Instantaneous Fabrication of Thin MEMS Features by Copper Electrodeposition Using Modified Inkjet Printer

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Microelectromechanical system (MEMS) has been used so far in today's scenario in mechatronic assemblies to enhance its functionality and mitigate the complexity of design. Micro electrodeposition technique enables to produce such features. This research is an attempt to fabricate the micro feature instantaneously using a modified ink jet printer on an aluminium substrate. The acidic electrolyte was prepared by using Cupric Sulphate Penta hydrate ($CuSO_{4.5}H_2O$) of 1M concentration with H_2SO_4. Multiple passes deposit the copper ion on Aluminium sheet with thickness of 0.2 mm. the feature design, Voltage and concentration of electrolyte has been taken as Input parameter. Surface characteristics have been discussed in this article. Result revealed thin metallic sheet can only be used for 6-7 passes due to wrinkles and edge deformation. If more passes will be carried out on an aluminium foil sheet then uniform deposition of copper metal ions will be possible. The concentration of $CuSO_{4.5}H_2O$ has played important role in this experimental process on deposition rate.

Keywords: MEMS, Electrodeposition, Copper, Inkjet, Thin Metallic Coating.

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1. INTRODUCTION

The electro deposition technique has been recognized as a favorable process in advanced manufacturing to fabricate prototype, model or micro size parts. Blix had observed that effect on the diffusion of ions on fabricated parts is directly proportional to concentration of the solution [1]. In order to obtain better quality parts, the above feature should be high. They have analyzed the electro deposition process for cobalt. They were examined the level of electrolyte to deposited cobalt layer and observed the sample structure of deposition of cobalt layer. They were found that the high surface development has been observed at the low potential difference. (Gomez, Pane, and Valles 2005) worked on Co-Ni and Co-Ni-Cu system in the medium of sulphate-citrate. They were found the properties of Co-Ni alloys and the condition of Co or Co-Ni ratio in the corresponding electrolyte solution. Author found that deposited Co-Ni-Cu of FCC structure and magnetic properties depend on the applied voltage difference [2].

Nevertheless, firstly, the Journal is peer reviewed, and any submitted manuscript undergoes the reviewing procedure. If the referees decline the paper, it could not be published. Secondly, strict requirements to the manuscript preparation exist, and submitted manuscript should be ready for publication. Simultaneously with the content reviewing, any manuscript is checked for compliance to the stated formatting requirements. If the checking is failed, the manuscript is returned to authors for revision.

2. INKJET PRINTING

2.1 Inkjet Printer

This study approaches an inkjet printing technology to fabricate micro size part. An inkjet printer has used for deposit metal droplets on the surface by incorporation of the nozzle and use of computer control that regenerates the digital image. Thermal ink jet printing techniques and piezoelectric printing techniques are two basic types of printing for fabricating polymer.

Wijshoff had analyzed fast moving micrometer droplet with ILIF in an inkjet printer. They were discussed distribution and essential condition for the formation of droplets with the help of acoustic detection [3]. From this paper, it has been shown that the spattering of electrolyte droplets due to impacts of surfactant and merging of drops.

Authors [4] have worked on printing technology and fabricated polyaniline (PANI) on photographic papers using a computer control thermal printer. They have found that surface resistivity decreases with number of layers deposited.

From the literature review, it has been observed that Most of the experimental studies of deposition are available for additive processing the material of polymer and plastic etc. limited experimental studies are available for electro deposition of metallic ions. A few researchers have been performing their work on the copper electrolyte solution. From a research point of view, this is a vast and an important area.

High speed selective jet electrodeposition also enables to produce MEMS features but practice is complex and take much time than the presented work [5-6]. The author also developed mathematical model to evaluate the material deposition rate.

3. EXPERIMENTAL SETUP

3.1 Apparatus

To develop the inkjet kind of deposition system, an inkjet printer HP3515 is used. For continuous ink sup-

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ply system (CISS), the electrolyte tank was used. Cupric sulphate has used as an electrolyte solution which was prepared by H_2O, $Cu_2SO_{4.5}H_2O$, and H_2SO_4. The copper strip was used to create a potential difference between the electrolyte and AFS which is as a surface to deposit of metal ions. All the chemicals, copper strips and printer are acquired from standard supplier.

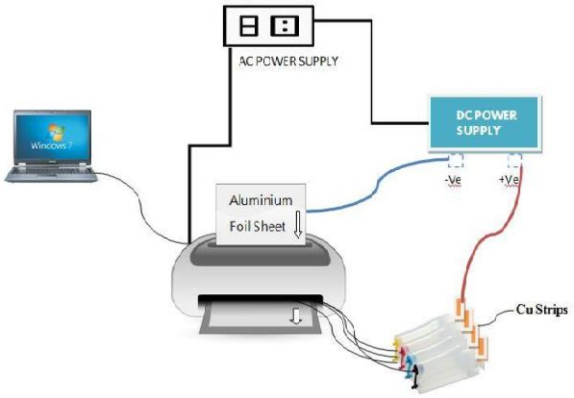

Fig. 1 – Framework for experimental setup

3.2 Procedure

In the beginning of the experiment, CISS installation has been done in an inkjet system for continuous flow of electrolyte. Electrolyte tank consists of 4 small tanks. These tanks are used to fill electrolyte for continuous flow. In CISS installation inkjet system has been connected electrolyte tank by using small plastic tubes. For CISS installation, the cartridge has been connected to a small tube for continuous flow at the time of deposition. Another side of this small tube has been connected with an electrolyte tank. By this process, the inkjet system has been connected to an electrolyte tank.

After the CISS installation, the electrolyte solution has been prepared by H_2O, $CuSO_{4.5}H_2O$, and H_2SO_4. The H_2SO_4 was mixed in solution to make it of 1M concentration. $CuSO_{4.5}H_2O$ was mixed in the solution with 9-22 g/l concentration. For preparation of electrolyte solution, firstly hand globes were used for safety purpose. 1000 ml beaker was used to make H_2SO_4 of 1 M concentration. 1000 ml distilled water has been filled in a beaker and then 36 ml H_2SO_4 was mixed in a beaker to make 1M concentrate H_2SO_4. Then $CuSO_{4.5}H_2O$ was mixed in the solution at 9-22 g/l concentration. Now electrolyte solution namely copper sulphate Pentahydrate has ready for use. It is blue in colour and hazardous,

Fig. 2 – Experimental setup of modified inkjet printer for instantaneous electrodeposition

therefore so proper safety precaution must be taken.

Electrolyte solution has been filled in tank by using injection. After filling the electrolyte in the tank, air is injected into the tank for the flow of electrolyte in a small plastic tube, which has been connected to cartridge. By this process, both the cartridges have been filled with electrolyte. These cartridges supplied electrolyte continuously at the time of experimental studies.

A paper of dimension 8.27”×11.69” and aluminium foil has been taken. Aluminium foil has fix on both sides of this paper by using the sticker. For preparing AFS, firstly foil cuts similar to the dimension of paper, then arranged it onto the paper. This arrangement of paper and aluminium foil is capable to go inside the inkjet system for deposition of metallic ions.

A setup was developed to create a potential difference between AFS and an electrolyte solution by using variable (0-12V) DC power supply. The set up consist of a small copper strip, which was inserted in electrolyte tank to give positive charge, because positive terminal of DC power supplier was connected to the small copper strip. Negative terminal of DC power supplier was connected to AFS. The electric wire has used to connect DC power supplier with AFS and electrolyte solutions. All these processes were used to create potential differences.

Now the experimental setup has been ready for experimental studies and statistical modelling of the input parameter and output variables. For experimental study firstly electrolyte solution has been prepared. 18 g/l concentrated electrolyte solution has been used. DC power supply is connected to electric board to confirm that process is working or not. Both AFS and electrolyte was connected to DC Power supplier by use of electric wire.

Then inkjet system, HP3515 has been connected with electric board and laptop. AFS loaded on the paper plate of inkjet system, and a print command was given from laptop image file. When AFS was inside the inkjet system, at that time both the cartridges are in contact with an AFS. Copper metal has been deposited on the AFS by the principal of electro deposition process.

According to the principal of electro deposition, when AFS has been in contact with both the cartridges, then at that time, electrolyte solution has been dissolved as Cu^{++} and $SO42^{-}$ ions. Cu^{++} ions have been deposited on AFS because of AFS was connected with negative terminal. Free ions of $SO42^{-}$ go in the direction of the copper strips which were used to give positive charge of electrolyte and combined with Cu^{++} ions. Copper strips emitted Cu^{++} ions. When AFS comes out from the inkjet system, then disconnect AFS from DC power supplier and again loaded it. This process has been performed 6-7 times onto the AFS.

4. RESULTS AND DISCUSSIONS

From the above experimentation process, following characterizations of deposit metallic ions have been studied.

4.1 Morphology of Deposited Copper Ions

Morphology of deposit metallic ions on the AFS has been done by using microscope. It has been studied by capturing images at 6 V and 18 g/l concentrations and 12 V and 18 g/l concentrations from the microscope.

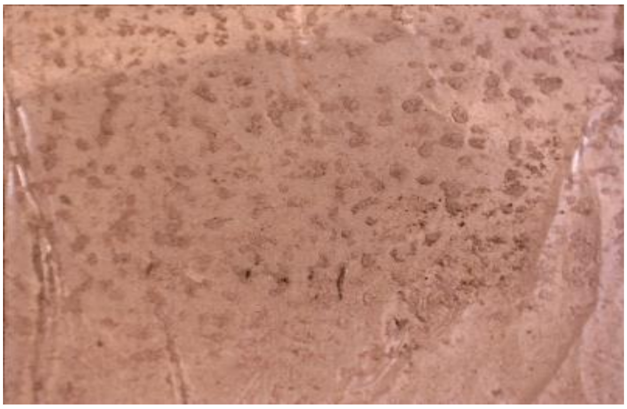

Fig. 3 – Deposition of copper ions on AFS at the 6 V and 18 g/l concentration

Fig. 4 – Deposition of copper ions on AFS at the 12 V and 18 g/l concentrated electrolyte solution.

Experimental study of both the captured images, it has been found that deposition of copper ions has in the doted form after 6 to 7 passes of the AFS. Difficulties arise after 6-7 passes of AFS because AFS begins to be wrinkled. By means of a greater number of passes, uniform deposition of copper metal ions will be possible. Hence studies of microscopic images, deposition of copper ions have in doted form.

4.2 Evaluate Weight of Aluminium Foil Sheet after Deposition

Before starting the experimental study, the weight of Aluminium foil has been measured which was 17.628 gm and after the experimentation process, it has found that it was increased. After the 6 to 7 passes, the final weight of sheet was 18.127 gm with the 6 V DC power supply and 18 g/l concentration. The same experimental study has been done for the 12 V DC power supply and 18/l concentration and the final weight of aluminium foil sheet was 18.324 gm which has also increased to .696gm. Percentage increased in weight of aluminium foil sheet was 2.83 % and 3.94 % at 6 V and 12 V respectively. This data strongly recommends that amount of deposition of Cu^{++} depends on voltages.

4.3 Variation of Deposition Rate with Respect to Potential Difference

For evaluating the deposition rate, some input and output parameters has been taken such as voltage and concentration of the electrolyte. Voltage has been taken as 2 V, 4 V, 6 V, 8 V, 10 V, 12 V voltage keeping the concentration of electrolyte constant. For these voltages, deposition of copper ions has been found out with respect to time in minute and the time for deposition of copper ions has been calculated when AFS is in contact with both the cartridges. It has been taken 7 passes of AFS in the printer.

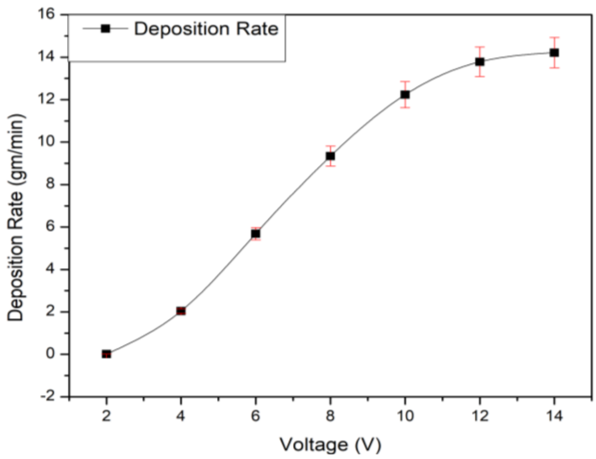

Fig. 5 – Deposition rate (gm/min) when increasing Voltage (V) at 18 g/l concentration

Deposition rate has measured out in gm/min with respect to a voltage. After that, voltage has been taken into horizontal axis or ordinates and deposition rate in the vertical or abscesses. The graph plotted between deposition rate (gm/min) and voltage (V). It has found that deposition rate has increased with increasing the voltage.

4.4 Variation in Deposition Rate with Respect to the Concentration of $CuSO_{4.5}H_2O$

For calculation of deposition rate with respect to concentration of $CuSO_{4.5}H_2O$ with other parameter i.e. 6V voltage and 0.5mA current kept constant.

Concentration of electrolyte has been taken as 9 gm/l, 12 gm/l, 15 gm/l, 18 gm/l, 21 gm/l and 24 gm/l. For these all concentration value, deposition of copper ions has been found out with respect to time in minute.

From the results, it has been found that deposition rate has slightly increased with increasing the concentration of $CuSO_{4.5}H_2O$ in the electrolyte solution.

4.5 The Cartridge Conditions before and after the Use of Electrolyte Solution

A new cartridge was used for experiment, when it was used with electrolyte solution then it has worked properly for some time and deposited ions of copper on AFS. After some experiments, the cartridge has not

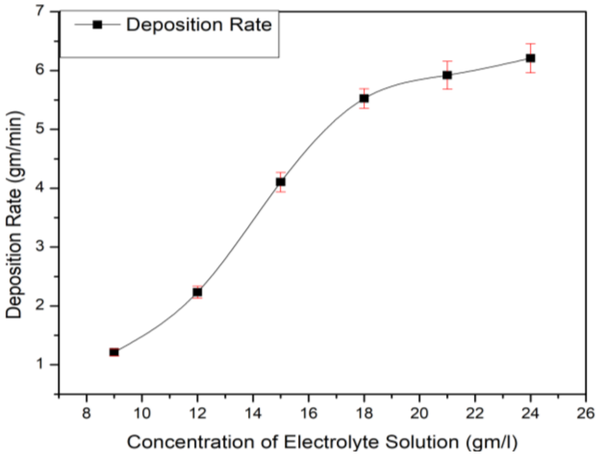

Fig. 6 – Effect of concentration (gm/l) over Deposition rate (gm/min) at the 6 V voltage

Fig. 7 – Cartridge conditions before and after experiment

working properly because of $CuSO_{4.5}H_2O$ precipitate in ink nozzle of the cartridge. A small current flow through resistor made it warm. The electrolyte contact with the heater resistor is vaporized into a tiny steam bubble inside the nozzle which is deposited on the AFS. To prevent the cartridges from $CuSO_{4.5}H_2O$ precipitates, the cartridges had cleaned by using distilled water.

5. CONCLUSION

In this paper, inkjet printing technology and electro chemical process has been explored. Factors affecting the deposition rate of copper ions have examined. Deposition rate has been calculated with respect to voltage and concentration of electrolyte. This experiment encompasses following conclusion-

• More number of passes of AFS ensures uniform deposition.

• Morphology of AFS shows that the deposition of copper ions is in dotted form. Deposition rate increases with respect to voltage and concentration of electrolyte solution.

• Proper precaution should be taken from time to time in order to prevent cartridges from CuSO4.5H20 precipitate. Failure to which can lead to permanent damage to cartridge.

It is big contribution to advance manufacturing technology i.e. additive manufacturing, 3*D* printing etc. It is good research area from the side of advanced manufacturing technology to deposit metallic ions for fabrication of prototype, model or to create the metallic part.

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