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THE EFFECTS OF ADDITIVES IN NICKEL AND COPPER ELECTROPLATING FOR MICROSTRUCTURE FABRICATION

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Abstract

The effect of additives in nickel and copper electroplating were investigated for MEMS applications. Saccharin and gelatin were used as additives in nickel and copper electroplating bath respectively. The morphology and surface hardness of electroplated coating were investigated with additive concentration. Microstructures were fabricated with optimum conditions.

Key words : *Electroplating, Nickel, Copper, MEMS, Saccharin, Gelatin*

1. INTRODUCTION

In MEMS the microstructures were fabricated by electroplating[1),2)]. The operating cost of electroplating is lower than any other dry process[3)]. Nickel, copper, gold and aluminum are most frequently used materials in MEMS electroplating[4)]. Nickel has excellent mechanical properties and copper has good electrical properties. The electroplating of nickel and copper were already established technique in electrochemical industry. However, when this technique is applied for the very small substrate, very complex shape of substrate gives the non-uniform current density therefore the uniform coating thickness is not easy to be obtained. To obtain uniform coatings, the roles of the additives are very important. In this research, the effects of the additives on the nickel and copper electroplating surface morphology and hardness of coating layer were investigated. After obtaining optimum conditions, microstructures were fabricated.

2. EXPERIMENTAL PROCEDURE

Typical sulfate baths were used for nickel and copper electroplating. Considering PR conditions, high pH bath were avoided. Saccharin was used as additive in nickel electroplating and gelatin was used as additive in copper electroplating. Table 1 and 2 shows bath compositions and operating condition in nickel and copper electroplating respectively. Nickel and copper were electroplated for 4hrs at $10mA/cm^2$ current density and

Table 1. Bath composition and operating condition in nickel electroplating.

Bath composition	Nickel sulfate : 260gpl Nickel chloride 45gpl Boric acid : 45gpl Saccharin : 0-5gpl
Operating condition	Temperature : 50℃ pH : 3.5-4 Current density: 10mA/cm^2

Table 2. Bath composition and operating condition in copper electroplating.

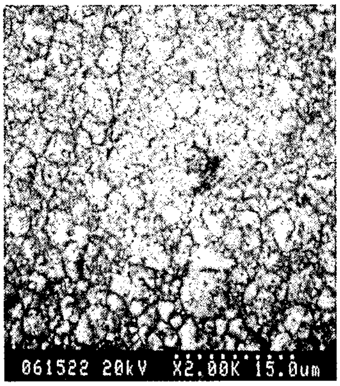
Bath composition	Copper(II) sulfate : 200gpl Sulfuric acid : 40gpl Gelatin : 0-1gpl
Operating condition	Temperature : 25℃ pH : 0.5 Current density : 10mA/cm^2

surface morphology was investigated with SEM. The hardness of the coating layer was measured with Vicker's hardness tester. Thick PR was used to fabricate microstructures.

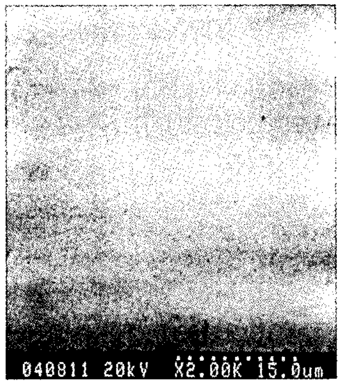
3. RESULTS AND DISCUSSION

3. 1 Effect of saccharin on nickel electroplating

Saccharin was added as a brightener in nickel electroplating. Saccharin is typical brightener in nickel electroplating. Fig. 1 shows the surface morphology of the electroplated nickel after 4hrs electroplating. Addition of saccharin had improved the surface smoothness. The concentration of saccharine was increased from 0 to 5gpl. However, the surface morphology was no longer improved with saccharin concentration over 1gpl. The hardness of nickel deposition was measured with Vicker's hardness tester. Table 3 shows the hardness of electroplated nickel with saccharin concentration. The hardness was increased with saccharin addition. However, it is



(a) without saccharin



(b) saccharin 0.5gpl

Fig. 1 Surface morphology of electroplated nickel

Table 3. Hardness of electroplated nickel with saccharin concentration.

Saccharin Concentration (gpl)	Vicker's Hardness (Hv)
0	560
0.5	770
1	640
2	630
3	650
5	500

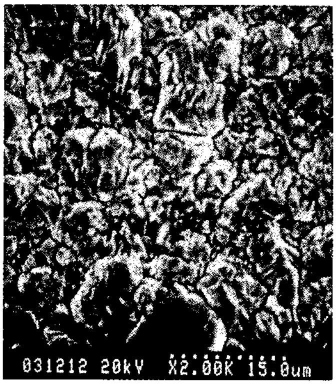
no longer improved with further addition of saccharin. Saccharin was adsorbed on the cathode especially on high current density site and then it lowered the current density[5]. As a result, the surface was flattened. Saccharine also inhibited the grain growth of nickel and then the grain size of nickel became smaller and then the hardness of electroplated nickel increased due to small grain size. Nickel deposition potential is similar to hydrogen evolution at pH 3-4. And then hydrogen evolution can not be avoided. Table 4 shows current utilization in nickel electroplating. The current utilization became lower with saccharin concentration. It is due to the growth of nickel was inhibited with addition of saccharin while hydrogen evolution was not affected. From the above results, optimum concentration of saccharin is 0.5gpl in nickel electroplating.

3. 2 Effect of gelatin on copper electroplating

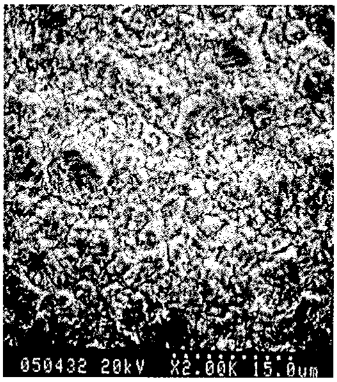
In copper electroplating gelatin was added as brightener. Fig. 2 shows the surface morphology of electroplated copper after 4hrs electroplating. The concentration of gelatin was increased from 0 to 1gpl. Surface of copper became smoother with gelatin addition. However, the surface morphology was no longer improved with gelatin concentration over 0.05gpl. The cracks and pores were found on deposited copper. Table 5 shows the hardness of electroplated copper with gelatin concentration. The hardness was increased with gelatin addition. However, it was no longer im proved with further addition of gelatin over 0.05gpl. Gelatin acted as inhibitor similar to saccharin. Not like nickel electroplating, the deposition potential of copper is higher than that of hydrogen evolution and then current utilization is 100% regardless of gelatin concentration.

Table 4. Current utilization with saccharin concentration.

Saccharin Concentration (gpl)	% utilization
0	>95%
0.5	>95%
1	>95%
2	93%
3	88%
5	72%



(a) without gelatin



(b) gelatin 0.05gpl

Fig. 2. Surface morphology of electroplated copper

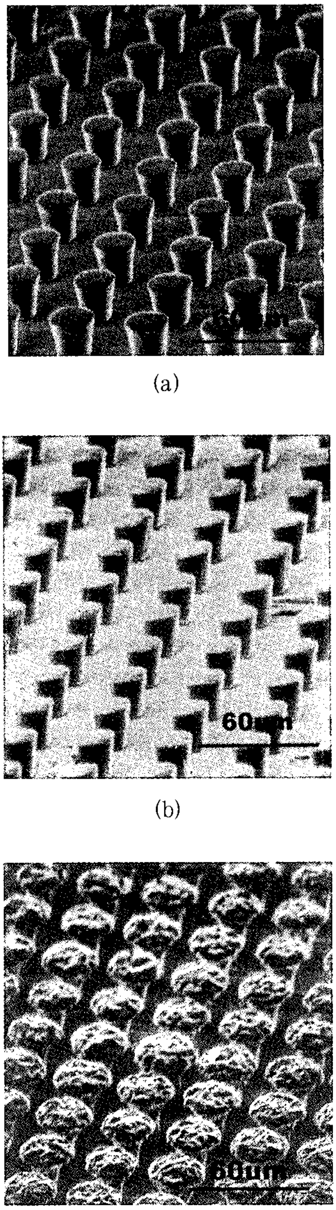
Table 5. Hardness of electroplated copper with gelatin concentration.

Gelatin Concentration (gpl)	Vicker's Hardness (Hv)
0	230
0.01	250
0.05	350
0.1	320
0.5	330
1	350

From above results, optimum gelatin concentration in copper electroplating is 0.05gpl.

3. 3 Microstructure fabrication

The optimum conditions obtained from planar electrodes were applied to microstructure fabrication. Fig. 3 shows SEM images of simple microstructures at different conditions. In Fig. 3 (a) and (b) nickel and copper microstructures were uniformly fabricated with saccharin and gelatin addition. However in Fig. 3 (c) copper microstructures were not uniform without additives. From Fig. 3 the optimum conditions obtained from planar electrode can be applied to MEMS microstructure applications.



(a) (b) (c)

Fig. 3 SEM images of Microstructures (a) nickel with saccharin 0.5gpl (b) copper with gelatin 0.05gpl (c) copper without gelatin

4. CONCLUSION

1) With saccharin addition, the electroplated nickel surface became uniform and smoother. The hardness of coating was increased with saccharin addition and best result was obtained at 0.5gpl saccharin addition.

2) With gelatin addition, the electroplated copper surface became uniform and smoother. The hardness of copper coating was increased with gelatin addition and best result was obtained at 0.05gpl gelatin addition.

3) With optimum condition obtained from planar electrode can be applied to microstructures fabrication in MEMS.

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