

A STUDY OF THIN METAL FILM FORMATION ON LTCC SUBSTRATE

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Abstract

The convention method of surface electrode formation is that the electrode paste such as Ag, Cu is used to maintain surface electrode on LTCC substrate by screen printer, which is connected through inner via electrically. The above patterns of electrode have serious effects such as the thickness non uniformity, unclarence of line and space and bad brightness. It is very difficult for these patterns to perform fine surface patterns for electrode pad. Therefore, this study has investigated thin film formation by sputter method instead of screen printing method. The used metal electrodes are Ti, Cu. We have analyzed bonding strength interface between LTCC and surface electrodes and have evaluated the structural morphology. The results confirm that adhesion strength is further improved by thick seed layer and electroform plating, as thickness of Ti seed layer increase in particular.

Key words

LTCC, Sputter, Surface electrode, Thin film. Electroforming plating, Adhesion strength

I. Introduction

Low temperature co-fired ceramics (LTCC) technology has been widely used for module or substrate in mobile/RF, wireless communication, automotive electronic fields and semiconductor probe card. LTCC has stronger characteristics than other solution as organic substrate; material strength, thermal dissipation property, miniaturization, multilayered 3D package structure, and harsh environmental operating aspects. In spite of these advantages, some technical issues are still remained uncertain [5-8]. LTCC consist of various materials such as alumina, many glass compositions to control low temperature sintering and electrical, physical properties. Due to various glass materials, LTCC have highly influence to prepare surface metal electrode which is used to connect with inner electrode, which acts on electrical power, signal, and ground [1-2].

In this study, we have confirmed the resolution of formed surface electrode before and after photo resist. In addition, we have evaluated solder ability on thin seed layer in electro forming plating. This evaluation is done by adhesion strength which is compared with seed layer thickness respectively [5]. Finally, we also have shown that the interface strength is higher according to thick Ti seed layer

formation [2,5].

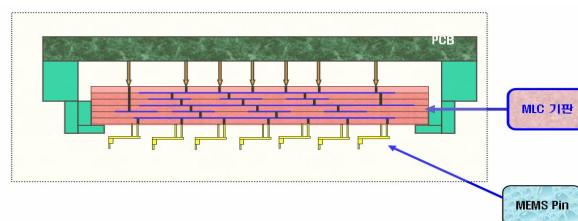


Fig. 1. General structures in Probe Card

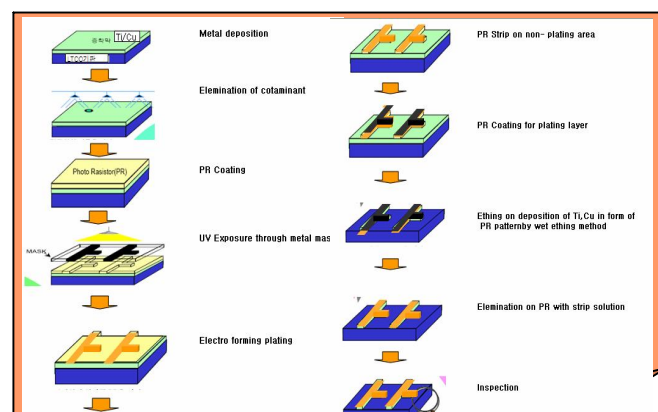


Fig. 2. Schematic Diagram of entire process in LTCC Substrate

II. Experimental Procedure

A. Materials and process

After surface polishing, the LTCC substrate is pre treated with alcohol ultra sonic washing and drying in 200 °C, 24hours in thermal oven. At first, seed layer formation process on LTCC surface on pad side was performed to form electrical pattern by using thick electro plating. Seed layer is consist of two layer such as Ti and Cu. Ti plays a strong role to maintain interface adhesion between LTCC and metal and Cu also plays a strong role to improve Cu in thick electro plating over 8 micro meter thickness . We used DC power sputter to form uniform and dense metal seed layer. After this, Photo resist process on seed layer surface was performed to form pad pattern. The used material for photo resist process is as table 1 follows. After develop, the electro plating is performed in rectangular plating bath. The electro plating took turn Cu, Ni, Au, step by step. We removed the used Photo resist solutions with TMAH (Tetra Methly Anhydride) solutions at room temperature and for 30 mins. Finally, We also removed the Ti and Cu seed layer, which is not need to reach the electro plating pad unnecessarily, in respective etchant. The used ethant is Hydro fluoric acid to remove Ti and hydro chloride, hydro sulphuric acid and water mixed solutions to remove Cu in regular sequence.

Table 1. The Properties of Main Process used in This Study

Metal Formation Method	<i>Sputter</i>
Mask	<i>2.33t Cr glass</i>
The used PR solutions	<i>THB-151N (Negative)</i>
UV Exposure	<i>365 nm</i>
Ti/Cu etchant	<i>BOE / Acid dislocation</i>

B. Evaluation

To measure the photo resist thickness, we used cyber scan profiler (CYBER VANTAGE, Cyber technologies) which is non contact type in laser sensing. The five points of entire areas was measured. The entire surface metal electrode pattern shape, line, space and resolution was confirmed by using high imaging microscope (STM6-F00-2, Olympus), according to photo resist formation and Electro plating. The micro structure and respective interface morphology was obtained by Scanning Electron Microscope (SEM, TM-1000, Hitachi). Finally, Die shear tester (4000-Series, Dage) was used to measure the adhesion strength for evaluating interface bond strength between surface metal electrode, which was attached to Au electro plating layer, and sintered LTCC substrate. This evaluation was related to estimate the reliability like thermal cycling test and high operating and preservation test.

III. Result and Discussion

A. Photo Resist Thickness on LTCC Substrate

In this experiment, we have prepared 120*120 millimeter and thickness 5 millimeter. The surface roughness is 0.6~0.7 micro meters (Ra). We have done Photo resist coating in 1,000rpm and hold time 30sec and baked LTCC substrate in 150 °C and for 30mins to harden Photo resist (PR) and remove solvent. After that, we evaluated the thickness of baked Photo resist. Fig.2 shows the PR thickness according to respective position. The uniform thickness have well indicated through various pattern size thickness is near to 20 micro meter compared with target thickness.

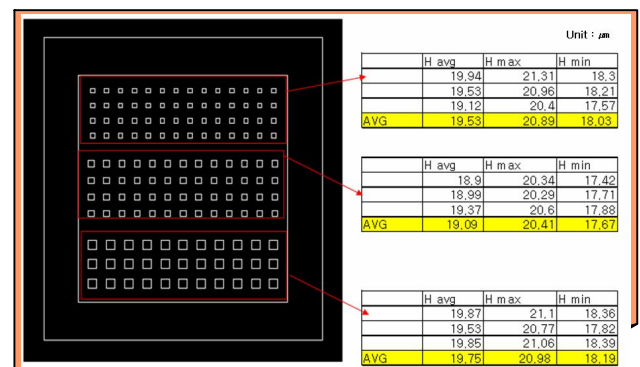


Fig. 3. The metal thin film patterns used and PR thickness according to respective positions.

To form pattern of metal for surface pad, the pattern resolution is very well after exposure and development according to Cr glass mask.

Fig. 4 shows the microscope image after formation. From this image, the formed pattern has exhibiting good line and space regardless of various pattern position of LTCC substrate. The film surface of Ti and Cu seed layer is also very good for electro plating and SMT.

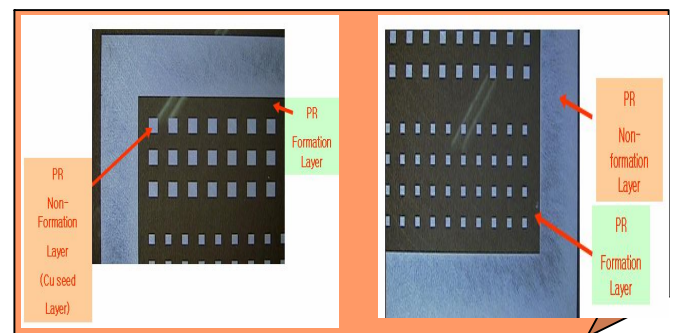


Fig. 4. The microscope image after PR formation .

After forming pattern, we have done the electro plating Cu, Ni, Au continuously and orderly [6].

Fig.5 shows the thickness of electro plating on seed layer for three kinds of metal. The electro plating thickness of metal pattern for Cu, Ni, and Au respectively is 8 micrometer, 4micrometer and 2micrometer. These values are conformed to target thickness for robust interconnection with interposer. The metal pattern thickness which was done by electro plating is much thicker as metal pattern areas are small domain compared with big domains relatively. But, there is no difference between same areas of metal pattern as to position of pattern done by electro plating. It might be possible that the thickness of electro plating is much thicker as contact point to flow an electric current is near to pattern domain. To solve this problem, it is need to prove design correctly and carefully considering the same electric current.

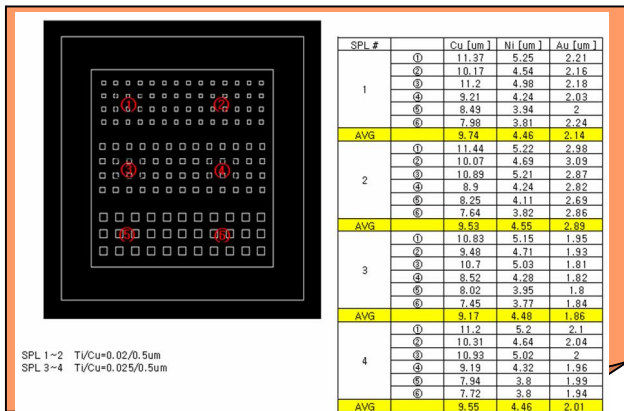


Fig. 5. Electro plating thickness of respective metal layer according to various pattern positions

B. Effect of metal pattern and chemical of LTCC Substrate after PR removal and metal etching

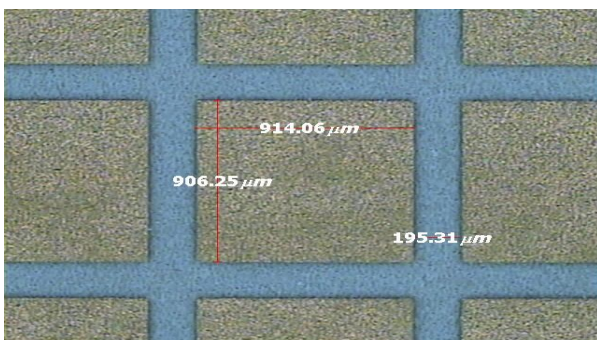


Fig. 6. The microscope image for line and space of surface metal pattern after Ti and Cu etching

As shown in Fig.6, the pattern size of line and space corresponds with the designed dimension which has 900 micrometer for square line and 200 micrometer for space. To confirm the chemical attack after electro plating, we have analyzed the ceramic surface by microscope. As for Fig.7, this result was proved that discoloration is not bringing against pattern defects [4]. The metal pattern colors done by electro plating on seed layer side in LTCC substrate has also good clearance without local dislocation [2].

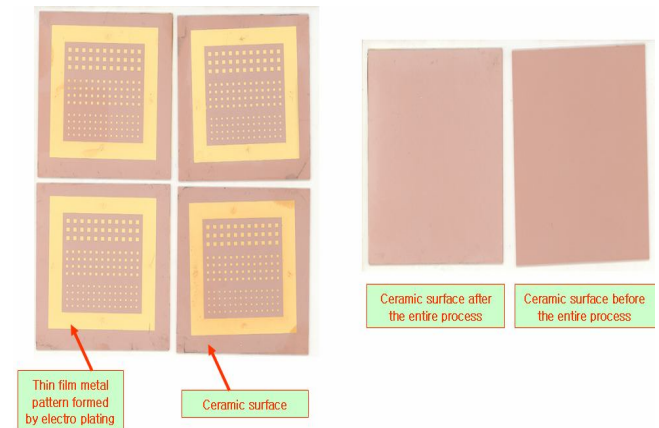


Fig. 7. The microscope image of metal pattern and ceramic surface after electro plating

Fig. 8 shows the cross section of respective layer from ceramic body to top electro plating layer. It seems to come about under cut in the edge of pattern. This has highly influence on weakness of interface bonding between ceramic and seed layer [5-7]. To solve these problems, it is need to cover thoroughly protective layer for metal pattern whenever the negative PR is coated.

Even through etching solution as high PH acid is infiltrated into Ti seed layer slightly, the degree of bonding and soldering is suited for SMT such as positive components

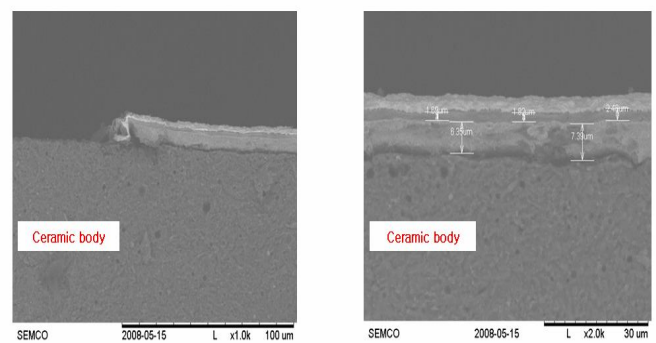


Fig. 8. The SEM image of cross section for respective layer including seed layer and electro plating layer

C. Effect of adhesion strength for basic Reliability

We have measured the adhesion strength after SMT on electro plated Au surface with solder paste. The soldering condition is holding temperature 280 °C, rate temperature 10 °C/min and holding time 5min. According to the thickness of Ti seed layer such as 0.01 μm , 0.02 μm . The adhesion strength is measured by die shear test with two samples. The measured test conditions is test speed of 300 micrometer per second, shear height of 800 micrometer and test load of 50 N.

As shown in Fig. 9, the adhesion strength is getting bigger, as the seed layer thickness increased [8]. In condition of Fig.9 (a), the value of adhesion strength is 19 N/mm². On the other hand, the value of adhesion strength is 11 N/mm² in condition of Fig.9 (b). A higher thickness of seed layer of Ti was increased the adhesion strength. In this results, we have suggested that the thick and stable seed layer of Ti has played an important role in obtaining high reliability such as thermal cycling, thermal shock and high moisture operating etc [3].

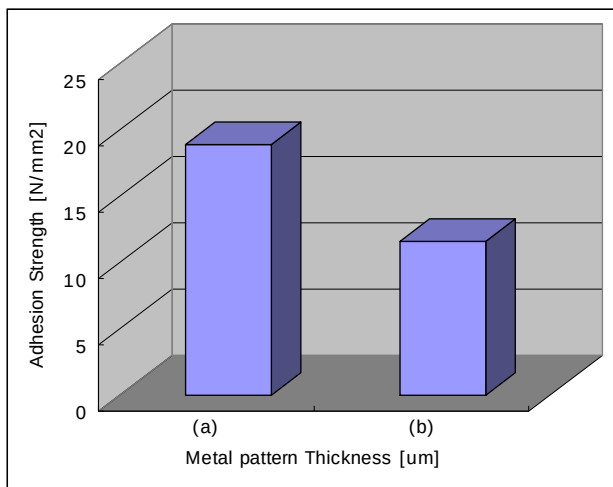


Fig. 9 The adhesion strength by die shear test according to metal thickness of seed

(a) Ti/Cu : 0.01/0.5 μm , (b) Ti/Cu : 0.02/0.5 μm

IV. Conclusion

This study shows that the metal thin films on LTCC substrate prepared Ti and Cu seed layer formation and electro plating thickly above entire 14 μm has good physical properties and high pattern solution for various electrical appliance including probe card, inspection chuck and high frequency components. After PR Process and electro plating to form surface electrode, it was found that the entire thickness (surface conductor) of low temperature co-fired ceramics (LTCC) substrate played a critical role on pattern solution and ceramic attack for high acid and remover. And secondly, Ti seed layer which is to maintain high adhesion strength between surface metal pattern and LTCC substrate is very important factor to keep high reliability and feasibility. The adhesions and chemical strength depends on the thickness of Ti for seed layer used for electro plating and etching time with regards to high acid solutions. Further more, it is very important to match with seed layer and electro plating layer of Cu.

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