EXPERIMENTAL RESEARCH OF ADAPTABILITY OF PALLADIUM COATED COPPER MATERIAL AS AN ALTERNATIVE FOR BARE COPPER OR GOLD MATERIAL IN CONVENTIONAL WIRE BONDING

Harsha S [1], Mahalakshmi S [1], Adarsh Mathew Abraham [2], Sathwik Dinakar G. [2]

[1] *Centre for Sensors, Vision Technology and Controls, Central Manufacturing Technology Institute, Bangalore.*
[2] *Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu*

Abstract

Wire bonding is the method of making electrical interconnections between an integrated circuit or semiconductor material and its packaging. In general, Gold (Au) wire is being used for wire bonding and is highly expensive. Copper (Cu) has better thermal and electrical conductivity than Au. Cu is a good alternative for wire bonding but the main drawback is that it gets oxidised easily. Oxidation of Cu wire leads to poor bonding. This paper compares the wire bonding performance of PdCu with Au and bare Cu wires. Wire bonding was performed by optimizing the bonding parameters. Further the wire bonding was evaluated using mechanical, electrical and Scanning Electron Microscope (SEM) characterizations.

Keywords: Palladium Copper, Wire bonding, bare copper, gold wire bonding

1. Introduction

In the fabrication process of micro systems, the electrical signals are drawn out from the sensing element to the read-out circuitry through the wire bonding process in most applications. Since the wire bonding process is an essential step in the fabrication process, the development towards new materials in terms of performance and cost is of necessity. Hence in this work, the Palladium coated copper wire is being explored for wire bonding application. Palladium coated copper (PdCu) is oxidation free and Pd provides good adhesion to Cu wire [1]. The presence of Pd on Cu helps to protect the bonded ball from corrosion and prevents the formation of cuprous oxide (CuO). The Pd Cu had a lifetime of over 90 days in air, as compared to just 7 days for bare Cu wire [2,3].

The performance reliability of the chip is dependent on the quality of wire bond. Therefore, quality assurance of wire bond is very important in the Integrated Circuit (IC) and micro systems assembly [4]. In mechanical characterization, the quality and robustness of the wire bonds are tested to evaluate the bond strength and wire pull test is carried out as per the MIL-STD 883 (above 3gF). In electrical characterization, the electrical testing helps the functional evaluation and to measure the resistance of wire bonds [4]. The SEM characterization is carried out to find ball dimensions (2.5 - 3 times of the wire diameter) and wedge width (1.2-5 times the wire diameter) as per the MIL-STD 883. It is also used to detect any pad splashing and bond deformation.

2. Literature Survey

PdCu plays an important role in prevention of oxidation problem. Pd has a good tensile strength than bare copper when bonded to Al pads [5]. Pd prevents the formation of Cuprous Oxide (CuO) and can form a bond with N_2 without requiring forming gas [1].

Challenges are to be faced in handling PdCu include the presence of Nano-voids in the wire bonds formed with N_2 which are not seen in Cu [6].

Pd distribution on Cu wires was compared based on the EFO parameters. The shape of the formed Free Air Ball (FAB) resulted in a higher yield of 96% at the medium current setting (70 mA). The result of High Temperature Storage Test (HTST) indicated that proportional Pd distribution could decelerate the corrosion of a bonded ball [7].

3. Experimentation

A number of experiments were conducted with 1mil (25µm) wire of Au, Cu and PdCu. The optimized process parameters of each material are as shown in Table 1. These parameters are chosen based on the impact they have on the performance on the wire bond and its evaluation. In wire bonding process, the two major types that are used extensively across several applications are ball-wedge and wedge-wedge wire bonding. Hence these two types are being considered for the purpose of evaluation of PdCu wire bonding in this work in comparison with Cu and Au materials.

Table 1: Optimized bonding parameters

Material	Bond Time (ms)		Ultrasonic Power (digits)		Bond Force (gF)		Temperature (˚C)	N_2 flow rate (NL/min)
	B1	B2	B1	B2	B1	B2		
Au (Ball-Wedge)	30	30	100	110	32	32	90	-
Cu (Ball-Wedge)	30	24	100	120	34	18	120	0.8
PdCu(Ball-Wedge)	36	22	120	95	40	28	130	0.8
Au (Wedge-Wedge)	24	24	120	140	30	36	100	-
Cu(Wedge-Wedge)	30	30	130	130	38	38	130	-
PdCu (Wedge-Wedge)	22	24	100	110	22	24	130	-

B1: Source bond | B2: Destination bond

4. Characterization Results and Discussion

Characterization methods considered for Au, Cu & PdCu are Mechanical, Electrical and SEM. The test results obtained from the best optimized parameters are tabulated in Table 2. The mechanical and electrical characterization results of ball-wedge and wedge-wedge wire bonding differ from each other since the process of ball formation involves more material and occupies more surface area on the bond pad. Hence the mechanical strength and the electrical resistance differs from the wedge-wedge bonding.

4.1 Experiment 1: Gold ball wedge bonding

The mechanical destructive test result of 1 mil Au ball-wedge bonding with the corresponding graphs and electrical resistance for 10 bonds are shown in Fig.1 & 2. The Standard Deviation (SD) is 0.57 and range is found to be 1.63. SEM characterization is shown in Fig.3.

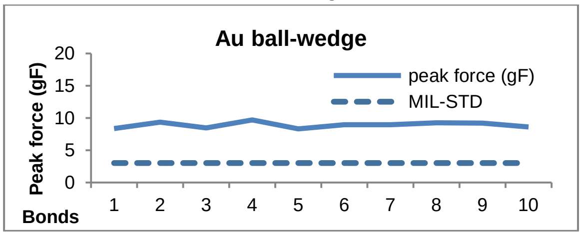

Fig 1: Mechanical Characterization

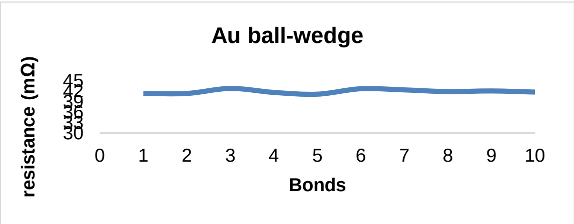

Fig 2: Electrical Characterization

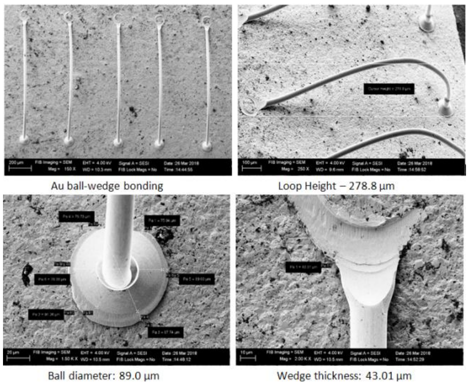

Fig 3: Au ball-wedge

4.2 Experiment 2: Gold wedge-wedge bonding

The destructive test result of 1 mil Au wedge bonding with the corresponding graphs of 10 bonds for mechanical and electrical are shown in Fig.4 & 5 respectively. The standard deviation and range are also calculated and found to be 0.69 & 2.2 respectively. SEM characterization is shown in Fig.6.

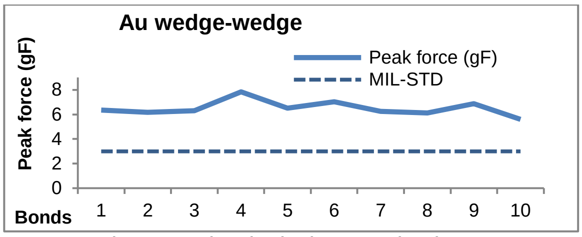

Fig 4: Mechanical Characterization

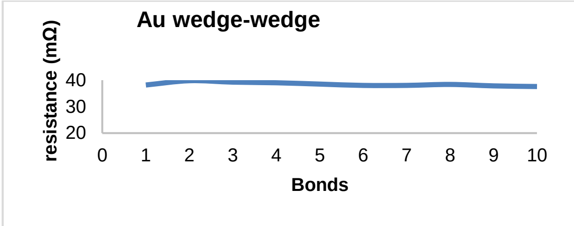

Fig 5: Electrical Characterization

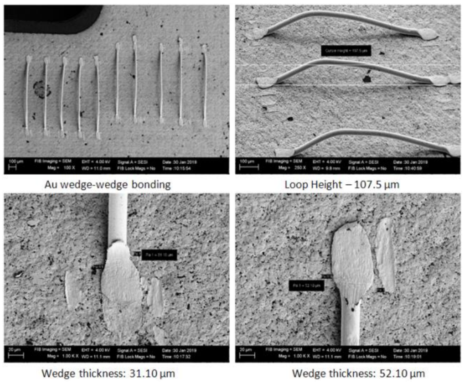

Fig 6: Au wedge-wedge

4.3 Experiment 3: Copper ball wedge bonding

The mechanical destructive test result of 1 mil Cu ball-wedge bonding with the graphs and electrical resistance for 10 bonds are shown in Fig.7 & 8. The Standard deviation and range are calculated and is noted as 1.08 & 3.64 respectively. SEM characterization is shown in Fig.9.

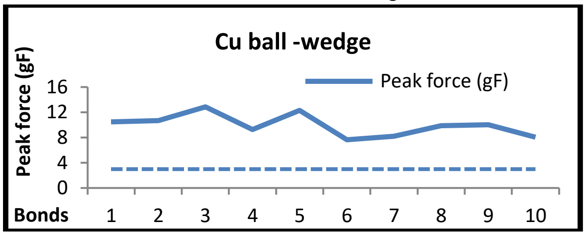

Fig 7: Mechanical Characterization

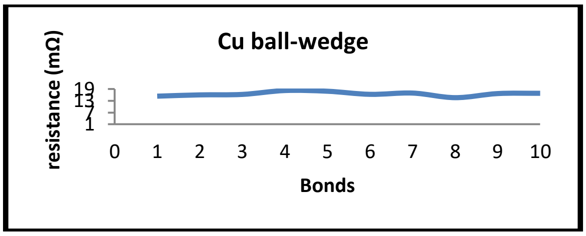

Fig 8: Electrical characterization

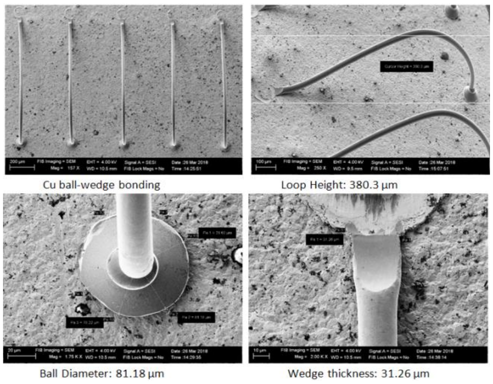

Fig 9: Cu ball-wedge bond

4.4 Experiment 4: Copper wedge –wedge bonding

The destructive test result of 1 mil Cu wedge bonding with the corresponding graphs of 10 bonds for mechanical and electrical are shown in Fig.10 & 11 respectively. The Standard deviation and range are calculated and found to be 0.87 & 2.58 respectively SEM characterization are shown in Fig.12.

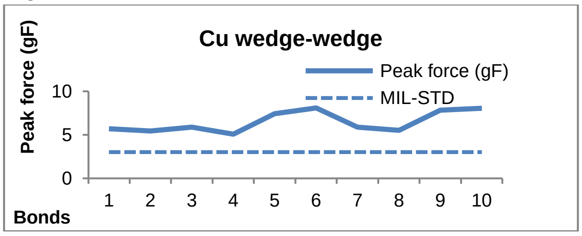

Fig 10: Mechanical Characterization

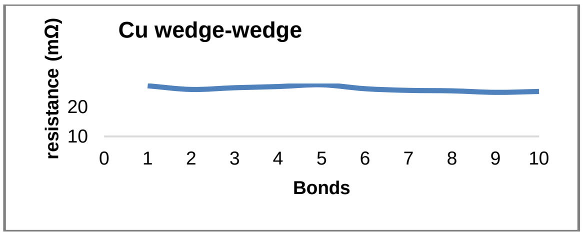

Fig 11: Electrical Characterization

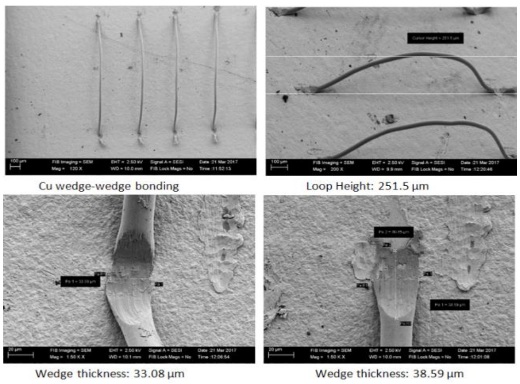

Fig 12: Cu wedge-wedge

4.5 Experiment 5: Palladium-Copper ball wedge bonding

The mechanical destructive test result of 1 mil PdCu ball-wedge bonding with the corresponding graphs and electrical resistance for 10 bonds are shown in Fig.13 & 14. The standard deviation and range are 0.80 & 2.2 respectively. SEM characterization is shown in Fig.15.

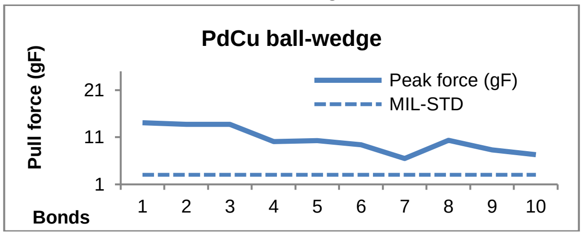

Fig 13: Mechanical Characterization

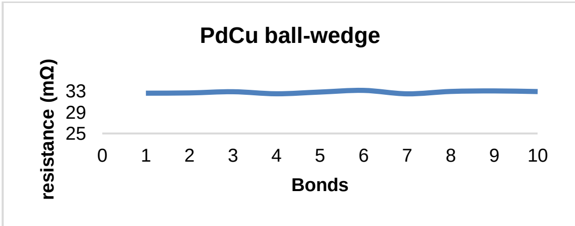

Fig 14: Electrical Characterization

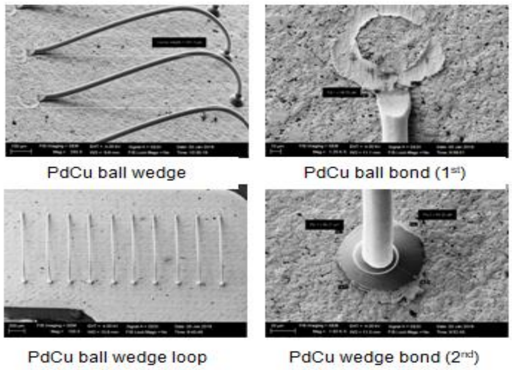

Fig 15: PdCu ball wedge

4.6 Experiment 6: Palladium- Copper wedge-wedge bonding

The destructive test result of 1 mil PdCu wedge bonding with the graphs of 10 bonds for mechanical and electrical are shown in Fig 16 & 17 respectively. The standard deviation and range are calculated and found to be 0.55 & 1.94 respectively. SEM characterization is shown in Fig.18.

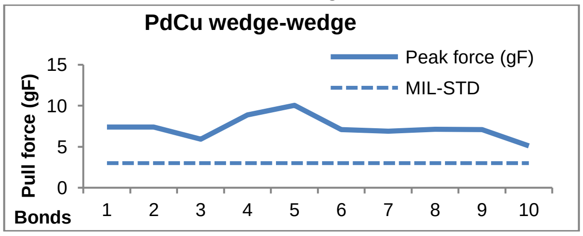

Fig 16: Mechanical characterization

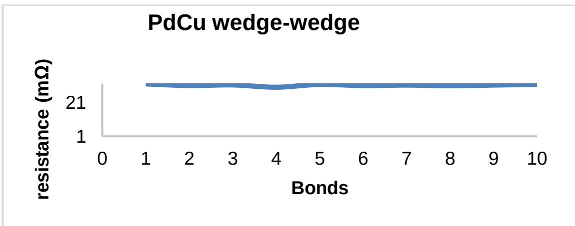

Fig 17: Electrical Characterization

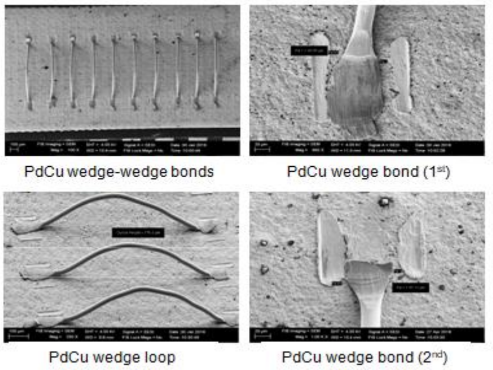

Fig 18: PdCu wedge-wedge

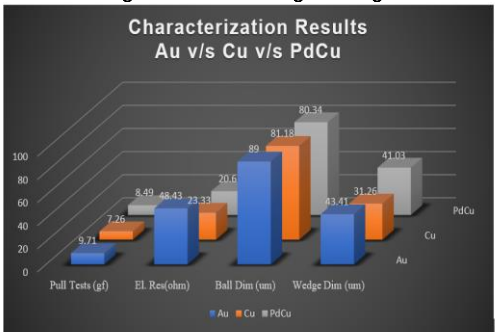

Fig 19: Characterization results comparison

From the six experiments conducted and their characterization results as shown above, the following can be arrived at.

For the electrical resistance in ball-wedge operation resistance of PdCu was found to be 78.41% and Cu was found to be 39.46% as compared to Au. Similarly for the wedge-wedge operation, the electrical resistance of PdCu was 78.72% and that of Cu was 66.47% as compared to Au. Although Cu offered lesser electrical resistance than PdCu, considering the oxidation issue, PdCu scores better than Cu and since the resistance offered is close to 20% lesser than Au, a considerably thinner PdCu wire could be used as a replacement in comparison to Au wire.

For the mechanical strength of the wire bond PdCu wire was found to have 93.86% of the breaking load of 15 gF given by the manufacturer of the PdCu wire.

From the SEM characterization, PdCu ball dimensions were found to have met the minimum requirement of 2.5 times of the wire diameter as per MIL STD 883 with a dimensional value of 69.31µm (2.77 times) and the wedge dimensions also met the minimum requirement of 1.2 times of the wire diameter with a value of 35.97µm (1.44 times). The characterization results of all the parameters viz., Pull test, Electrical resistance, ball diameter and wedge dimensions are given in Fig 19.

Table 2: Characterization results

Material	Mechanical (gF)	Electrical (mΩ)	SEM (µm)		
			Ball diameter	1st Wedge width	2nd Wedge width
Au (Ball-Wedge)	9.71	41.88	94.54	-	48.66
Au (Wedge-Wedge)	7.83	39.49	-	31.10	52.19
Cu (Ball-Wedge)	12.87	16.53	75.64	-	34.40
Cu (Wedge-Wedge)	8.08	26.25	-	33.08	38.59
PdCu (Ball-Wedge)	14.08	32.84	69.31	-	34.59
PdCu (Wedge-Wedge)	10.06	31.09	-	45.65	35.97

5. Conclusion

In this research work, Au, Cu and Pd-Cu wires are successfully bonded with optimized parameters. The mechanical destructive pull test of PdCu is found to be greater in its bond strength and reliability than Au. Also the electrical resistance of PdCu is almost closer to Au. The requirement is to obtain repeatable electrical resistance which should not exceed standard deviation >1. The standard deviation obtained for Cu is 1.08 for which electrical resistance was varying in high range. From SEM characterization, it can be inferred that the bond dimensions are meeting as per the standards. No bond splash or deformation was found. The experiments and their results shown in table 2 indicate that PdCu can be used as better alternative than gold or copper in wire bonding.

6. References

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