as monopropellants. Hydrazine is the most commonly used monopropellant with a high specific impulse. But it is difficult to handle because of its high toxicity. HAN and ADN are good alternatives for monopropellant thrusters, but they have high viscosity, which causes large feeding pressure losses and also require preheating for propellant decomposition, which is the disadvantage of their use as micro thruster propellants.

Hydrogen peroxide can be used as a propellant, with several advantages like high density, storability, nontoxicity, cost-effective handling process, and easily decomposed by a catalyst (Ag, Pt, MnO_2, Pt/Al_2O_3), didn't require any preheating. Moreover, it decomposes into oxygen and water which do not harm the environment. The decomposition process for hydrogen peroxide follows:

$$2H_2O2(l) \rightarrow 2H_2O_{(g)} + O_{2(g)} + Heat$$

The heat energy generated depends on the concentration of H_2O_2. For a concentration of 100wt.% H_2O_2, it produces a heat of 2884.47 KJ/kg and has a decomposition temperature of 1022 K.

The main aim was to increase the efficiency of the micro thrusters, by changing all parameters like temperature, pressure, the flow rate of propellant, design of thrusters, use of different catalysts, etc. Using the photographic development method, nanostructures are developed supporters like glass beads and activated Alumina. Clean the glass beads with DI water and dip them in 2M AgNO3 solution and 4m KBr solution, after being exposed to a halogen lamp. Then dip in the developer solution (ID 78) to develop nanostructures of Sliver salts. The catalyst (Ag) used in micro thrusters is on the nanoscale, so they exhibit several superior and fascinating properties as compared to bulk. Nanostructures have different properties like large surface-to-volume ratio, size and shape tunable optical properties, and catalytic activity.



(a) (b)

Fig 4: (a) Glass Beads and (b) Activated Alumina

2.4 NADI VAIDHYA (NADI PARIKSHA)

Nadi Vaidhya is the ancient ayurvedic technique of diagnosis through the pulse. It can accurately diagnose physical, mental, and emotional imbalances as well as diseases. It is a non-invasive science that enables one to reach the root cause of health issues and not just address the symptoms. It understands the vibratory frequency of the pulse at various levels on the Radial artery. The pulse examined both the physical and mental characteristics of the patient. Nadi Vaidya (Nadi Doctor or Pulse Diagnosis Doctor) senses the signals (Laya-movements, Gati-speed, Pattern of movements) obtained through the artery due to contraction and relaxation of the blood vessels and also the movement of blood in the artery and change in the diameter.

(a) (b)

Fig 5: (a)Measuring pulse and (b)Different nervous in the body [11]

According to the Hatha yogic scriptures, the human body has 72,000 nadis and to maintain good health one needs a free flow of prana (the Sanskrit word for breath) inside the nadis. The word “nadi” does not mean “nerve”. Nadis are pathways or channels of prana in the system. There are 3 doshas or three internal states of a body namely Vata (energy of air and ether, movement and impulse, creativity and connection), Pitta (govern the metabolism and the transformation that takes place in the body), and Kapha (composed out of the earth and water components). Kapha pulse is predominant in the morning time, pitta pulse is predominant during mid-day and the Vata pulse can be observed in the late afternoon and evening.

Any imbalance of these elements in the body leads to several disorders. The imbalance of Vata elements can cause up to 80 disorders in the human body, similarly, the

imbalance of the Pitta element can cause up to 40 disorders and the Kapha element can cause up to 20 disorders in the human body.

To examine the pulse of the patient, the left hand of the patient should be kept free and slightly flexed at the forearm. The 3 fingers of the right hand, the index finger, the middle finger, and the ring finger of the examiner just touch the radial artery. The index finger should be placed near the thumb and the other two fingers are placed next to it. Vata pulse is studied by the tip of the index finger, placed over the radial artery, pitta pulse is studied by the tip of the middle finger and the Kapha pulse is by the tip of the ring finger placed on the artery.

The main aim of the study is to replicate this using nanostructure. Nanowires have the property of changing in resistance, it increases while stretching. So, nanowires are printed on the fingertips of the gloves (or fingers made with the help of a 3D printer) and arranged as above. Depending upon the pulse received, the resistance of the nanostructures will change. So, a database has to be made to know more about how the resistance of the nanostructure change according to the pulse and can detect the disorder.

Results and Discussion

3.1 SILVER NANOWIRES ON CHROMATOGRAPHIC PAPER BY INKJET PRINTER

First of all, it has to be assured that all the black ink in the cartridge should be completely removed, by washing it with DI water and IPA for 10 minutes and sonicate. Test patterns were printed to assure that no black ink remained in the cartridge. Then loading calculations are done to know the amount of solution dispensed on each print. The loading calculations are done by printing with Di water on chromatographic paper. By taking the difference in weight, before and after each print the water dispersed in each print is calculated, and with that, the mass AgNO3 in each print is calculated.

LOADING CALCULATION FOR INKJET PRINTER											
No. of print	**Initial Wt**	**Final Wt**	**Mass deposited in 1 print**	**Area**	**Mass deposited per unit area**		**Volume of water deposited**	**Molecular Wt (Ag)**	**Molarity of $AgNO_3$**	**Mass of $AgNO^3$ deposited**	**Avg mass deposited**
	g	**g**	**g**	**cm_2**	**g/cm^2**	**mg/cm^2**	**ml/cm^2**	**g/mol**	**M**	**mg/cm^2**	**mg/cm^2**
1	23.9347	23.9130	0.0217	25.0	0.00087	0.8680	0.00087	107.8682	2	0.1873	0.1886
2	23.9117	23.8679	0.0219		0.00088	0.8760	0.00088			0.1889	
3	24.0912	24.0260	0.0217		0.00087	0.8693	0.00087			0.1875	
4	24.2447	24.1571	0.0219		0.00088	0.8760	0.00088			0.1889	
5	24.2131	24.1029	0.0220		0.00088	0.8816	0.00088			0.1902	

Table 1: loading calculation for inkjet printer

Four samples of 1 mg, 2mg, and 3mg loadings were developed by PowerPoint, and 2 samples had 3 mg loading, each of the four samples having a 2x2 $inch^2$ area. For $AgNO_3$ and

KX, two separate cartridges are taken. 300 µL of each solution was filled using a pipette in their cartridges and the layers were printed as per the format shown below.

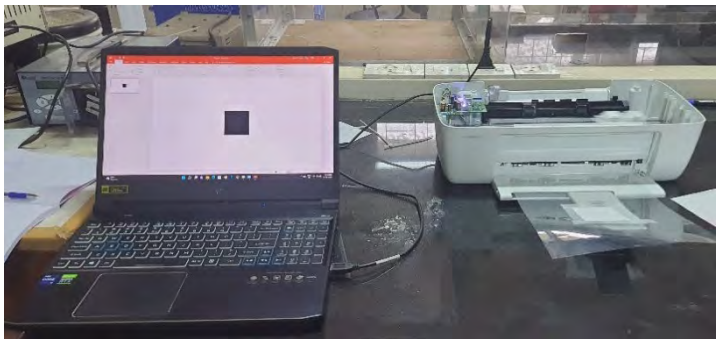
1 mg: *KAAAKK (3 prints of each solution)*

2 mg: *KKKAAAAAKK (5 prints of each solution)*

3 mg: *KKKKKAAAAAAAKK (7 prints of each solution)*

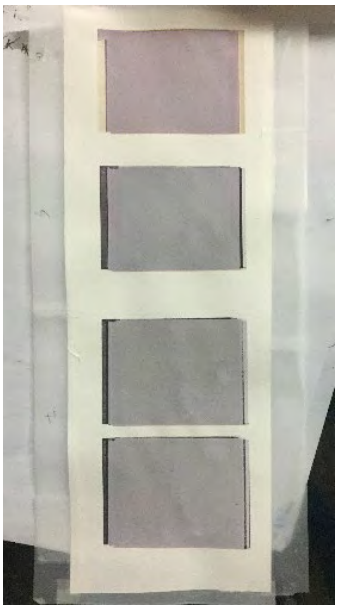
Where K is KX, and A is $AgNO_3$.

(a)

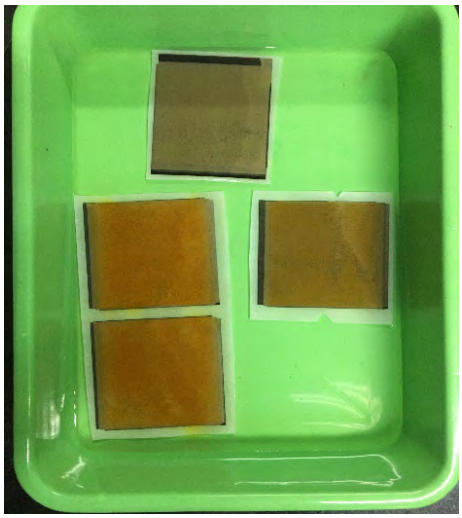


(d)

(b)



(e)



(c) (f)

Fig 6: (a) break opened cartridge (b)exposing to halogen lamp (c)immersing the exposed substrate in ID 78 (d) printing of salt using inkjet printer (e)substrate after exposed to halogen lamp for 15 minutes (f)after the development of nanowires

Preparation of solution										
Solution		**Total volume (ml) (Vol)**	**Molarity (M)**	**Wt %**	**converting wt% to mol%**	**Molecular Wt (g/mol)**	**Avg molecular Wt (m)**	**Mass of substance m=(M*Vol*m)**	**Total No. of moles**	**Mass of substance required (g)**
$AgNO_3$		15	2			169.8700			0.03	5.0961
KBr	95% KBr	15	4	95	0.7983	119.0020	120.7109	7.2427		6.8805
	5% KI			5	0.0301	166.0028				0.3621

Table 2: Preparation of 2M AgNO3 and 4M KBr (95% KBr and 5% KI are in weight percentage)

Carefully, all the layers were printed on chromatographic paper. $AgNO_3$ is not printed first so that all the silver molecules could be transformed into nanowires. If it was printed as the first layer, we may lose some of them due to their absorption on the paper. The sample should be dried thoroughly after each layer of the salt solution is printed. Once all the layers are printed, they are exposed under the halogen lamp for 15 minutes for the formation of latent images. A latent image is a small cluster of metallic silver atoms formed in a silver halide crystal due to the reduction of interstitial silver ions by photoelectrons. A slight yellowish thin film of the substrate confirms the formation of latent images. the exposed substrate is then immersed in ID 78 (developer solution) which electrochemically reduces

silver halide crystals into metallic silver grains, where the latent image centers act as a catalyst. As KBr solution was used and due to the fact that ID 78 supplies electrons at a faster rate implies that nanowires are formed. The resistance of each of the samples was measured using a multimeter.

Sample No	Silver Loading (mg)	Resistance(Ω/□)
1	1	16.0
2	2	18.3
3	3	1.6
4	3	2.0

a) Preparation of developer solutions

For the development of nanostructures, we are mainly using three different types of developer solutions, D76, D72, and ID 78.

D76 is a slow developer solution compared to the other developer solutions. It mainly gives nanowires, why because here the electron comes to the nucleation sites (latent image centers) very slowly so it forms nanoparticles. If we add a small amount of KCl to the developer solution, it will provide nanoparticles.

D72 gives frame-like structures, and if KBr is used it will provide wires. But generally, for nanowires, we use the ID78 solution

ID78 is the fastest developer solution, which is mainly used for the development of nanowires.

For developing nanowires, we mainly use ID78, they are fast than other solutions.

Not only does the developer solution decide the formation of different nanostructures, but it also depends on the halides (Cl, Br...) that we use. If we use KCl (smaller lattices) we get nanoparticles/fryums and for KBr (larger lattices) it is nanowires, that is due to the difference in the size of halides. KBr has larger lattices so the particles combine and coiled each other to form nanowires.

So, if we want nanowires use KBr and ID 78 solution.

Developer solution						
D76		**D72**		**ID 78**		**Remark**
Substance	**for 25ml**	**Substance**	**for 25 ml**	**Substance**	**for 25 ml**	
Warm water	18.75 ml	Warm water	12.5 ml	Warm water	15 ml	If we use KX for printing then use KX for the developer solution.
Metol	50 mg	Metol	3.1 g	Sodium sulphite	1.25 g	
Sodium sulphite	2.5 g	Sodium sulphite	1.125 g	Hydroquinone	0.3 g	
Hydroquinone	125 mg	Hydroquinone	.3 g	Sodium carbonate	1.55 g	
Borax	50 mg	Sodium Carbonate	1.6875 g	Phenidone	12.5 mg	
For nanoparticles add KCl	.75 g	KBr/KCl	47.5 mg	KBr/KCl	112.5 mg	
Add water to make up the required amount of solution						

Table3: Preparation of developer solution

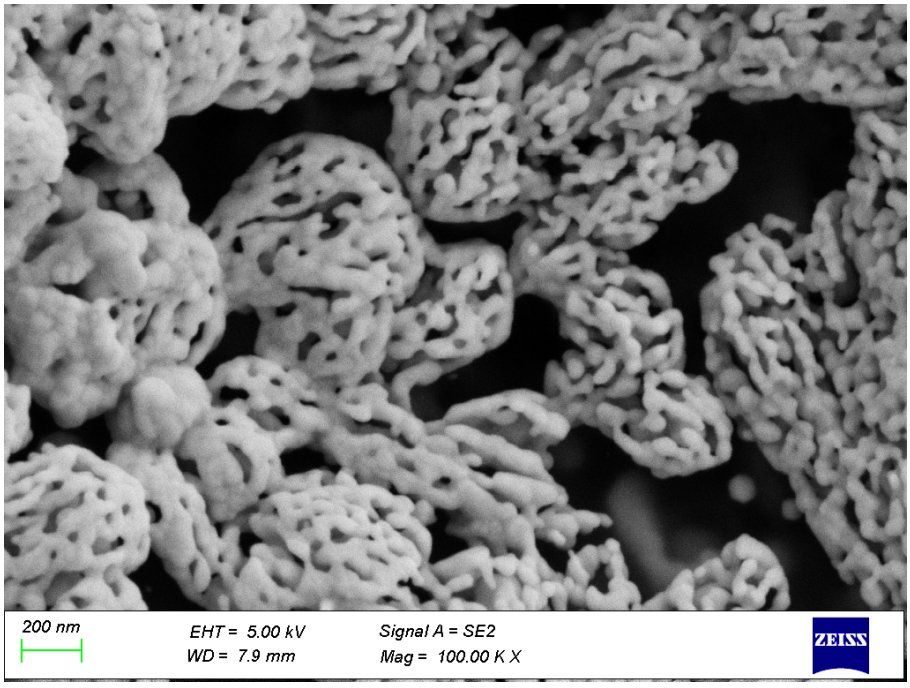


Fig : SEM image of fryums (SEM done by Rupesh Pawar)

3.2 SILVER NANOWIRES ON CHROMATOGRAPHIC PAPER BY 3D PRINTER

In inkjet printers, we can't print all types of salt, so 3D printers are introduced. But like in inkjet printers there is no cartridge to fill the solutions, so we use different types of pens (marker pen, brush pen). First of all, the ink from the pens should be removed completely by the same method used to clean the cartridge in the inkjet printer. But the pen can't be attached directly to the 3D printer, it is required to make appropriate pen holders for each of the pens. The appropriate holders are designed and 3D printed with the same printer. The design is done with the help of an online 3D designing software, "**Vectary**". 3D printers support G-codes, so the STL file is converted to Gcode with the help of "**Creality Slicer**" software. In **Creality Slicer** software, the feed rate, nozzle temperature, bed temperature, etc everything is adjusted for that model to be printed. Given below are some parts of the G-codes used to print the pen holders:

(FullGcode:https://drive.google.com/file/d/1QtjMr5BzzTdKkMPkhcvQIblQ_IPM2nf_/view?usp=sharing)

M190 S60.000000

M109 S200.000000

;Sliced at: Mon 27-06-2022 17:59:35

;Basic settings: Layer height: 0.2 Walls: 0.8 Fill: 10

;Print time: 1 hour 17 minutes

;Filament used: 5.35m 15.0g

;Filament cost: None

;M190 S60 ;Uncomment to add your own bed temperature line

;M109 S200 ;Uncomment to add your own temperature line

G21 ;metric values

G90 ;absolute positioning

M82 ;set extruder to absolute mode

M107 ;start with the fan off

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G28 X0 Y0  ;move X/Y to min endstops
G28 Z0     ;move Z to min endstops
G1 Z15.0 F4800 ;move the platform down 15mm
G92 E0                  ;zero the extruded length
G1 F200 E3              ;extrude 3mm of feed stock
G92 E0                  ;zero the extruded length again
G1 F4800
;Put printing message on LCD screen
M117 Printing...

;Layer count: 185
;LAYER:-2
;RAFT
G0 F4800 X95.631 Y71.642 Z0.300
;TYPE:SUPPORT
G1 F1200 X128.632 Y71.642 E4.11607
G1 X129.317 Y71.670 E4.20157
G1 X130.187 Y71.773 E4.31084
G1 X131.505 Y72.087 E4.47983
G1 X132.351 Y72.397 E4.59221
G1 X133.071 Y72.728 E4.69105
G1 X133.756 Y73.113 E4.78906
G1 X134.409 Y73.548 E4.88692
G1 X135.103 Y74.095 E4.99713
G1 X136.058 Y75.048 E5.16541
G1 X136.620 Y75.757 E5.27825
G1 X137.059 Y76.416 E5.37701
G1 X137.444 Y77.101 E5.47502
G1 X137.773 Y77.816 E5.57318
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G1 X138.078 Y78.643 E5.68312

G1 X138.391 Y79.947 E5.85039

G1 X138.515 Y80.936 E5.97471

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G1 X93.570 Y132.320 E5348.90203

G0 X93.005 Y132.320

G1 X88.234 Y127.550 E5349.12642

G0 X87.669 Y127.550

G1 X92.439 Y132.320 E5349.35079

G0 X91.873 Y132.320

G1 X87.520 Y127.967 E5349.55554

G0 X87.520 Y128.532

G1 X91.307 Y132.320 E5349.73369

G0 X90.742 Y132.320

G1 X87.520 Y129.098 E5349.88524

G0 X87.520 Y129.664

G1 X90.176 Y132.320 E5350.01017

G0 X89.610 Y132.320

G1 X87.520 Y130.229 E5350.10850

G0 X87.520 Y130.795

G1 X89.045 Y132.320 E5350.18024

G0 X88.479 Y132.320

G1 X87.520 Y131.361 E5350.22534

G0 X87.520 Y131.927

G1 X87.913 Y132.320 E5350.24383

M107

G1 F2100 E5347.74383

G0 F4800 X87.913 Y132.320 Z42.000

;End GCode

M104 S0 ;extruder heater off

M140 S0 ;heated bed heater off (if you have it)

G91 ;relative positioning

G1 E-1 F300 ;retract the filament a bit before lifting the nozzle, to release some of the pressure

G1 Z+0.5 E-5 X-20 Y-20 F4800 ;move Z up a bit and retract filament even more

G28 X0 Y0 ;move X/Y to min endstops, so the head is out of the way

M84 ;steppers off

G90 ;absolute positioning

M81

;CURA_PROFILE_STRING:

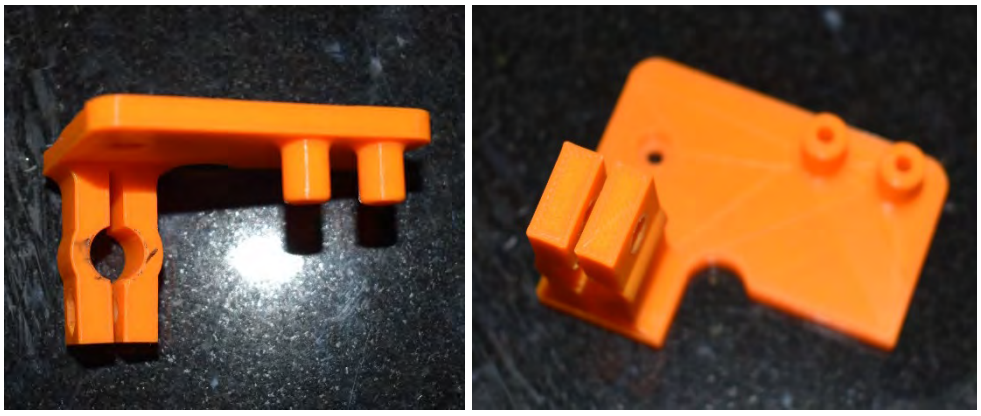


Fig 6: pen holder made by 3D printing

After the holder is made, the nozzle of the 3D printer is removed and the pen holder is attached in that place. To print the solution, we need to make another g-code, a 6x2 rectangle coded to find the loading calculation of the different pens. Using the code, DI water is printed on the Chromatographic paper to find the amount of water deposited in every print with

different pens. After that, the amount of AgNO3 deposited in a single print is found. The code for the 6x2 rectangle is :

USBC éšª $

* Â× f

M190 S35.000000

M109 S0.000000

;Sliced at: Sat 05-02-2022 12:26:35

;Basic settings: Layer height: 0.2 Walls: 0.8 Fill: 10

;Print time: 12 minutes

;Filament used: 0.733m 2.0g

;Filament cost: None

;M190 S0 ;Uncomment to add your own bed temperature line

;M109 S0 ;Uncomment to add your own temperature line

G21 ;metric values

G90 ;absolute positioning

M82 ;set extruder to absolute mode

M107 ;start with the fan off

G28 X0 Y0 ;move X/Y to min endstops

G28 Z0 ;move Z to min endstops

G1 Z28.0 F4800 ;move the platform down 15mm

G92 E0 ;zero the extruded length

G1 F200 E3 ;extrude 3mm of feed stock

G92 E0 ;zero the extruded length again

G1 F4800

;Put printing message on LCD screen

M117 Printing...

;LAYER:-1

```
;RAFT
G0 F4800 X94.999 Y79.939 Z25.500
;TYPE:SUPPORT
G1 F1200 X94.999 Y140.059 E404.86384
G0 F4800 X95.399 Y140.059
G1 F1200 X95.399 Y79.939 E407.56330
G0 F4800 X95.799 Y79.939
G1 F1200 X95.799 Y140.059 E410.26276
G0 F4800 X96.199 Y140.059
G1 F1200 X96.199 Y79.939 E412.96222
G0 F4800 X96.599 Y79.939
G1 F1200 X96.599 Y140.059 E415.66168
G0 F4800 X96.999 Y140.059
G1 F1200 X96.999 Y79.939 E418.36113
G0 F4800 X97.399 Y79.939
G1 F1200 X97.399 Y140.059 E421.06059
G0 F4800 X97.799 Y140.059
G1 F1200 X97.799 Y79.939 E423.76005
G0 F4800 X98.199 Y79.939
G1 F1200 X98.199 Y140.059 E426.45951
G0 F4800 X98.599 Y140.059
G1 F1200 X98.599 Y79.939 E429.15897
G0 F4800 X98.999 Y79.939
G1 F1200 X98.999 Y140.059 E431.85843
G0 F4800 X99.399 Y140.059
G1 F1200 X99.399 Y79.939 E434.55789
G0 F4800 X99.799 Y79.939
G1 F1200 X99.799 Y140.059 E437.25735
G0 F4800 X100.199 Y140.059
```

G1 F1200 X100.199 Y79.939 E439.95681

G0 F4800 X100.599 Y79.939

G1 F1200 X100.599 Y140.059 E442.65627

G0 F4800 X100.999 Y140.059

G1 F1200 X100.999 Y79.939 E445.35573

G0 F4800 X101.399 Y79.939

G1 F1200 X101.399 Y140.059 E448.05518

G0 F4800 X101.799 Y140.059

G1 F1200 X101.799 Y79.939 E450.75464

G0 F4800 X102.199 Y79.939

G1 F1200 X102.199 Y140.059 E453.45410

G0 F4800 X102.599 Y140.059

G1 F1200 X102.599 Y79.939 E456.15356

G0 F4800 X102.999 Y79.939

G1 F1200 X102.999 Y140.059 E458.85302

G0 F4800 X103.399 Y140.059

G1 F1200 X103.399 Y79.939 E461.55248

G0 F4800 X103.799 Y79.939

G1 F1200 X103.799 Y140.059 E464.25194

G0 F4800 X104.199 Y140.059

G1 F1200 X104.199 Y79.939 E466.95140

G0 F4800 X104.599 Y79.939

G1 F1200 X104.599 Y140.059 E469.65086

G0 F4800 X104.999 Y140.059

G1 F1200 X104.999 Y79.939 E472.35032

G0 F4800 X105.399 Y79.939

G1 F1200 X105.399 Y140.059 E475.04978

G0 F4800 X105.799 Y140.059

G1 F1200 X105.799 Y79.939 E477.74923

G0 F4800 X106.199 Y79.939

G1 F1200 X106.199 Y140.059 E480.44869

G0 F4800 X106.599 Y140.059

G1 F1200 X106.599 Y79.939 E483.14815

G0 F4800 X106.999 Y79.939

G1 F1200 X106.999 Y140.059 E485.84761

G0 F4800 X107.399 Y140.059

G1 F1200 X107.399 Y79.939 E488.54707

G0 F4800 X107.799 Y79.939

G1 F1200 X107.799 Y140.059 E491.24653

G0 F4800 X108.199 Y140.059

G1 F1200 X108.199 Y79.939 E493.94599

G0 F4800 X108.599 Y79.939

G1 F1200 X108.599 Y140.059 E496.64545

G0 F4800 X108.999 Y140.059

G1 F1200 X108.999 Y79.939 E499.34491

G0 F4800 X109.399 Y79.939

G1 F1200 X109.399 Y140.059 E502.04437

G0 F4800 X109.799 Y140.059

G1 F1200 X109.799 Y79.939 E504.74383

G0 F4800 X110.199 Y79.939

G1 F1200 X110.199 Y140.059 E507.44328

G0 F4800 X110.599 Y140.059

G1 F1200 X110.599 Y79.939 E510.14274

G0 F4800 X110.999 Y79.939

G1 F1200 X110.999 Y140.059 E512.84220

G0 F4800 X111.399 Y140.059

G1 F1200 X111.399 Y79.939 E515.54166

G0 F4800 X111.799 Y79.939

G1 F1200 X111.799 Y140.059 E518.24112

G0 F4800 X112.199 Y140.059

G1 F1200 X112.199 Y79.939 E520.94058

G0 F4800 X112.599 Y79.939

G1 F1200 X112.599 Y140.059 E523.64004

G0 F4800 X112.999 Y140.059

G1 F1200 X112.999 Y79.939 E526.33950

G0 F4800 X113.399 Y79.939

G1 F1200 X113.399 Y140.059 E529.03896

G0 F4800 X113.799 Y140.059

G1 F1200 X113.799 Y79.939 E531.73842

G0 F4800 X114.199 Y79.939

G1 F1200 X114.199 Y140.059 E534.43787

G0 F4800 X114.599 Y140.059

G1 F1200 X114.599 Y79.939 E537.13733

G0 F4800 X114.999 Y79.939

G1 F1200 X114.999 Y140.059 E539.83679

G0 F4800 X115.399 Y140.059

G1 F1200 X115.399 Y79.939 E542.53625

G0 F4800 X115.799 Y79.939

G1 F1200 X115.799 Y140.059 E545.23571

G0 F4800 X116.199 Y140.059

;LAYER:0

M106 S127

G1 F4800 E601.32327

G0 X119.400 Y85.600 Z28

M107

G1 F4800 E727.05634

G0 X101.166 Y134.259 Z28

;End GCode

M104 S0 ;extruder heater off

M140 S0 ;heated bed heater off (if you have it)

G91 ;relative positioning

G1 E-1 F300 ;retract the filament a bit before lifting the nozzle, to release some of the pressure

G1 Z+0.5 E-5 X-20 Y-20 F4800 ;move Z up a bit and retract filament even more

G28 X0 Y0 ;move X/Y to min endstops, so the head is out of the way

M84 ;steppers off

G90 ;absolute positioning

M81

;CURA_PROFILE_STRING:eNrtWktv20YQvhJGf8QeEzRWSUqKnQg8NKmdS1IEtYsmvhArciluTXKJ3aVl2dB/77fLhyhbap3GaB6lDjb4cWZ2duabh2FldMVkmDK+SHXgjnxnSbMs1CmPLgumFKBjRzItaaS5KEJW0HnGgnNZMUeJjMdhZg1sFDzYSDhsxKxQXK8Cz3VKyQsdqpKxODhuHzXLSyapriQLfHcH6gc7wPEucLILnHbgnMVbpz13HVWVpZA6+FUUzCkzqhMh85DGKVO4ZvAbTXQrE8YVzUJ2rWVl370SOnWWvGShFksmg1OaKdYDwiuRVTkLvKkjxA0LVcpZFjdiiAzNGXyKOX5rqHujo+l92Nz9HjjeBU52gdM+mGRiiSy4TiFubjI4xG8Y8jrp57XLTQ+juagKHTwfbaE2Gs0r7/lo2n+X8yLEwxXLcK2tN5HI57xYBD9n2R0Fnm9F190+LRWlheZCa5Fv8XLsWOq54ZLHOg0TaAhp7ynmf7IIfOPFpVUWV0xmtLSuA0Biaic3t27M11yuUd91eGGJXD8bQ5bxVDK60eSFYtptnsfT+vl68xwJkdm4NHXCwYyxk9C2lOKmli45mJbxgiFUNrQNtKBlMDZH26c2XhkrFjoFxYxXxlhSwdGuimus9mHaewhzem0j1HmVAEVVMFOlFkwZRU3zRDeErYtcIw29mq/DVSM2RE2EDedRZdxyEGWHomJhHcVGvSkpvSpZ8Ba3VR1Ei0XWL83QGq59m3bg9QocV5oWkaHwUYff9GEjX3JJM0P05ho8L0H9XMQtMoeb/YAj3xJVjxDJBS+C6ah5tiKqpJGh77hF51SxO2zc4EbFkhJV0MijDTEJim4r+Ud3325UbYGal5RLkCBEW66LY4MZC34NqKrRNyxTwR1015mdxtaJCb9GzUnJQc2wKmwbMPMA+Qppm/D9IvOuzfVlEBJRsiKcc612CaD6zay4Qpw111FqIl2LlVmFZCBD4NAiaAs7YiZe4XVw6N2BVoB+AA+kHi0ik+vZWcYjFhOqX5LbmK7W5qdm+GUqcX0we0UVjwhqVuNU9ZK8NQEkdSVBJeuNxzX5AxeFzO32jFyTU1AVcH/swfR7M3yIOQfvmvFUH3ratGaC0MS1Yt2q6766znvQsj570dOKhNJ9LfMMq++8Fy45u90589Zk9nuBJmz1tSA0jslKVJKIZUEgS3qyxFDCmHNfdOYeauqemTe+R5rPDG1BIthXNKuYOngDb9s3dI7GUmlGSoHggVJIxsG7Y78TQIKIHRIxsmMObRVMRR/A1aNO0mSfLLlOiU4ZQe8jIkngxzH54JKPrvED7Yp8+OmjMYQmSFgRK3Q4ZYUu3MZZI3RxX8QjFx6aAzm97Q+RdaNgjmzXCRKbiHjTPMddfXLSXXfzmd0wKaxSc7mY1K3dnHOKrYicjO9oNIJknOe4GDENnMC16PLTDyF0QXlhj9q+DLhbaWIzj0SQHCSnC0ZEQd6+/oWoSDJWIOjeEXnfyIxGIwcxaqvupIjJm9dNaibkbIdXvbuYekNRSpuod97E3atg5WJL2I0KecITw0CS4gqE66eIhEce8JlJhlSh72zRDm9dNaibkbIdXvbuYekNRSpuod97E3atg5WJL2I0KecITw0CS4gqE66eIhEce8JlJhlSh72zRD

uE4OURIxq77D8p2S6lZ1pYmJWhypJ58xIxREz8jUe9ezwyfcCrDmCBK5Myk0HJGIsYoG
suvH93RFD5MyYdDH5Q1P3az7YJUZXMkRcRb

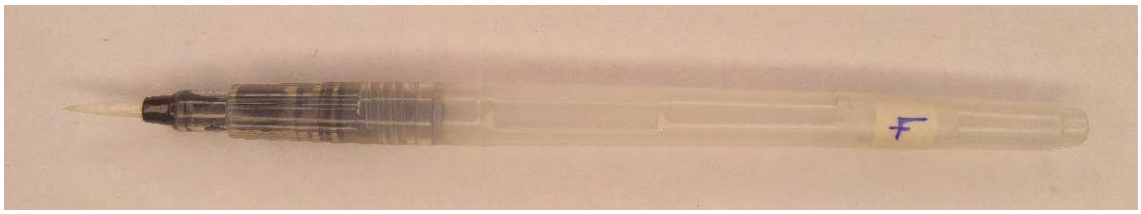
The different types of pens used for printing are chromium-plated pen (.1mm,.2mm,.3mm,.5mm,.8mm), marker pen (Faber-castell B, SB,1.5mm,.5mm), and brush pen. The best pen among them is the B marker pen of Faber castell. With this pen the print is uniform and it didn't tear the paper and no bruises. While using chrome-plated pens the paper gets torn due to the metal tip and the solution is not getting uniformly coated. After some prints, air bubbles are formed inside the pen which blocks the water to come out. In the brush pen, the water initially comes in a large amount, after that water won't come out. So, we can't use both the chrome-plated and brush pen for printing in a 3D printer because they are not continuous.

(a)

(b)

(c)

(d)



(e)

(f)

Fig 7: (a) Different types of chrome-plated pens, (b) Marker pen of .5mm diameter(pen-1), (c) Marker pen of diameter 1.5mm(pen-2), (d) brush like Marker pen B (pen-3), (e) brush pen (pen-4), (f) Brush like marker pen SB (pen-5)

a) Chrome plated pen

Chrome plated pen can be used to print gold, or platinum salt, it won't corrode the chrome tip. But with this pen, we can't print, because it will tear the paper due to its metal tip and it makes scratches on the surface. And also in between the print, the solution coming from the pen will stop due to the formation of an air bubble inside the pen, and it's due to the surface tension of water. To solve this, we print using 5%,10%, and 20% ethanol solution, it works but the scratching and tearing problem can't be solved. So, to remove tearing and scratching due to the metal nib the chrome plated pen is changed, and use a brush pen and marker pen of different diameters.

(a)

(b)

(c)

Fig 7: (a) formation of ai bubble inside chrome plate pen, (b) Scratches will printing, (c) Tearing the chromatographic paper while printing

b) Brush pen

Due to the metallic nib of the chrome-plated pen, it tears and scratches the paper, so to solve these brush pens are used. The brush won't tear or scratches the paper because its nib is a brush. But here also the solution is not coming uniformly, initial it come in some large volume after some times during the printing it will stop dispensing the salt solution. So, we can't use a brush pen for printing the salt solution.

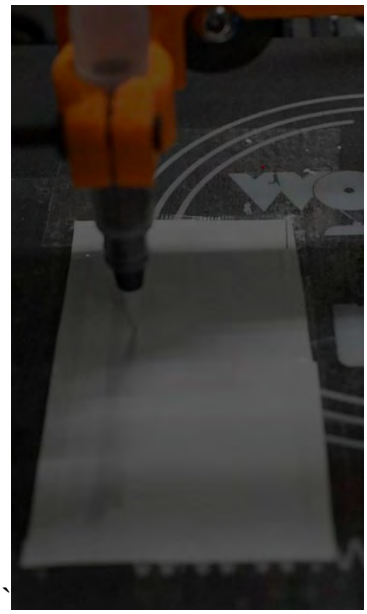


Fig 8: brush pen solution is not dispensing

c) Marker pens

In the above two pens, the printing is not continuous, to make it continuous and not scratch the surface, Marker pens are put forward. Here the tip of the marker pen is made of synthetic fibers and porous ceramics which won't scratch the surface. Due to its porous nature solution will dispense will on the surface. During the printing, we can notice that the dispensing of salt solution in the paper is uniform and continuous throughout the printing. Here, mainly we use marker pens by Faber castell. Different pens having diameters of 0.5mm,1.5mm, B, and SB are printed on chromatographic paper for different times, to find which is best among these. From this, the pen "B" (pen-3) is the best, which shows the best printing, less spreading, uniform and continuous through the printing, no scratches, and brooches, etc.

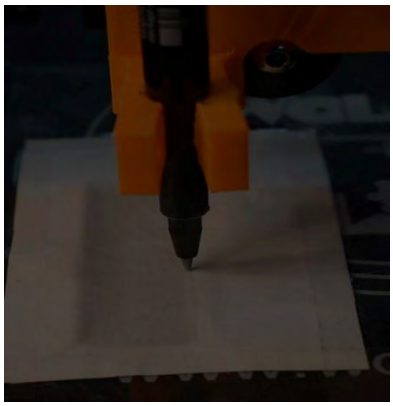


Fig 9: continuous printing by marker pen B (pen-3)

Loading calculation and amount of Ag deposited in each print for different pens are calculated. Here the concentration of $AgNO_3$ taken is 2M and the area wants to print is 12 cm^2 also the molecular weight of Ag is 107.8682 g/mol, which is fixed for all pens. The table below shows the details of loading calculation and mass of Ag deposited:

a) Calculation for pen 1 having a diameter of 0.5mm

LOADING CALCULATION using a pen- 1									
Feed rate	**No. of print**	**Initial Wt**	**Final Wt**	**Mass deposited in 1 print**	**Mass deposited per unit area**	**Volume of water deposited**	**Mass of $AgNO^3$ deposited**	**Avg mass deposited**	**Remark**
		g	**g**	**g**	**g/cm^2**	**ml/cm^2**	**mg/cm^2**	**mg/cm^2**	
250	1	6.3344	6.1494	0.0617	0.0051	0.0051	1.1087	1.3437	print in the same sheet
	2	6.1895	6.0412	0.0742	0.0062	0.0062	1.3331		
	3	6.2798	6.1914	0.0884	0.0074	0.0074	1.5892		
250	1	6.4278	6.3572	0.0706	0.0059	0.0059	1.2693	1.1071	print in different sheet
	2	6.4968	6.3691	0.0639	0.0053	0.0053	1.1479		
	3	6.3655	6.2146	0.0503	0.0042	0.0042	0.9042		
200	1	6.3049	6.2491	0.0558	0.0047	0.0047	1.0032	1.0179	print in different sheet
	2	6.4353	6.3091	0.0631	0.0053	0.0053	1.1344		
	3	6.4973	6.3444	0.0510	0.0043	0.0043	0.9163		

Here if we notice that for 250 feedrate there are two different amounts of Ag deposition can be found, one is that all the prints are taken in the same sheet itself, and the other is indifferent sheet. The tip of the marker is also hard so that it will make some brooches in the paper after every print, this will increase the area of contact. That is the reason for the increase in the amount of salt deposition on the same sheet of paper. So this pen can't be used for the deposition of salt on chromatographic paper or any other surfaces.

Fig : pen-1 with diameter 0.5mm

b) Calculation for pen 2 having a diameter of 1.5mm

LOADING CALCULATION using pen- 2									
Feed rate	**No. of print**	**Initial Wt**	**Final Wt**	**Mass deposited in 1 print**	**Mass deposited per unit area**	**Volume of water deposited**	**Mass of $AgNO^3$ deposited**	**Avg mass deposited**	**Remark**
		g	**G**	**g**	**g/cm^2**	**ml/cm^2**	**mg/cm^2**	**mg/cm^2**	
100	1	6.1403	5.9556	0.1847	0.0154	0.0154	3.3205	3.6675	FAILED, the paper Is torn due to the high amount of water deposition. Very large spreading
	2	5.9914	5.7681	0.0223	0.0186	0.0186	4.0145		
200	1	5.8477	5.7355	0.1122	0.0094	0.0094	2.0171	2.0397	small spreading
	2	5.8689	5.6391	0.1149	0.0096	0.0096	2.0657		
	3	5.8260	5.4862	0.1133	0.0095	0.0095	2.0363		
250	1	6.0548	5.9467	0.1081	0.0091	0.0091	1.9434	1.8939	very small spreading
	2	5.9994	5.7942	0.1030	0.0085	0.0085	1.8446		
	3	6.0309	5.6303	0.1335	0.0011	0.0011	2.4007		

Pen 2 can't also be used for printing the solution because the diameter of the pen is very large, 1.5mm, so more solution is dispensed into the chromatographic paper, which causes the paper to tear. Also, if we increase the feed rate of the printing, it helps to solve the tearing problem but the spread of the solution will still be there. The nip of this pen is also hard, so it also causes the formation of brooches. So, we can't use this pen for printing.

Fig: Pen-2 with a diameter of 1.5mm

c) Calculation for pen 3, B marker pen

LOADING CALCULATION using pen- 3							
Feed rate	**Initial Wt**	**Final Wt**	**Mass deposited in 1 print**	**Mass deposited per unit area**	**Volume of water deposited**	**Mass of $AgNO^3$ deposited**	**Avg mass deposited**
	G	**g**	**g**	**g/cm^2**	**ml/cm^2**	**mg/cm^2**	**mg/cm^2**
100	6.5580	6.4285	0.1295	0.0108	0.0108	2.3282	1.9281
	6.4258	6.3033	0.1225	0.0102	0.0102	2.2023	
	6.5260	6.3954	0.1306	0.0109	0.0109	2.3479	
	6.3932	6.2883	0.1049	0.0087	0.0087	1.8859	
	6.5199	6.3918	0.1281	0.0107	0.0107	2.3029	
	6.3892	6.2790	0.1102	0.0092	0.0092	1.9812	
	6.4684	6.3100	0.1584	0.0132	0.0132	2.8477	
	6.3191	6.2381	0.0810	0.0068	0.0068	1.4562	
	6.4891	6.3641	0.1250	0.0104	0.0104	2.2473	
	6.3625	6.2886	0.0739	0.0062	0.0062	1.3286	
	6.4411	6.3297	0.1114	0.0092	0.0092	2.0028	
	6.3288	6.2466	0.0822	0.0069	0.0069	1.4778	
	6.2443	6.1679	0.0764	0.0064	0.0064	1.3735	
	6.3850	6.2827	0.1023	0.0085	0.0085	1.8392	
	6.2810	6.2087	0.0723	0.0060	0.0060	1.2998	
125	6.5678	6.4846	0.0832	0.0069	0.0069	1.4957	1.4901
	6.5651	6.4804	0.0847	0.0071	0.0071	1.5227	
	6.4803	6.4099	0.0704	0.0059	0.0059	1.2657	
	6.5491	6.4664	0.0827	0.0069	0.0069	1.4868	
	6.5632	6.4778	0.0854	0.0071	0.0071	1.5353	
	6.4778	6.3994	0.0784	0.0065	0.0065	1.4094	
150	6.5397	6.4678	0.0719	0.0059	0.0059	1.2926	1.3721
	6.5637	6.4891	0.0746	0.0062	0.0062	1.3411	
	6.5568	6.4820	0.0748	0.0062	0.0062	1.3448	
	6.5852	6.5200	0.0652	0.0054	0.0054	1.1722	
	6.6060	6.5254	0.0806	0.0067	0.0067	1.4491	
	6.6015	6.5218	0.0797	0.0066	0.0066	1.4329	

This is the best pen among these pens, for this pen the nib is soft so no brooches will be formed. And can print without any spreading by adjusting that the nib should just touch the chromatographic paper. But, before every print, the pen wants to be fully saturated to get a

uniform loading in every print. If it is not fully saturated every time the dispensation of solution will decrease with each print. In this pen, we can change the diameter from 1-5mm by adjusting the tip of the pen, so that how much the tip touches the paper.

Fig: pen-3, Faber castell B marker pen with variable diameter 1-5mm

d) **Calculation for pen 5, SB marker pen**

LOADING CALCULATION using pen- 5							
Feed rate	**Initial Wt**	**Final Wt**	**Mass deposited in 1 print**	**Mass deposited per unit area**	**Volume of water deposited**	**Mass of $AgNO^3$ deposited**	**Avg mass deposited**
	G	**g**	**g**	**g/cm^2**	**ml/cm^2**	**mg/cm^2**	**mg/cm^2**
100	6.5470	6.3798	0.1672	0.0139	0.0139	3.0059	3.0269
	6.3960	6.2346	0.1614	0.0135	0.0135	2.9017	
	6.2821	6.1056	0.1765	0.0147	0.0147	3.1731	
200	6.3614	6.2397	0.1217	0.0101	0.0101	2.1879	2.2218
	6.2366	6.1136	0.1230	0.0103	0.0103	2.2113	
	6.2123	6.0816	0.1307	0.0109	0.0109	2.3497	
	6.2799	6.1541	0.1258	0.0105	0.0105	2.2616	
	6.2522	6.1293	0.1229	0.0102	0.0102	2.2095	
	6.3163	6.1989	0.1174	0.0098	0.0098	2.1106	
250	6.2406	6.1359	0.1047	0.0087	0.0087	1.8823	1.8068
	6.2394	6.1335	0.1059	0.0088	0.0088	1.9039	
	6.3338	6.2307	0.1031	0.0086	0.0086	1.8535	
	6.2908	6.2186	0.0722	0.0061	0.0061	1.2981	
	6.2396	6.1454	0.0942	0.0079	0.0079	1.6935	
	6.1559	6.0613	0.0946	0.0079	0.0079	1.7007	

This is also a good pen to print on different surfaces, but B is the best one. This pen also can change its diameter from 0.5-5mm, according to the contact with the paper. For this too, we want to fill the salt solution and make it fully saturated so that the deposition of Ag salt on each paper will be the same. Or the dispensing of salt solution in each print will decrease, the decrement is given below:

LOADING CALCULATION using the pen- 5 (fully saturated and print until the solution is over)									
Feed rate	**SI No.**	**Initial Wt**	**Final Wt**	**Mass deposited in 1 print**	**Mass deposited per unit area**	**Volume of water deposited**	**Mass of $AgNO^3$ deposited**	**Avg mass deposited**	**remark**
		G	**g**	**g**	**g/cm^2**	**ml/cm^2**	**mg/cm^2**	**mg/cm^2**	
100	1	6.4508	6.3192	0.1316	0.0111	0.0111	2.3659	1.4436	Up to 8th print solution is coming perfect, but from 8th print there are small spaces where solution is not getting printed
	2	6.3184	6.1998	0.1186	0.0099	0.0099	2.1322		
	3	6.1993	6.0892	0.1101	0.0092	0.0092	1.9794		
	4	6.0883	5.9829	0.1054	0.0088	0.0088	1.8949		
	5	5.9828	5.8845	0.0983	0.0082	0.0082	1.7672		
	6	5.8841	5.7844	0.0997	0.0083	0.0083	1.7924		
	7	5.7838	5.6873	0.0965	0.0081	0.0081	1.7349		
	8	5.6863	5.5983	0.0880	0.0073	0.0073	1.5821		
	9	5.5978	5.5196	0.0782	0.0065	0.0065	1.4059		
	10	5.5195	5.4389	0.0806	0.0067	0.0067	1.4491		
	11	5.4387	5.3746	0.0641	0.0053	0.0053	1.1524		
	12	5.3745	5.3050	0.0695	0.0058	0.0058	1.2495		
	13	5.3050	5.2581	0.0469	0.0039	0.0039	0.8432		
	14	5.2578	5.1964	0.0614	0.0051	0.0051	1.1038		
	15	5.1959	5.1322	0.0637	0.0053	0.0053	1.1452		
	16	5.1321	5.0857	0.0464	0.0039	0.0039	0.8342		
	17	5.0857	5.0366	0.0491	0.0041	0.0041	0.8827		
	18	5.0363	4.9990	0.0373	0.0031	0.0031	0.6706		

Fig : pen 5, Faber castell SB marker pen with variable diameter of .5-5 mm

After finding the best pen to print salts using a 3D printer, two new pens of Faber castell B marker pens are taken for 2M $AgNO_3$ and 4M KBr solution. First of all, remove the black ink from the nib and refill of marker pen by washing it with DI water and IPA and sonicate it for 10 minutes. After that test samples are printed to assure that there is no black ink left in that pen. Then the refill is dried in the oven at a temperature of 110^0C for 30 minutes to remove the water inside it.

After drying the refill for 30 minutes, weight is noted. As time progresses the weight of the refill should increase by absorbing the moisture from the air, but here it is reversed the weight decreases with time.

Marker pen refill wt (After drying 30 min)				
Time	**Weigh t**	**Time interval (min)**	**weight difference**	**Total Wt Loss**
Before Drying (2:46 pm)	1.3970	0	0.3954	0.3954
After Drying (3:16 pm)	1.0016	30		
3:21 PM	1.0010	5	0.0006	0.1914
3:30 PM	0.9996	9	0.0014	
3:37 PM	0.9984	7	0.0012	
3:45 PM	0.9971	8	0.0013	
3:50 PM	0.9961	15	0.0010	
4:00 PM	0.9943	10	0.0018	
4:08 PM	0.9928	8	0.0015	
4:29 PM	0.9892	21	0.0036	
4:50 PM	0.9858	21	0.0034	
5:18 PM	0.9806	28	0.0052	
5:30 PM	0.9783	22	0.0023	
5:50 PM	0.9747	20	0.0036	
6:35 PM	0.9663	45	0.0084	
6:55 PM	0.9626	20	0.0037	
7:20 PM	0.9578	25	0.0048	
8:15 PM	0.9496	55	0.0082	
9:46 PM	0.9356	91	0.0140	
10:21 PM	0.9293	35	0.0063	
10:37 PM	0.9227	16	0.0066	
12:20 PM	0.8102	823	0.1125	

The refill is made of polymers, when we heat it at 110^0C the temperature inside the oven will rise to a temperature of 145^0C sometimes, which causes the decomposition of the polymers and also the formation of carbon particles. So when we kept it outside, the carbon particles will mix with the air, and gradually the weight will decrease. So, the oven temperature should reduce to 90-95^0C.

After the water is fully removed, the two refills are fully saturated with $AgNO_3$ and KBr solutions. And the pens are then attached to the appropriate pen holders made by the same 3D printer and attached to printer. The chromatographic paper is set in the printing area of the printer and the G-code is made for the pattern to be printed on the paper with help of that software. And the G-code is fed into the 3D printer. After everything is ready, the G-code is

initiated. Then the printing fill start, so first KBr is printed, and after that $AgNO_3$ is printed. If it was printed as the first layer, we may lose some of them due to their absorption on the paper. And after every print, the paper is dried well and the nib of the pen also wants to be cleaned, due to the reaction occurring at the tip or the point of contact between the solution. The nip is cleaned with IPA and DI water and dried, and the process will continue till the last of the print.

After printing the paper is kept under the halogen lamp for 15 minutes for the formation of latent image centers. This is then put in the ID78 developer solution for the development of nanowires, for 20 minutes. Then wash it with DI water.

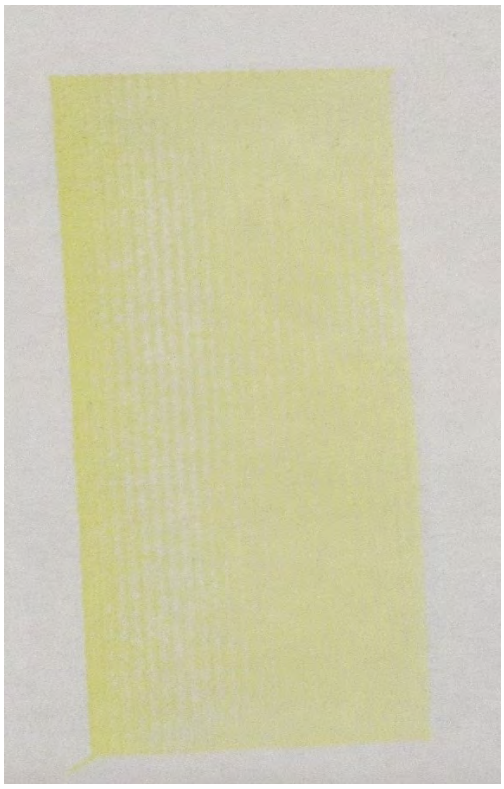
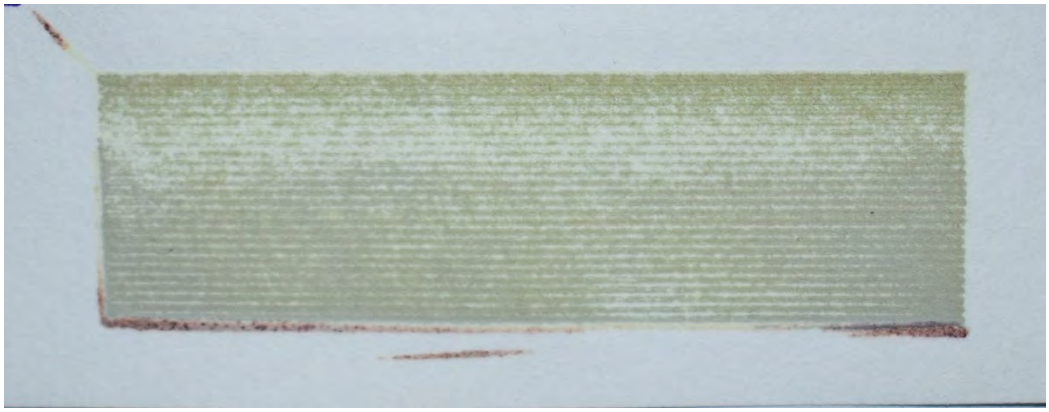
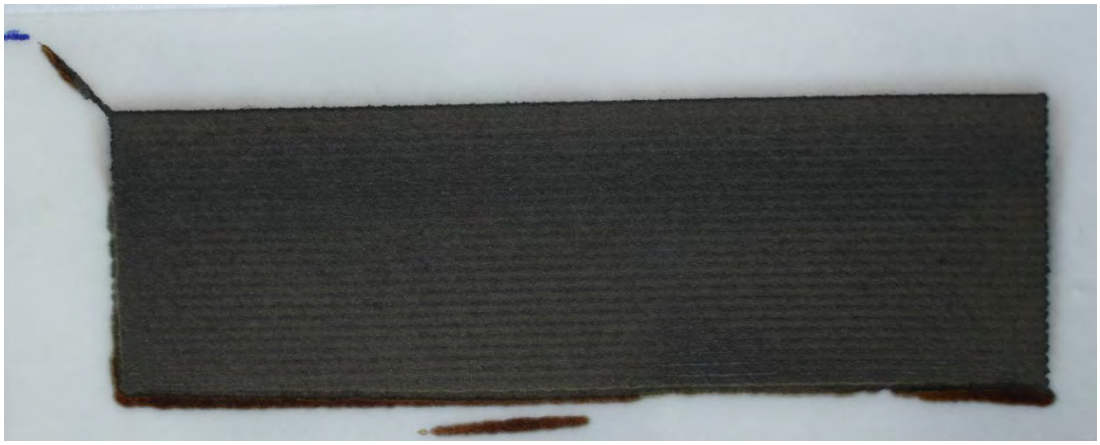


Fig : After printing both KBr and $AgNO_3$



(a)



(b)

Fig : (a) After exposure to halogen lamp, and (b) developed in developer solution ID78 after exposure to halogen lamp

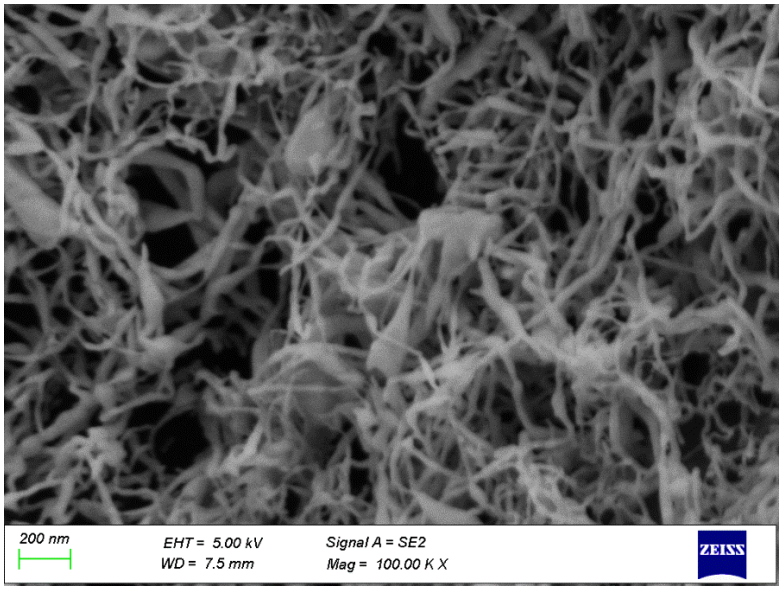


Fig : SEM image of nanowires (SEM done by Rupesh Pawar)

3.3 MICRO THRUSTERS-MAKING OF CATALYST

Microthrusters are composed of small mechanical parts and generally produce thrust, with this force microsatellites are moving in space. They use hydrogen peroxide as the propellant, but the decomposition of H_2O_2 is incomplete. So, here we are mainly focusing to increase the efficiency of the combustion of H_2O_2 by changing the catalyst and its supporter and also by fabricating new models.

Material	**Electric Energy**	**Propellant**	**Catalyst**	**Input Flow Rate (mL/min)**	**Thrust (mN)**	**Specific Impulse (s)**
Ceramic	45 V	HAN	Ag	N/A	100–200	32.3–64.5
N/A	10–15 W	92 wt% H_2O_2	Ag	9.56	182	101
Si-Pyrex glass	0–10 V	H_2O_2	Pt	0.09–0.44	2.0–6.5	65–105
Si-Pyrex glass	44 J	50 wt% H_2O_2	MnO_2	0.20–1.25 (mg/s)	0.3–1.1	80–180
Ceramic	3.7 W	30 wt% H_2O_2	Pt/Al_2O_3	0.05	0.84–0.96	92–106
Glass	N/A	90 wt% H_2O_2 + Ethanol	Pt/Al_2O_3	1.7	30.2	77.6
Glass	N/A	90 wt% H_2O_2	Pt/Al_2O_3	3	48	70.4

Table: some catalyst and their supporters

In the lab, Ag is used as catalyst and glass beads and activated alumina as the supporter. To coat sliver nanowires in glass we follow these steps:

Procedure to develop nanowires in supporters		
Steps	**Time (min)**	**Temperature(^{0}c)**
1.Wash the beads with DI water and IPA	10	
2.Sonicate	10	
3.Dry the beads	30	110
4.Take the weight of the beads		
5.Dip the beads in AgNO3 solution	30	
6.Dry the beads	30	110
7.Take the weight of the beads		
8.Dip the beads in KBr solution	30	
9.Dry the beads	30	110
10.Expose to halogen lamp	15	
11.Develop it using a developer solution	20	
12.Wash it with DI water	10	
13.Dry the beads	30	110

By using this step, we try to coat silver nanowires in glass beads. Given below is the calculation of how much amount of silver is get attached to the glass beads.

Experimental Calculation (in grams) – **1**	
Wt of bottle	49.7756±0.0001g
Wt of bottle + glass beads	54.2851±0.0001g
Wt of beads	4.5095±0.0001g
Wt of bottle + glass beads + 4ml $AgNO_3$ solution	59.3127±0.0001g
Wt of bottle + glass beads + 4ml AgNO3 Solution after 30min	59.2876±0.0001g
Wt of bottle +glass beads + $AgNO_3$ Adsorbed on beads after drying	54.5078±0.0001g
Wt of glass beads + $AgNO_3$ adsorbed on the beads	4.7322±0.0001g
Wt of AgNO3 adsorbed on the beads	0.2227±0.0001g

In experiment -1, the sliver nanowires didn't get attached, when put in the developer solution some of the sliver nanoparticles get separated from the glass beads and the remaining get separated when washed with water. Glass is hydrophobic in nature, that's why the silver particles get separated from the glass beads. So experiment -1 was a failure.

So the next step is to make glass hydrophilic (Water loving). Glass beads are made hydrophilic by layer-by-layer deposition of polyelectrolytes. After cleaning the glass beads with DI water, it is dipped in the PDDA (polycation) solution. Glass beads are so small that we can't pick one by one, we use a tea bag and fill the beads inside it and dip them in the PDDA solution for 10 minutes. The glass beads are taken outside and dried with a hairdryer and put in water for 10 minutes, to reduce swelling caused by excess polyelectrolyte. The glass beads are again dried and dipped in the PSS (polyanion). Six bilayers (coating of polycation over polyanion) are made over the beads. $AgNO_3$ is first so layer-by-layer deposition wants to be stopped with polyanion (PSS), that is, Ag has a positive charge.

Fig: PSS and PDDA solution

After the layer-by-layer deposition, two different compositions of the solution is made to coat nanowires. (a) 2M AgNO3 and 4M 95%KBr and 5%KI and (b) 70% Ethanol and 30% 2M AgNO3 and 20% Ethanol and 80% 4M 95% KBr and 5%KI .

Preparation of solution

Composition	Solution		Total volume (ml) (Vol)	Volume of Ethanol to be added (ml)	Molarity (M)	Wt %	converting wt% to mol %	Molecular Wt (g/mol)	Avg molecular Wt (m)	Mass of substance m=(M*Vol*m)	Total No. of moles	No. of moles	Mass of substance required (g)
$AgNO_3$ in mol%	$AgNO_3$		15	0	2			169.8700			0.03	0.03	5.0961
95% KBr and 5%KI are in wt%	KBr	95% KBr	15	0	4	95	0.7983	119.002	120.71086	7.2427			6.8805
		5% KI				5	0.0301	166.003					0.3621
70% Ethanol and 30% 2M $AgNO_3$	30% $AgNO_3$		10	7	2			169.8700			0.02	0.006	1.0192
20% Ethanol and 80% 4M 95% KBr and 5%KI	80% KBr	95% KBr	10	2	4	95	0.7983	119.002	120.71086	3.8627			3.6696
		5% KI				5	0.0301	166.0028					0.1931

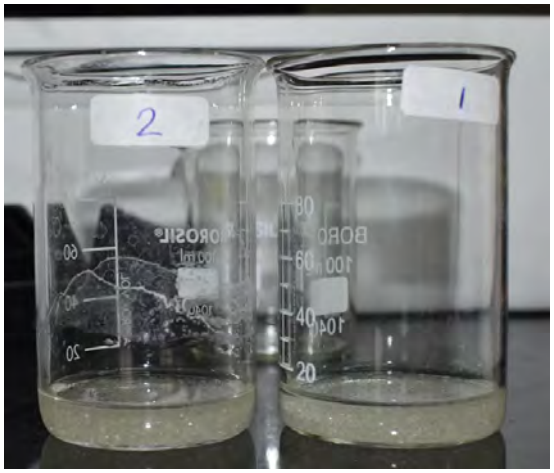
Take two beakers and name them 1 and 2, 1: 2M AgNO3 and 4M 95%KBr and 5%KI and 2: 70% Ethanol and 30% 2M AgNO3 and 20% Ethanol and 80% 4M 95% KBr and 5%KI. Then add glass beads to the two beakers and follow the same step mentioned above to coat on supports.

Experimental Calculation (in grams)(Beaker 1)(2M AgNO3)(4M KBr)

Wt of beaker	61.0765±0.0001g
Wt of beaker + glass beads (before drying)	67.8129±0.0001g
Wt of beaker +glass beads (After drying)	67.7860±0.0001g
Wt of beads	6.7095±0.0001g
Wt of beaker + glass beads + 7ml $AgNO_3$ solution	76.5621±0.0001g
Wt of beaker +glass beads + $AgNO_3$ Adsorbed on beads after drying	68.2947±0.0001g
Wt of glass beads + $AgNO_3$ adsorbed on the beads	7.2182±0.0001g
Wt of AgNO3 adsorbed on the beads	0.5087±0.0001g

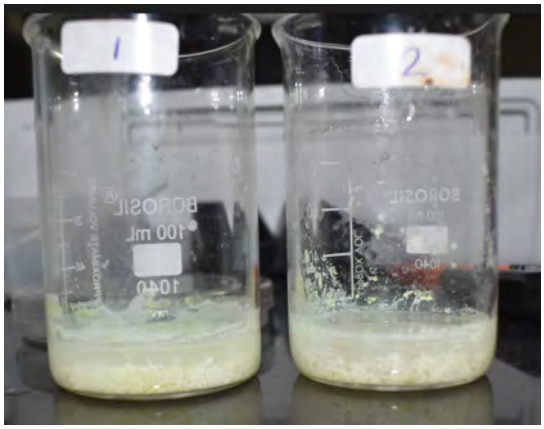
Experimental Calculation (in grams)**(Beaker 2)(70% Ethanol and 30% 2M AgNO3)(20% Ethanol and 80% 4M KBr)**	
Wt of beaker	58.7927±0.0001g
Wt of beaker + glass beads (before drying)	66.9395±0.0001g
Wt of beaker +glass beads (After drying)	66.9064±0.0001g
Wt of beads	8.1137±0.0001g
Wt of beaker + glass beads + 7ml $AgNO_3$ solution	74.2082±0.0001g
Wt of beaker +glass beads + $AgNO_3$ Adsorbed on beads after drying	66.9450±0.0001g
Wt of glass beads + $AgNO_3$ adsorbed on the beads	8.1523±0.0001g
Wt of AgNO3 adsorbed on the beads	0.0386±0.0001g

Comparing these two, beaker 2 is good, which is 70% Ethanol and 30% 2M AgNO3 and 20% Ethanol and 80% 4M 95% KBr and 5%KI.



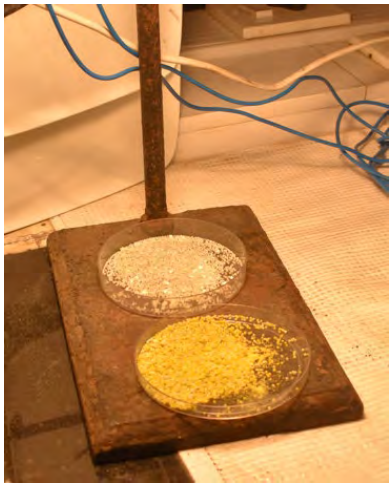
(a)

(b)

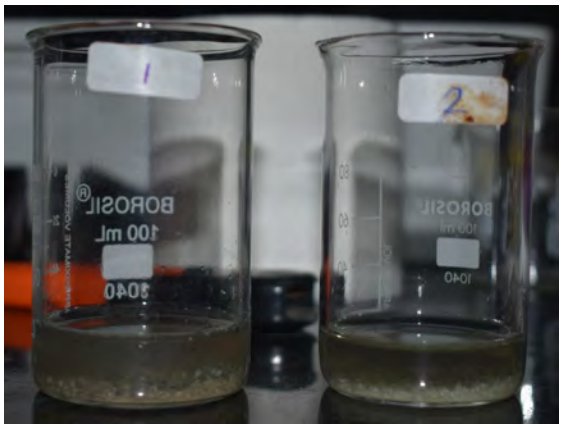


(c)

(d)



(e)



(f)

(g)

(h)

(i)

Fig : (a) beads in $AgNO_3$, and (b) solution dried after dipping in $AgNO_3$ and, (c) in KBr solution, (d) solution dried after dipping in KBr, and (e) Exposed to a halogen lamp, and (f) in the developer solution, and (g) developed glass beads, and (h) developed sample 2, and (i) developed sample 1

After making the glass beads hydrophilic the silver gets attached to them and forms nanowires over them. This experiment was a success.

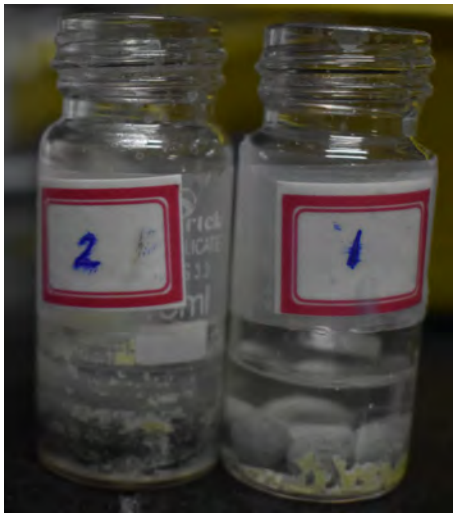
The next support is activated Alumina, here also we coat using the two different solutions of $AgNO_3$ and KBr, using the same procedure used to coat glass beads. No need for layer-by-layer deposition of polycation and polyanion. Alumina is directly washed and coated with $AgNO_3$ using the same steps.

Experimental Calculation (in grams) **for bottle -1 (2M $AgNO_3$)(4M 95%KBr and 5%KI)**	
Wt. of bottle	11.3479±0.0001g
Wt. of bottle + Alumina beads	13.6236±0.0001g
Wt. of beads	2.2757±0.0001g
Wt. of bottle + Alumina beads adsorbed (3ml $AgNO_3$) (After drying)	13.7778±0.0001g
Wt. Alumina beads adsorbed	2.4299±0.0001g
Wt. of $AgNO_3$ adsorbed on Alumina	0.1542±0.0001g

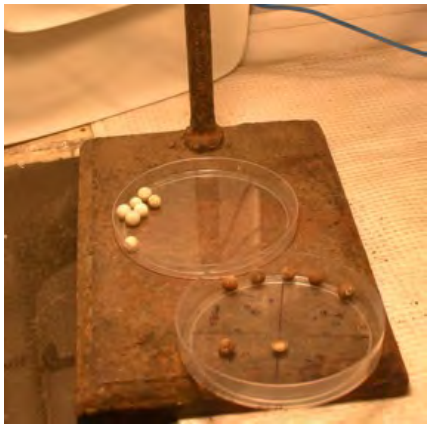
Experimental Calculation (in grams) **for bottle -2 (70% Ethanol and 30% 2M $AgNO_3$)(20% Ethanol and 80% 4M 95%KBr and 5%KI)**	
Wt. of bottle	11.2395±0.0001g
Wt. of bottle + Alumina beads	13.2944±0.0001g
Wt. of beads	2.0549±0.0001g
Wt. of bottle + Alumina beads adsorbed (3ml $AgNO_3$) (After drying)	13.3065±0.0001g
Wt. Alumina beads adsorbed	2.0670±0.0001g
Wt. of $AgNO_3$ adsorbed on Alumina	0.0121±0.0001g

Comparing these two, bottle 2 is good, which is 70% Ethanol and 30% 2M AgNO3 and 20% Ethanol and 80% 4M 95% KBr and 5%KI.

(a)



(b)



(c) (d)

Fig: (a) Alumina in $AgNO_3$ and (b)After in KBr solution, (d) Expose to halogen lamp, and (e) developed Alumina

Different Methods for ccoating catalyst in supporters

Deposition methord	catalyst	Size and material of the structure	scale	thickness or loading
Susp. after thermal ox.	Al_2O_3	40mm x 40mm x 10mm FeCrAl mi- croreactor	0.6-1mm	60μm
Susp. after pretreatment and primer dep.	Al_2O_3	Slabs of Al and FeCrAl, tubes of α-Al_2O_3	-	5-80μm
Suspension	Al_2O_3	6mm O.D. Stainless steel tubes	-	20-200μm
Suspension	Al_2O_3	FeCrAl foam	0.5-1mm	12-54μm
Suspension	Al_2O_3	78mm long stainless steel microchan- nels	100-300μm	10μm
Susp. after thermal ox.	Pt/Al_2O_3	9mm O.D. x 12mm FeCrAlY foam	0.5-1mm	1.5g/in^3
Suspension	Pt/Al_2O_3	5mm x 10mm x 0.35mm Si sensor	-	10-30μm
Susp. after thermal ox. and primer dep.	Pd/Al_2O_3	FeCrAl foams	2-4mm	5.5mg/cm^2
Susp. after thermal ox.	Pd/Al_2O_3	160mm x 250mm FeCrAl fibre panels	35-45μm (fi- bre O.D.)	2wt-%
Suspension	Bi-Mo/Montmorillonite,	80mm long stainless steel tubes	10mm I.D.	300-600 μm

Susp. + plasma spraying	Al_2O_3 and other oxides	30mm x 100mm FeCrAl mesh	-	50μm
Hybrid	$CeO_2-Al_2O_3$	Ceramic monoliths	1mm	10μm
Hybrid	CeO_2-ZrO_2 - $La_2O_3-Al_2O_3$	40mm x 20mm ceramic monoliths	1mm	8-15wt-%
Hybrid	Al_2O_3 and other oxide	30mm x 100mm FeCrAl mesh	-	50μm
Hybrid after thermal ox.	ZrO_2	38mm O.D. x 120mm long FeCrTi fin	4mm	20μm
Hybrid after chemical ox.	CuO/ZnO-Al_2O_3	30cm long quartz and fused silica cap-	0.2-4mm I.D.	1-25μm
Hybrid	Hexaaluminates,	8cm O.D. cast Al_2O_3 disk	-	26-163μm
Hybrid	SiO_2	FeCrAl monolith	1mm	30-50μm
Sol-gel after thermal ox.	Al_2O_3	FeCrAl foams	2-4mm	2-3mg/cm^2
Sol-gel	Al_2O_3	30mm x 30mm glass plate	-	10-20μm
Sol-gel	Al_2O_3	Ceramic monoliths	1mm	3-10wt-%
Sol-gel	Al_2O_3	4.9mm O.D. x 10cm long α-Al_2O_3	-	100μm
Sol-gel (after thermal ox.	Al_2O_3	10mm x 20mm Si microreactors and	5-50μm	1μm
Sol-gel	Pt, Al_2O_3	10mm x 40mm Si microreactor	60-600μm	2.5μm
Sol-gel	Pt/Al_2O_3	6 to 54mm long Si microchannel	75-500μm	3μm
Sol-gel	Rh/Al_2O_3	35mm long α-Al_2O_3 tubes	-	9μm
Sol-gel	Pd/Al_2O_3 , La_2O_3 or SiO_2	FeCrAl monolith	1-2mm	2wt-%
Sol-gel	Ni/La_2O_3, Rh/Al_2O_3	Ceramic monoliths, foams and tubes	1-5mm	13wt-% (Ni), 100-300nm
Sol-gel	$CeO_2-Al_2O_3$ and Pd/oxide	Ceramic monoliths	1mm	2μm/layer
Sol-gel	Al_2O_3 -La_2O_3	12.7mm x 25.4mm Ceramic foams	1mm	6-20wt-%
Sol-gel	Al_2O_3 -La_2O_3	60mm O.D. x 20mm cylindrical ce- ramic foams	4mm	5wt-%
Sol-gel	SiO_2, Al_2O_3 and TiO_2	Stainless steel microreactor	100-200μm	2-3μm

Sol-gel	SiO_2	10mm x 30mm Si microreactor	5-100μm	0.2-10μm
Sol-gel	SiO_2	24mm x 32mm micro cover glasses	-	$< 1\mu m$
Sol-gel	SiO_2, Al_2O_3	0.49mm thick panel of sintered metal fibres	2-30μm	0.5-0.8μm
Sol-gel	ZrO_2	Ceramic fibre mats	10μm	1-2μm
Sol-gel	Barium hexaaluminate	α-SiC honeycomb	-	10μm
Electrophoretic deposition	Al_2O_3	Stainless steel microstructured foils	400μm	2-4μm
Electrophoretic deposition	Al_2O_3	Stainless steel gauze from 50μm O.D. wires	-	1-15μm
Electroless plating	Cu-Zn	21mm x 120mm x 0.4mm Al plates	1mm	50-100μm
Electrodeposition	ZrO_2 , La_2O_3 /ZrO_2	10mm x 10mm x 0.5mm stainless steel plates	-	0.5-2μm
Impregnation	Rh	15mm x 15mm Al_2O_3 foams and Fe-CrAl monolith	100μm-1mm	-
Impregnation	Fe_2O_3	20mm x 20mm stainless steel microstructured foils	70-200μm	1-10μm
Impregnation	Ni/La_2O_3	Cordierite monoliths	1-5mm	9wt-%
Precipitation	Al_2O_3	Woven fabrics from 0.35mm O.D. glass fibres	-	6wt-%
Colloidal polymer solution	Pd	450mm long glass microchannel	100μm	18μm
CVD	Al_2O_3	15mm x 15mm microstructured stainless steel plates	140-200μm	10μm
CVD	Mo_2C	Si substrate	-	320nm
Plasma-CVD	TiO_2	124μm soda-lime glass beads	-	7-120nm

Table : Different methods for coating catalyst on supporter[3]

3.4 NADI VIDHYA – PRINTING IN GLOVES

Nanostructures are so sensitive that even a small disturbance changes its resistance value (or conductance). This property is utilised to replicate the skill used by the tribals to diagnose disease by measuring the pulse with three fingers, popularly referred to as Nadi Vidhya. They can even tell which part of the body has the problem and give us a solution to the problem.

The three fingers are made of stretchable materials (FILAFLEX 60A,70A, 82A) by 3D printing. And nanowires are developed on the tip of the fingers, so when holding on the artery vein, due to the pulse the tip will stretch and the resistance will change. By measuring the change in the resistance, and comparing with the data can understand that which part of the body have problem.

The Gcode used for printer is:

(Finger-code:https://drive.google.com/file/d/1_n3FmhqlRkk8MMkr3_GWOy-oGifuNBJK/view?usp=sharing)

```
M190 S60.000000
M109 S220.000000
;Sliced at: Thu 23-06-2022 17:19:15
;Basic settings: Layer height: 0.15 Walls: 0.8 Fill: 15
;Print time: 55 minutes
;Filament used: 1.999m 5.0g
;Filament cost: None
;M190 S60 ;Uncomment to add your own bed temperature line
;M109 S220 ;Uncomment to add your own temperature line
G21        ;metric values
G90        ;absolute positioning
M82        ;set extruder to absolute mode
M107       ;start with the fan off
G28 X0 Y0  ;move X/Y to min endstops
G28 Z0     ;move Z to min endstops
G1 Z15.0 F3000 ;move the platform down 15mm
G92 E0                  ;zero the extruded length
G1 F200 E3              ;extrude 3mm of feed stock
```

```
G92 E0                  ;zero the extruded length again
G1 F3000
;Put printing message on LCD screen
M117 Printing...

;Layer count: 261
;LAYER:0
M106 S127
G0 F3000 X99.511 Y150.364 Z0.300
G0 X99.126 Y150.659
;TYPE:SKIRT
G1 F1200 X99.511 Y150.364 E0.02420
G1 X101.049 Y149.644 E0.10892
G1 X101.567 Y149.357 E0.13847
G1 X101.960 Y149.133 E0.16103
G1 X102.262 Y148.955 E0.17852
G1 X102.949 Y148.509 E0.21939
G1 X103.558 Y148.113 E0.25563
G1 X104.730 Y147.534 E0.32085
G1 X105.239 Y147.292 E0.34896
G1 X105.979 Y147.020 E0.38830
G1 X106.769 Y146.709 E0.43066
G1 X107.648 Y146.490 E0.47585
G1 X108.583 Y146.257 E0.52392
G1 X109.465 Y146.160 E0.56819
G1 X110.495 Y146.063 E0.61981
G1 X111.652 Y146.127 E0.67762
G1 X112.408 Y146.194 E0.71548
G1 X113.143 Y146.350 E0.75297
G1 X114.057 Y146.540 E0.79954
G1 X115.659 Y147.127 E0.88466
G1 X117.491 Y148.035 E0.98667
```

G1 X118.278 Y148.536 E1.03322

G1 X118.905 Y148.955 E1.07084

G1 X119.649 Y149.575 E1.11916

G1 X120.170 Y150.040 E1.15400

G1 X121.061 Y151.020 E1.22008

G1 X121.517 Y151.627 E1.25795

G1 X121.945 Y152.214 E1.29420

G1 X122.414 Y152.893 E1.33537

G1 X122.952 Y153.828 E1.38919

G1 X123.383 Y154.641 E1.43509

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;TYPE:WALL-OUTER

G1 F1020 X112.875 Y163.137 E1998.57566

G1 X112.856 Y163.284 E1998.57935

G1 X112.636 Y164.239 E1998.60380

G1 X111.554 Y164.507 E1998.63161

G1 X111.437 Y164.501 E1998.63453

G1 X110.361 Y164.121 E1998.66299

G1 X109.928 Y163.906 E1998.67505

G1 X109.822 Y163.163 E1998.69378

G1 X109.704 Y162.933 E1998.70022

G1 X109.689 Y162.852 E1998.70228

G1 X109.878 Y162.056 E1998.72269

G1 X110.433 Y161.523 E1998.74188

G1 X110.521 Y161.496 E1998.74418

G1 X111.463 Y161.345 E1998.76798

```
G1 X112.263 Y161.947 E1998.79295
G1 X112.341 Y162.044 E1998.79606
G0 F3000 X112.213 Y163.017
;TYPE:FILL
G1 F600 X111.338 Y163.893 E1998.82694
G0 F3000 X111.319 Y163.886
;TYPE:SKIN
G1 F1500 X112.205 Y163.000 E1998.85820
G0 F3000 X112.017 Y162.623
G1 F1500 X110.901 Y163.738 E1998.89755
G0 F3000 X110.491 Y163.582
G1 F1500 X111.800 Y162.273 E1998.94373
G0 F3000 X111.478 Y162.030
G1 F1500 X110.365 Y163.143 E1998.98299
G0 F3000 X110.292 Y162.650
G1 F1500 X110.974 Y161.969 E1999.00704
G0 F3000 X112.242 Y163.529
G1 F1500 X111.908 Y163.862 E1999.01880
;LAYER:260
G1 F1620 E1996.01880
G0 F3000 X110.794 Y162.686 Z39.300
;TYPE:WALL-OUTER
G1 F1620 E1999.01880
G1 F540 X110.803 Y162.691 E1999.01906
G1 X110.778 Y162.694 E1999.01969
G1 X110.794 Y162.686 E1999.02013
M107
G1 F1620 E1996.02013
G0 F3000 X110.794 Y162.686 Z44.236
;End GCode
M104 S0                 ;extruder heater off
M140 S0                 ;heated bed heater off (if you have it)
```

G91 ;relative positioning

G1 E-1 F300 ;retract the filament a bit before lifting the nozzle, to release some of the pressure

G1 Z+0.5 E-5 X-20 Y-20 F3000 ;move Z up a bit and retract filament even more

G28 X0 Y0 ;move X/Y to min endstops, so the head is out of the way

M84 ;steppers off

G90 ;absolute positioning

M81

;CURA_PROFILE_STRING:

(a)

(b)

(c) (d)

Fig : (a) 3D printed fingers, and (b) FILAFLEX 82A, and (c) FILAFLEX 70A, and (d) FILAFLEX 60A

The nanowires are developed by following the same procedure used in glass beads. Only one solution, 2M $AgNO_3$, and 4M KBr are used for the development of nanowires. But the coating is not well, and the resistance is measured to be zero.

(a) (b)

(c) (d)

Fig: (a)finger in $AgNO_3$ solution, (b)After dipping in KBr, (c)dipped in the developer solution, and (d) nanostructures developed finger

Finger gloves are ordered, to make the sensor on it, when the 3D printed finger fails. The resistance of each glove is measured initially before developing nanowires on it. The resistance of some gloves is:

Finger Gloves (length=3cm & breadth=2.3cm)			
Glove's No.	**Resisitance (kΩ)**	**Avg Resistance (kΩ)**	**Ω/ □ (R/(L/B))**
1	12.10	12.49	9.51
	11.95		
	12.60		
	12.50		
	12.10		
	13.20		
2	7.40	7.83	6.01
	8.01		
	8.20		
	7.80		
	7.35		
	8.20		
3	305.00	302.00	231.53
	295.00		
	312.00		
	310.00		
	288.00		
4	116.30	117.32	89.94
	120.60		
	111.00		
	119.00		
	112.00		
	125.00		

With the help of Vectary and Creatily software, the desired pattern to print on the gloves can be made. And with the help of Faber castell B marker pen, we can print $AgNO_3$ and KBr on the gloves, for developing nanowires.

Fig : checking the resistance of finger gloves by multimeter

APPENDIX

a) Loading calculation and amount of Ag deposition

Feed rate	No. of print	Initial Wt	Final Wt	Mass deposited in 1 print	Area	Mass deposited per unit area	Volume of water deposited	Molecular Wt (Ag)	Molarity of $AgNO_3$	Mass of $AgNO^3$ deposited	Avg mass deposited
		g	g	g	cm^2	g/cm^2	ml/cm^2	g/mol	M	mg/cm^2	mg/cm^2
250	1	6.2798 ±0.0001	6.1914 ±0.0001	0.0885 ±0.0001	12.0± 0.1	0.0074±0.0001	0.0074±0.0001	107.8682 ±0.0001	2.0± 0.1	1.5965 ± 0.0827	1.3592± 0.1694
	2	6.1895 ±0.0001	6.0412 ±0.0001	0.0742 ±0.0001		0.0063±0.0001	0.0063±0.0001			1.3591± 0.0713	
	3	6.3344 ±0.0001	6.1494 ±0.0001	0.0618 ±0.0001		0.0052±0.0001	0.0052±0.0001			1.122±0.0601	

(with error calculation)

Feed rate =250

Only for 1 print,

Initial weight = 6.2798 ±0.0001 g

Final weight= 6.1914±0.0001g

Mass deposited in 1 print = (initial weight – final weight)/ no of prints

= (6.2798 ±0.0001 - 6.1914±0.0001g)/1

= (6.2798 - 6.1914) ± {$\sqrt{}$ [($.0001^2$) +($.0001^2$)]}

= 0.0884±.0001g

Mass deposited per unit area = mass deposited / area

=0.0884±0.0001 /(12.0±0.1)

= (0.0884/12.0)± {(0.0884/12.0)*$\sqrt{}$ [$(.0001/0.0884)^2$ +$(0.1/12.0)^2$]}

=0.0074±(0.000062)g

$= 0.0074 \pm 0.0001 g$

Mass of $AgNO_3$ deposited=volume of water deposited * molarity * molecular wt

$=0.0074 \pm 0.0001 * 107.8682 \pm 0.0001 * 2 \pm 1$

$=0.0074*107.8682*2 \pm \{(0.0074*107.8682*2)* \sqrt{[(0.0001/0.0074)^2+(0.0001/107.8682)^2 +(.1/2)^2]}\}$

$= 1.5965 \pm 0.0827 \ mg/cm^2$

The remaining are done in the same way, for all loading calculations printed in Inkjet and 3D printer.

b) Experimental calculation for mass of Ag absorbed in glass beads

Experimental Calculation (in grams)**(Beaker 1)(2M AgNO3)(4M KBr)**	
Wt of beaker	61.0765±0.0001g
Wt of beaker + glass beads (before drying)	67.8129±0.0001g
Wt of beaker +glass beads (After drying)	67.7860±0.0001g
Wt of beads	6.7095±0.0001g
Wt of beaker + glass beads + 7ml $AgNO_3$ solution	76.5621±0.0001g
Wt of beaker +glass beads + $AgNO_3$ Adsorbed on beads after drying	68.2947±0.0001g
Wt of glass beads + $AgNO_3$ adsorbed on the beads	7.2182±0.0001g
Wt of AgNO3 adsorbed on the beads	0.5087±0.0001g

Weight of beaker = 61.0765±0.0001g

Weight of beaker + glass beads (After drying) =67.7860±0.0001g

Weight of glass beads=$(67.7860-61.0765) \pm \{\sqrt{[(.0001^2) + (.0001^2)]}\}$

$=6.7095\pm0.0001g$

Weight of beaker +glass beads + $AgNO_3$ Adsorbed on beads after drying

$=68.2947\pm0.0001g$

Weight of glass beads + $AgNO_3$ adsorbed on the beads

$=(68.2947-31.0765) \pm \{\sqrt{[(.0001^2) + (.0001^2)]}\}$

$=7.2182\pm0.0001g$

Weight of AgNO3 adsorbed on the beads $=7.2182\pm0.00014 - 6.7095\pm0.00014$

$=(7.2182-6.7095) \pm \{\sqrt{[(.0001^2) + (.0001^2)]}\}$

$=0.5087 \pm 0.0001g$

c) Preparation of solution

Preparation of solution													
Composition	**Solution**		**Total volume (ml) (Vol)**	**Volume of Ethanol to be added (ml)**	**Molarity (M)**	**Wt %**	**converting wt% to mol %**	**Molecular Wt (g/mol)**	**Avg molecular Wt (m)**	**Mass of substance m=(M*Vol*m)**	**Total No. of moles**	**No. of moles**	**Mass of substance required (g)**
$AgNO_3$ in mol%	$AgNO_3$		15	0	2			169.8700			0.03	0.03	5.0961
95% KBr and 5%KI are in wt%	KBr	95% KBr	15	0	4	95	0.7983	119.0020	120.7109	7.2427			6.8805
		5% KI				5	0.0301	166.0028					0.3621
70% Ethanol and 30% 2M $AgNO_3$	30% $AgNO_3$		10	7	2			169.8700			0.02	0.006	1.0192
20% Ethanol and 80% 4M 95% KBr and 5%KI	80% KBr	95% KBr	10	2	4	95	0.7983	119.0020	120.7109	3.8627			3.6696
		5%KI				5	0.0301	166.0028					0.1931

1) For 2M $AgNO_3$,

Molecular weight of $AgNO_3$ = 169.87g/mol

Molarity of $AgNO_3$ =2M

Volume required = 15 ml

No. of moles = Molarity * volume

=2*15*10^-3

=0.03

Mass of substance = no. of moles * molecular weight

=0.03*169.87

=5.0961g

2) For 4M KBr (95% KBr and 5% KI, are in Wt.%)

Basics : 100g substance

Molecular weight of KBr=119.002g/

Molecular weight of KI=166.028g/mol

95g KBr : 5g KI

Converting wt.% to mol%

95/119.002 KBr : 5/166.028 KI

0.7983 KBr : 0.030115 KI

Average molecular weight = [(0.7983*119.002)+(0.030115*166.028)] / (0.7983+0.030115)

= 120.7115g/mol

Molarity of KBr= 4M

Volume required= 15ml

Molarity = no. of moles / volume

No. of moles= molarity * volume

= 4*15*10^-3

= 0.06 mol

Mass of substance = no. of moles * average molecular weight

=0.06*120.7115

= 7.24269g

Weight of KBr=0.95*7.24269

= 6.8806g

Weight of KI = 0.05* 7.24269

=0.3621g

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