VAPOUR DEPOSITION ON LTCC FOR 3D STRUCTURES

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Paper deals with an area of thin film layers made for LTCC interconnections. The thin layers were realized using physical vapour deposition (thin film technology). Cooper and silver were used for deposition. Cooper thin film layer properties were affected adversely by sintering but the silver thin film layer was unaffected without any change of parameters. The deposited thin film layers on the LTCC substrate were tested for reliability using current loading. The possibility of deposited layers ultrasonic wire bonding and interconnection were tested and discussed too.

Keywords: LTCC, thin film, thick film, 3D structure

1. INTRODUCTION

A conductive layer can be fabricated in various ways and therefore we can distinguish thin and thick films by their thickness. They can also be classified according to the used material and to the way of the layer creation. Each particular layer has its specific properties and features that are given by the technology used for its fabrication. The LTCC (Low Temperature Co-fired Ceramics) is rather a new type of substrate. This material enables the creation of 3D structures because the layers are applied over themselves. The 3D structure increases the density of integration per area unit, which can be achieved by the creation of conductive interconnections. By the combination of thin films with LTCC increases a possibility to create more complicated motives on one substrate.

The main aim is the fabrication of the conductive layout on a substrate and then a 3D structure is applied. One of possible methods for conductive layers creation is a physical vapour deposition (also known as thin film technology). This method uses some kind of metal for the conductive layer fabrication that is deposited on the ceramic substrate using physical vapour deposition. Gold, silver, platinum, cooper and other metals can be used for deposition on LTCC. After the deposition process, the fabricated layer is sintered in air atmosphere for 4 hours.

Presented paper is focused on finding of optimal fabrication process for thin film conductive layer deposition on the Low Temperature Co-fired Ceramics (LTCC) substrate. The fabricated layer is tested for quality which is very important factor for 3D structure reliability. The layer fabricated using optimized fabrication process is used for conductive connections on the LTCC substrate. The next possible ways for contacting, such as particular layers of 3D structure interconnection and wire bonding are examined and discussed here too.

2. Experimental Results

2.1. Physical vapour deposition

For the first tests of physical vapour deposition of thin film layers, cooper and silver were used. The cooper deposition was not successful, because it was not conductive after sintering. The colour of the fabricated layer was also different. This phenomenon is showed in the figures 1 and 2. The sheet resistance after sintering is almost thousands of MΩ. This problem can be caused by the strong oxidation or the deposited layer was burnt already.

Silver appeared to be better material than copper. The deposited silver layer before sintering is shown in the figure 3. The layer of silver was conductive and its resistance was about hundreds of mΩ after sintering. The colour of the layer after sintering remained the same as is shown in the figure 4. A wire was contacted by soldering process. It is shown in the figure 4. The mechanical test of soldered wire was finished by the substrate breaking, but the deposited silver layer was not ripped off. It confirmed good adhesion of the deposited silver layer to the substrate. This way fabricated LTCC substrate with deposited silver layer was used for tests mentioned below.

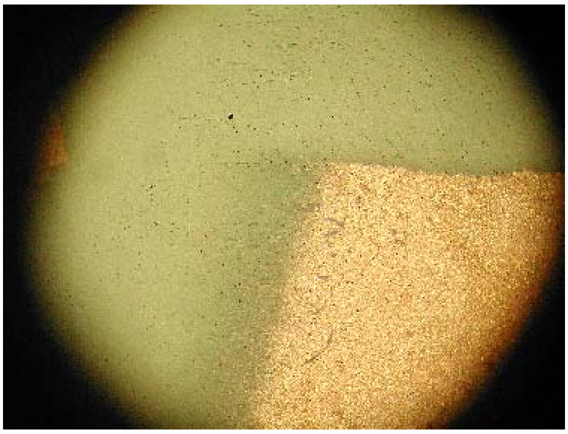

Fig.1.: The copper thin film layer before sintering (electrically conductive layer)

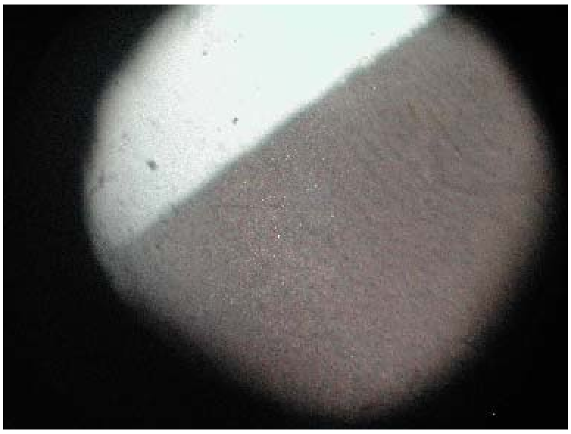

Fig.2.: The copper thin film layer after sintering (electrically nonconductive layer)

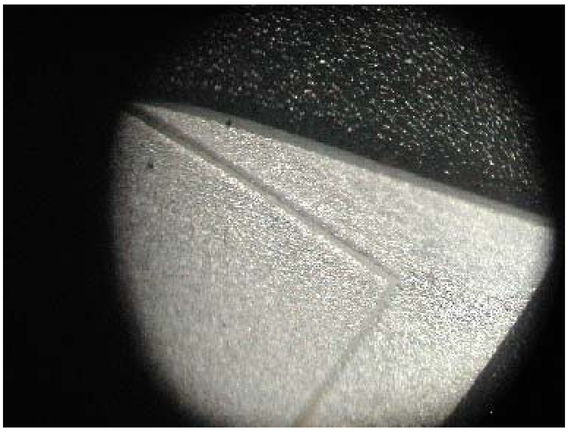

Fig.3.: Silver thin film layer before sintering

Fig.4.: The silver layer after sintering with the soldered wire

2.2. The current test

In the following step, five samples were created from a tape on which the silver thin film layer was deposited. Then the tape was cut into small samples consisted of wires and contact pads. The design of one of those fabricated samples is shown in the figure 5. These samples were used for finding of maximal current that can be applied before the layer destruction.

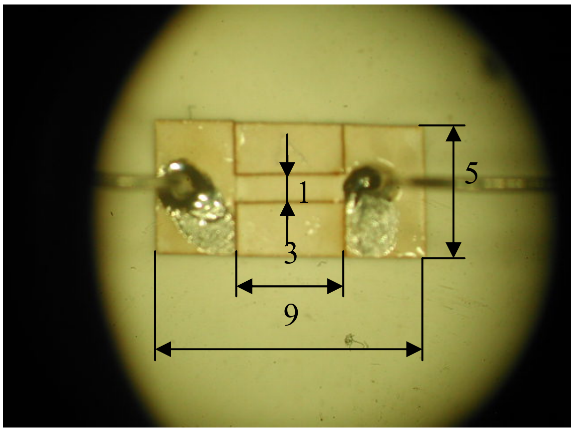

Fig.5.: Design of fabricated sample for non-destructive current tests (size in millimetres)

A cable from voltage source was contacted on the pads. The power supply can provide voltage range from 0 to 20 V and current range from 0 to 5 A. Measurement was carried out at 5 V. The current was changed from 0 to 5 A. During the measurement the passing current limit for the layer before its destruction was found. The resistance of each sample was measured before the test. Obtained results are shown in the table 1. During the test the applied current was linearly increased. The passing current heats the substrate. The layer was destructed after 5 seconds of the applied current of 4,27 A.

Table 1.: The resistance of each sample before the test

Number of sample	**1**	**2**	**3**	**4**	**5**
Resistance [mΩ]	85	72	82	73	75

2.3. Wire-bonding on the deposited layer

Next the deposited layer was tested to wire bondability. The wire-bonding is one of the methods for making the interconnection between two conductive layers or substrates. For example it is realized by ultrasonic wire bonding using gold, aluminium or cooper wire. The wire bonding is possible to be made on that layers only which have good quality of surface without any oxidation and higher roughness.

The five prepared samples were ultrasonically wire bonded. The results are shown in the figures 6 and 7. The aluminium bonding wire diameter was 100 μm. From the figures 6 and 7 is clear, that the deposited silver thin film layers were wire bondable. The welds were of good quality. Detail of one ultrasonic bond is show in the figure 8. It concluded that the deposited silver thin film layers are suitable for wire bonding.

Fig.6.: Wire bonding on deposited layer

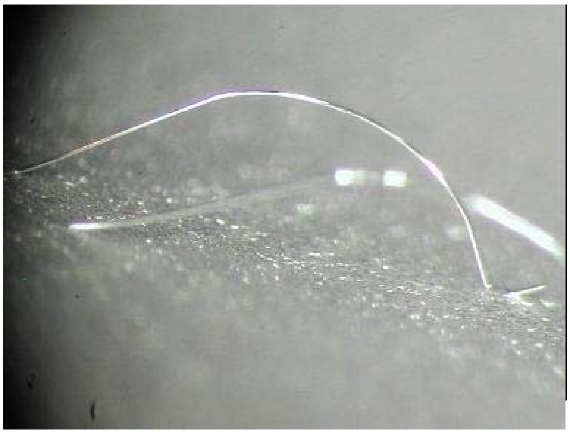

Fig.7.: Detail of one bonded aluminium wire

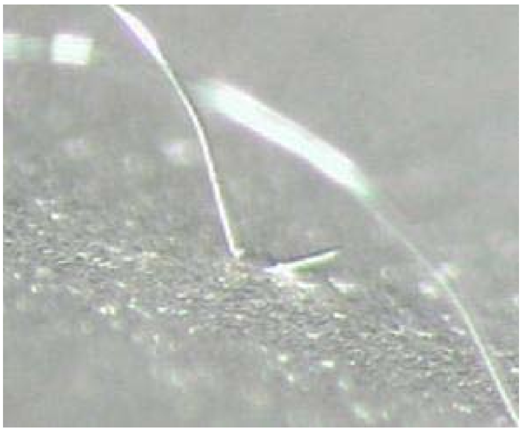

Fig.8.: Detail of one ultrasonic bond (weld)

2.4. Interconnection by the physical vapour deposition

The interconnection is one of methods how to fabricate a junction between particular layers in 3D structure. This method can increase density of integration. The main aim of this test was to fabricate a reliable interconnection. The LTCC sample contained fifteen holes that were cut by laser (ALS 300, Aurel, Italy). On the LTCC sample were physically vapour deposited silver thin film layer and sintered. Sample of one successfully made hole is shown in the figures 9 and 10. The holes diameters differs from 100 to 600 μm. In the hole's walls there were observed various fabrication defects. For example it was bad adhesion of silver during the physical vapour deposition process (see figure 11) and the affect of sintering to silver thin film layer adhesion (see figure 12). We supposed that the main fabrication problems observed on some holes of higher diameters can be caused by a shape of the hole and a smoothness of its wall.

From the obtained results was clear that the reliable interconnection can be fabricated using thin film technology. The silver layer was not stable on the air, where it oxidized. All these facts concluded that this kind of interconnection is possible to be successfully used inside the structure because there is no air inside.

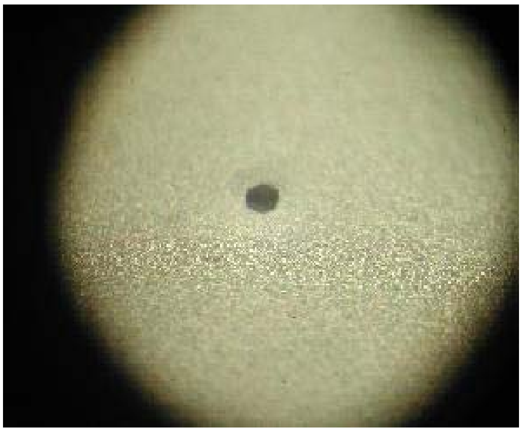

Fig.9.: Interconnection made by physical vapour deposition after sintering

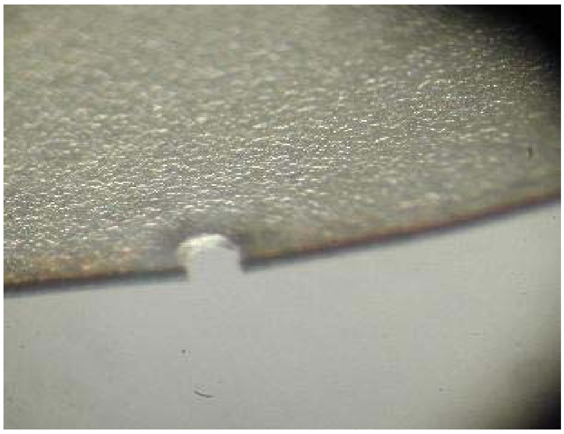

Fig.10.: Detail of good interconnection (good adhesion of deposited silver thin film layer)

Fig.11.: Detail of defect in the hole (bad adhesion of deposited silver thin film layer to the substrate)

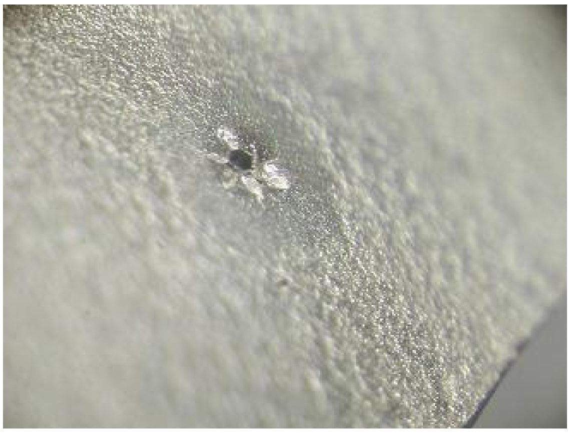

Fig.12.: Detail of defected hole after sintering

3. CONCLUSION

The paper describes physical vapour deposition of metal thin film layer on the LTCC. The deposited layer thickness (generally about tens of nanometres) was not measured in this work.

From the results was clear that at least for our experiments with LTCC the cooper is not good material because it was burned out during the LTCC sintering. The silver layer had good results and it was used for all tests in this work. There was tested maximal applied current at the deposited thin film layer, its bonding and interconnection. All of mentioned methods can be applied on the LTCC substrate. The maximal applied current that led to deposited layer destruction was 4,27 A for 5 seconds. The obtained results concluded that the deposited silver thin film layers are suitable for reliable wire bonding. and interconnection made by physical vapour deposition.

The thin layer is also good for creation of reliable conductive connection inside the 3D structure. The observed problem of deposited layer oxidation can be suppressed by increase of layer thickness, e.g. using the galvanization. It is an objective of next experiments. Deposited layer thickness and their resistance measurement will be in centre of investigation in the future works too.

4. ACKNOWLEDGEMENT

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